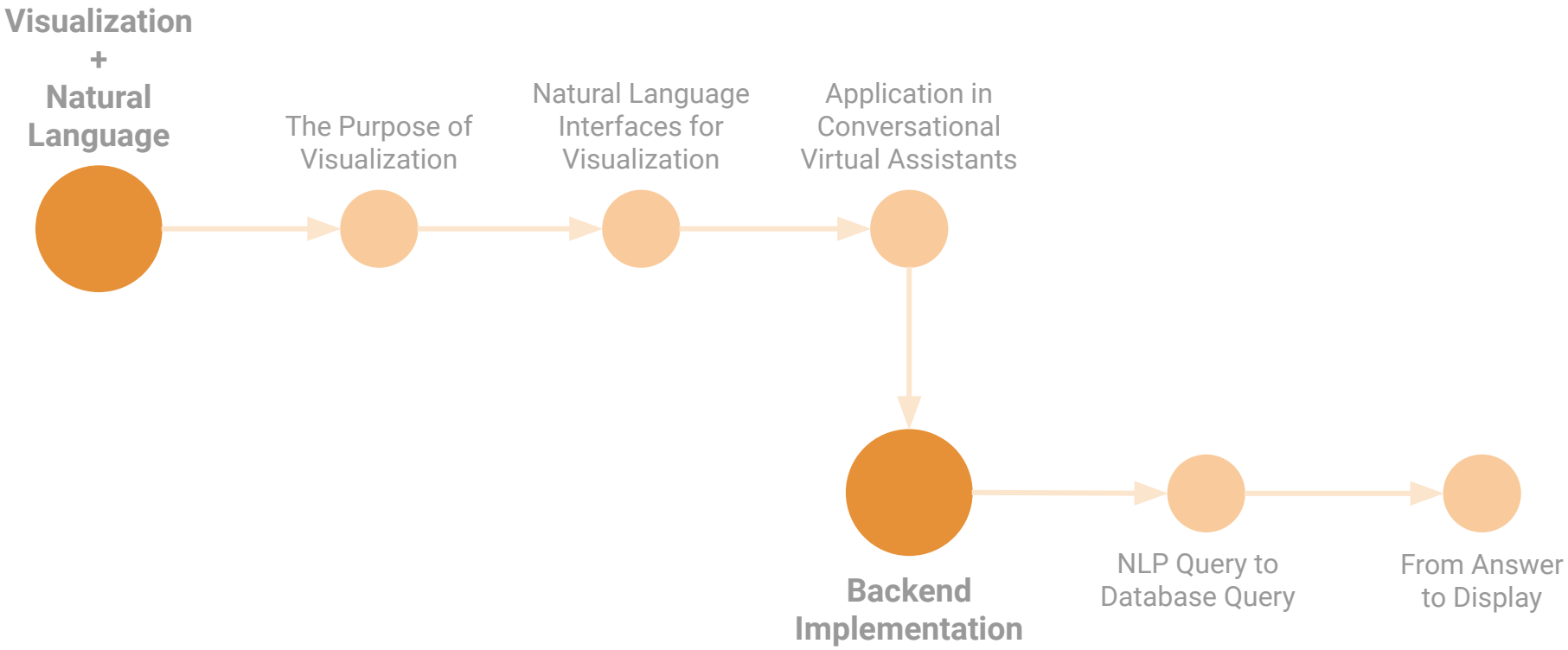
Natural Language Question-Answering with Visualizations

Bianca Yu, Hannah DeBalsi

CS 294W Spr 2020

Outline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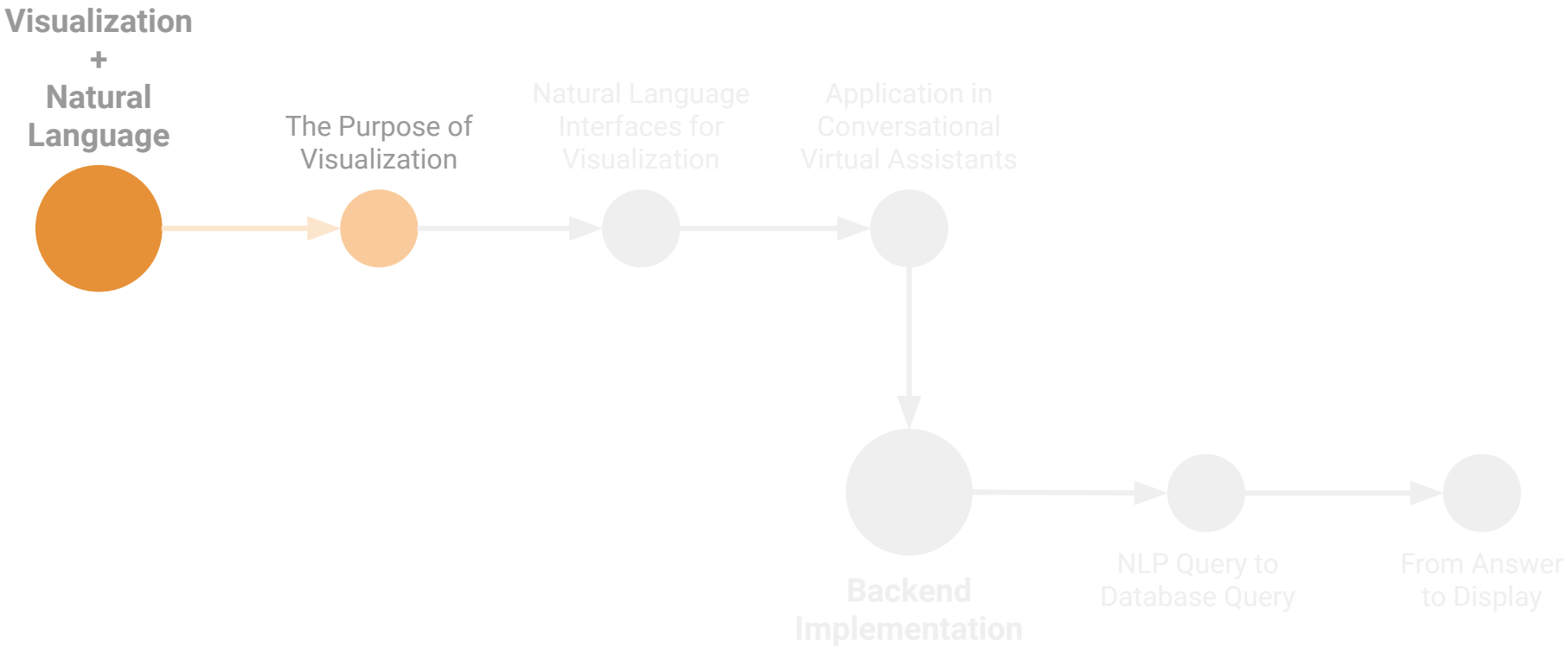
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What is **visualization**?

- “**Transformation** of the symbolic into the geometric” (McCormick et al. 1987)

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  (McCormick et al. 1987)

- "... finding the **artificial memory** that best supports our **natural means of perception**."
  (Bertin 1967)

What is **visualization**?

- "**Transformation** of the symbolic into the geometric"
  (McCormick et al. 1987)

- "... finding the **artificial memory** that best supports our **natural means of perception**."
  (Bertin 1967)

- "The use of computer-generated, interactive, visual representations of data to **amplify cognition**."
  (Card, Mackinlay, and Shneiderman 1999)

We use visualization to ...

- **Record** information

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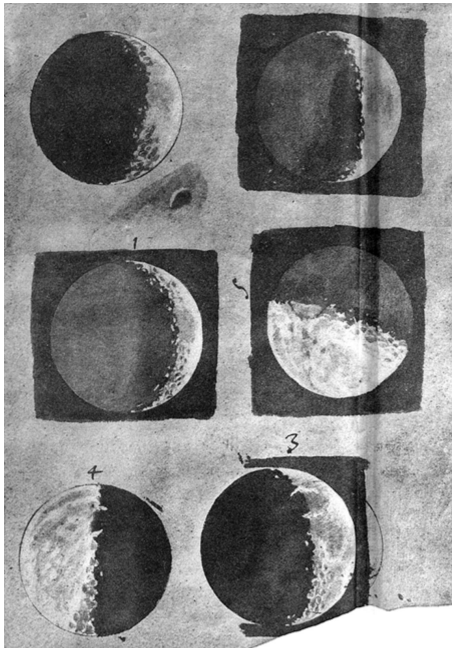

http://galileo.rice.edu/sci/observations/moon.html

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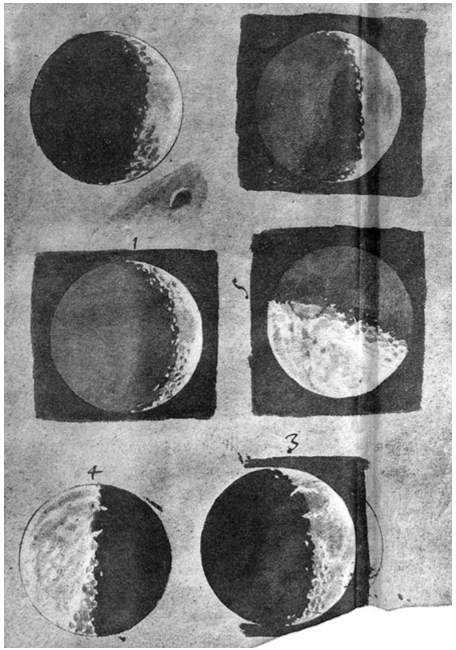

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Getty Images

We use visualization to ...

- **Record** information
- **Analyze** information

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  - See data in context
  - Make a decision

See data in context

- Example: Cholera outbreak, 1854

Tufte. *Visual and Statistical Thinking* 1997

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Make a decision

- Example: Challenger space shuttle launch, 1986

Wikipedia

Make a decision

- Example: Challenger space shuttle launch, 1986

Blow By History
SRM-15 worst Blow-By
- 2 case joints (80°), (110°) arc
- much worse visually than SRM-22

SRM 22 Blow-By
- 2 case joints (30-40°)

SRM-13A, 15, 16A, 18, 23A 24A
- nozzle Blow-By

	History of O-ring Temperatures (degrees-F)			
Motor	M&T	Amb	O-ring	Wind
DM-1	68	36	47	10 mph
DM-2	76	45	52	10 mph
QM-3	72.5	40	48	10 mph
QM-4	76	48	51	10 mph
SRM-15	52	64	53	10 mph
SRM-22	77	78	75	10 mph
SRM-25	55	26	29 27	10 mph 25 mph

HISTORY OF O-RING DAMAGE ON SRM FIELD JOINTS

SRM No.	Cross Sectional View: Erosion Depth (in.)	Cross Sectional View: Perimeter Affected (deg)	Cross Sectional View: Nominal Dia. (in.)	Top View: Length Of Max Erosion (in.)	Top View: Total Heat Affected Length (in.)	Clocking Location (deg)
22A	None	None	0.280	None	None	36°--66°
22A	NONE	NONE	0.280	NONE	NONE	338°-18°
15A	0.010	154.0	0.280	4.25	5.25	163
15B	0.038	130.0	0.280	12.50	58.75	354
15B	None	45.0	0.280	None	29.50	354
13B	0.028	110.0	0.280	3.00	None	275
11A	None	None	0.280	None	None	--
10A	0.040	217.0	0.280	3.00	14.50	351
2B	0.053	116.0	0.280	--	--	90

*Hot gas path detected in putty. Indication of heat on O-ring, but no damage.
**Soot behind primary O-ring.
***Soot behind primary O-ring, heat affected secondary O-ring.

Clocking location of leak check port - 0 deg.

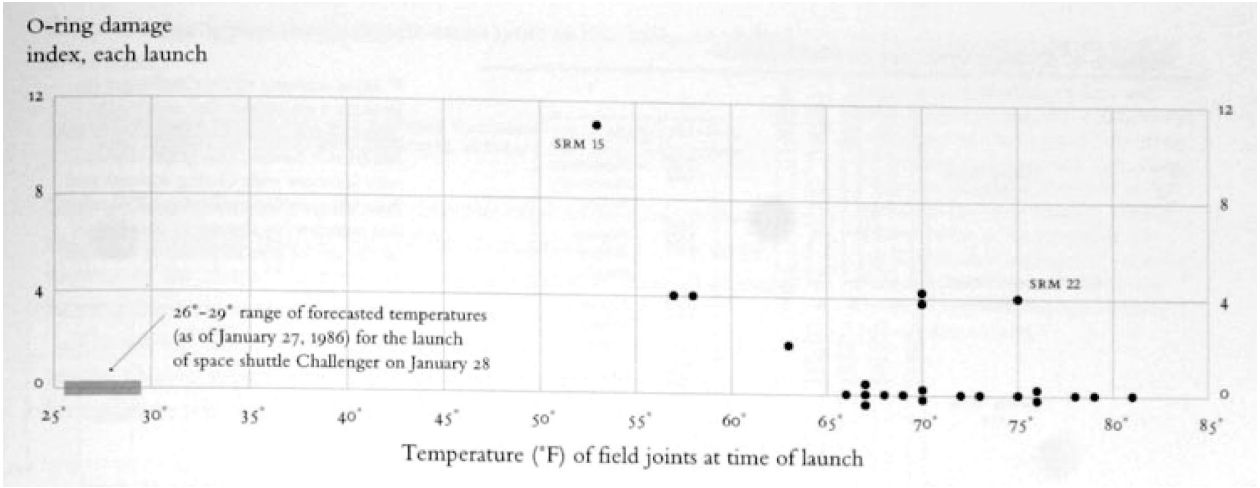
OTHER SRM-15 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY AND NO SOOT NEAR OR BEYOND THE PRIMARY O-RING.

SRM-22 FORWARD FIELD JOINT HAD PUTTY PATH TO PRIMARY O-RING, BUT NO O-RING EROSION AND NO SOOT BLOWBY. OTHER SRM-22 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY.

Tufte. *Visual and Statistical Thinking* 1997

Make a decision

- Example: Challenger space shuttle launch, 1986



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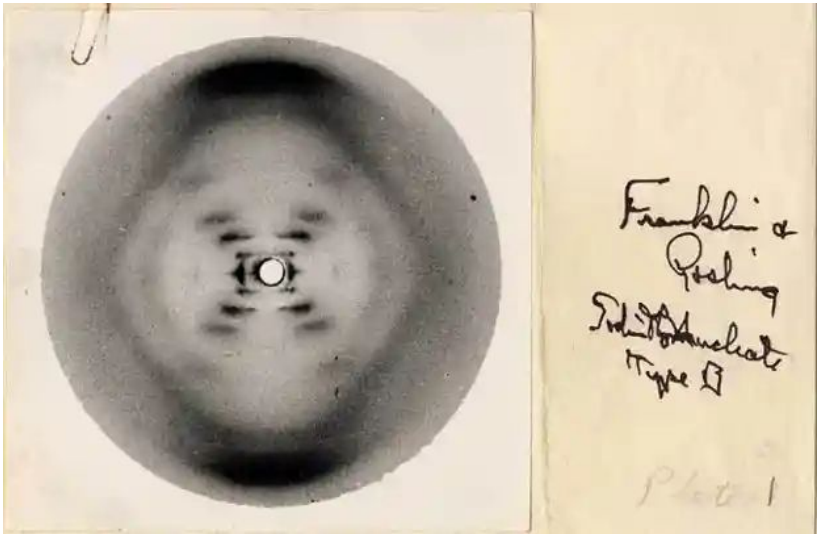

Rosalind Franklin and RG Gosling

Graphs in statistical analysis

“Graphs can have various purposes, such as:

(i) to help us **perceive and appreciate** some broad features of the data,

(ii) to let us look behind those broad features and **see what else is there**.”

(Anscombe 1973)

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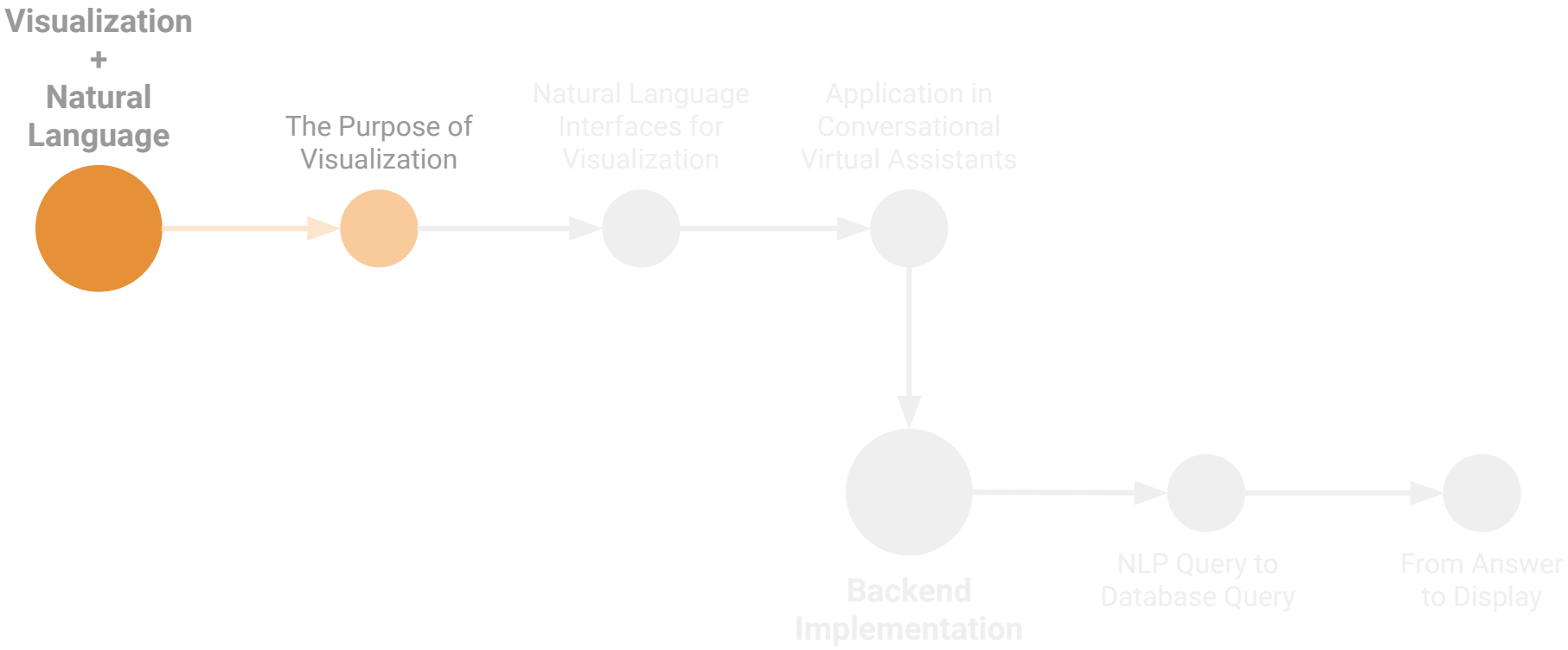
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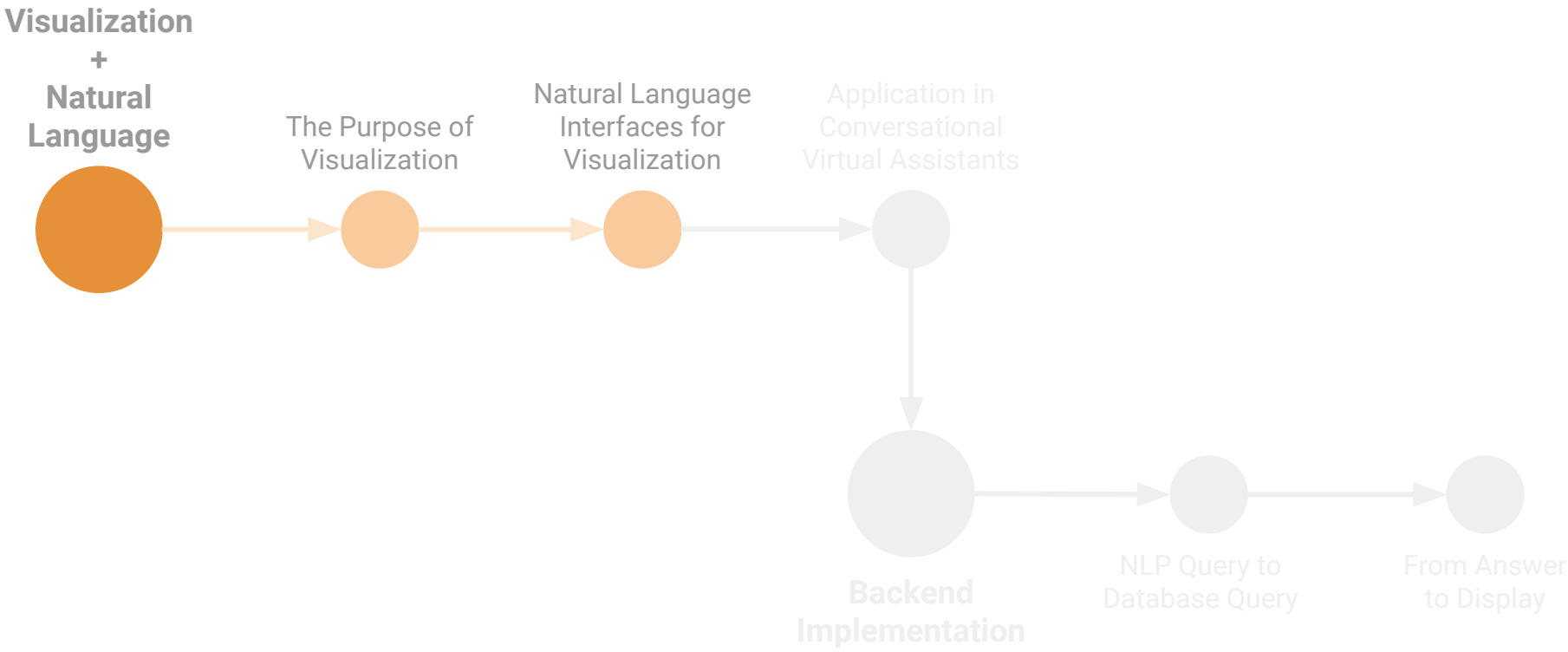
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Why implement natural language interaction?

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- “Natural language interaction allows users to **ask questions directly** in complex programs **without having to learn how to use an interface**.” (Gao et al.)

- Users of sophisticated visual analytic tools are “... usually domain experts with **marginal knowledge of visualization techniques**.” (Sun et al.)

Types of current natural language interfaces

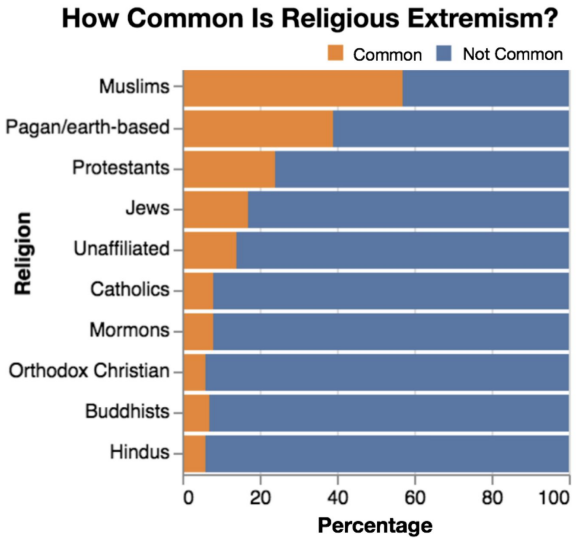
1

Those that **answer questions about existing visualizations**

2

Those that **create a new visualization**

1) Answering questions about existing visualizations



Q1: *What is the percentage of response 'Common' for Catholics?*

A(Sempre): ***92***

A(Ours): ***8***. *I looked up the length of the orange bar for 'Catholics'.*

Q2: *Which religion has the longest orange component?*

A(Sempre): ***Hindus***

A(Ours): ***Muslims***. *I looked up 'Religion' of the longest orange bar.*

Q3: *What does the blue field represent?*

A(Sempre): ***24***

A(Ours): ***Not Common***. *I looked up what blue represents by looking at the legend.*

2) Creating new visualizations

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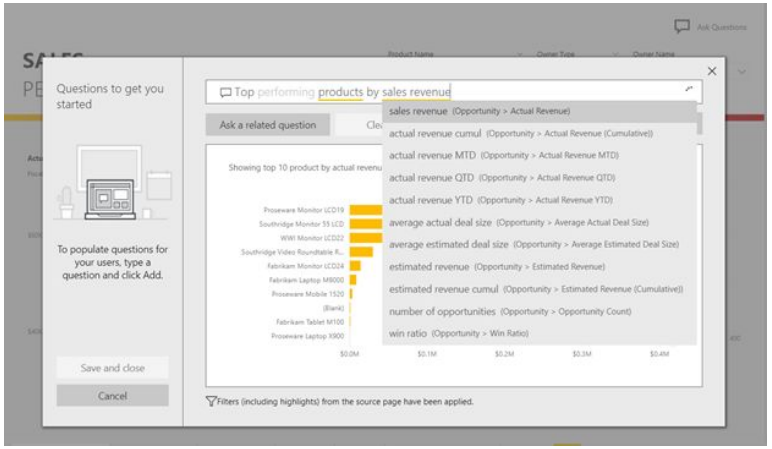
- Commercial
  - IBM
  - Microsoft
  - Wolfram Alpha

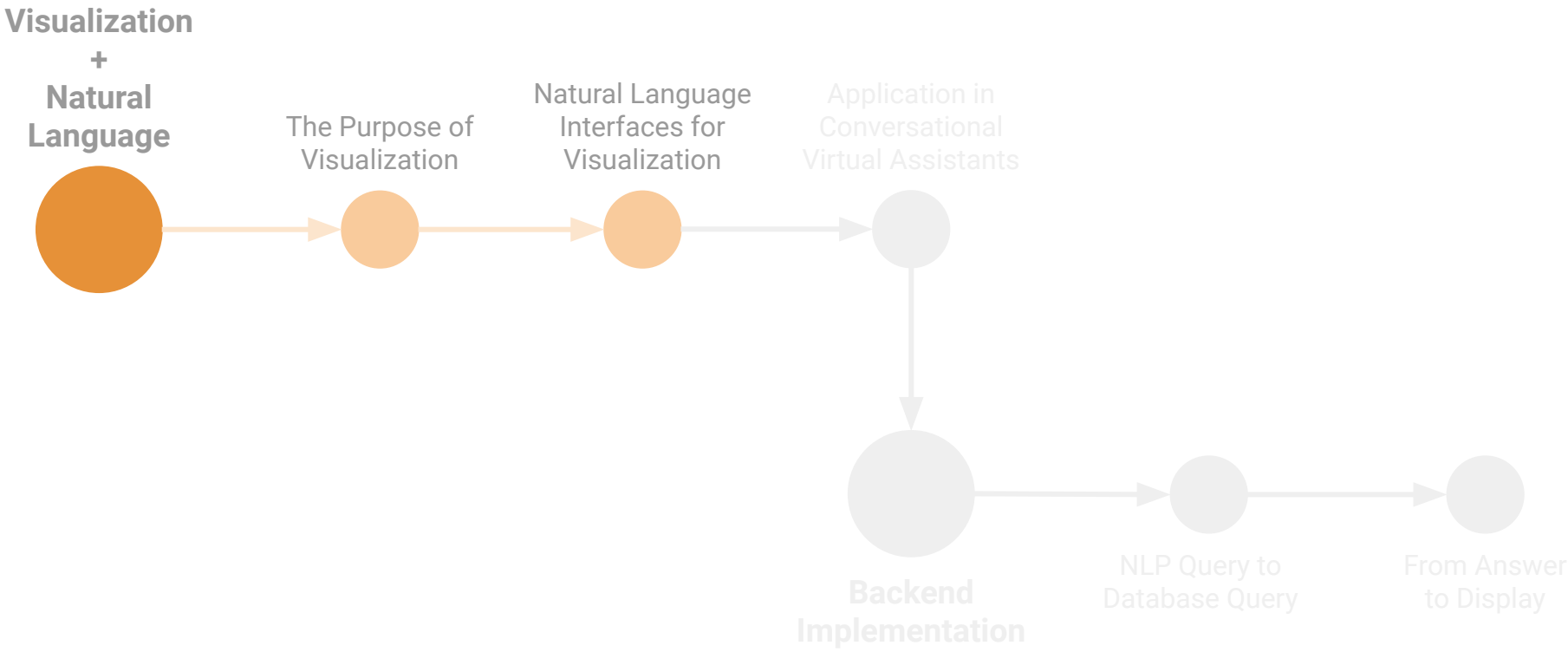


2) Creating new visualizations

- Commercial
  - IBM
  - Microsoft
  - Wolfram Alpha

- Research Projects
  - Articulate
  - DataTone

Outline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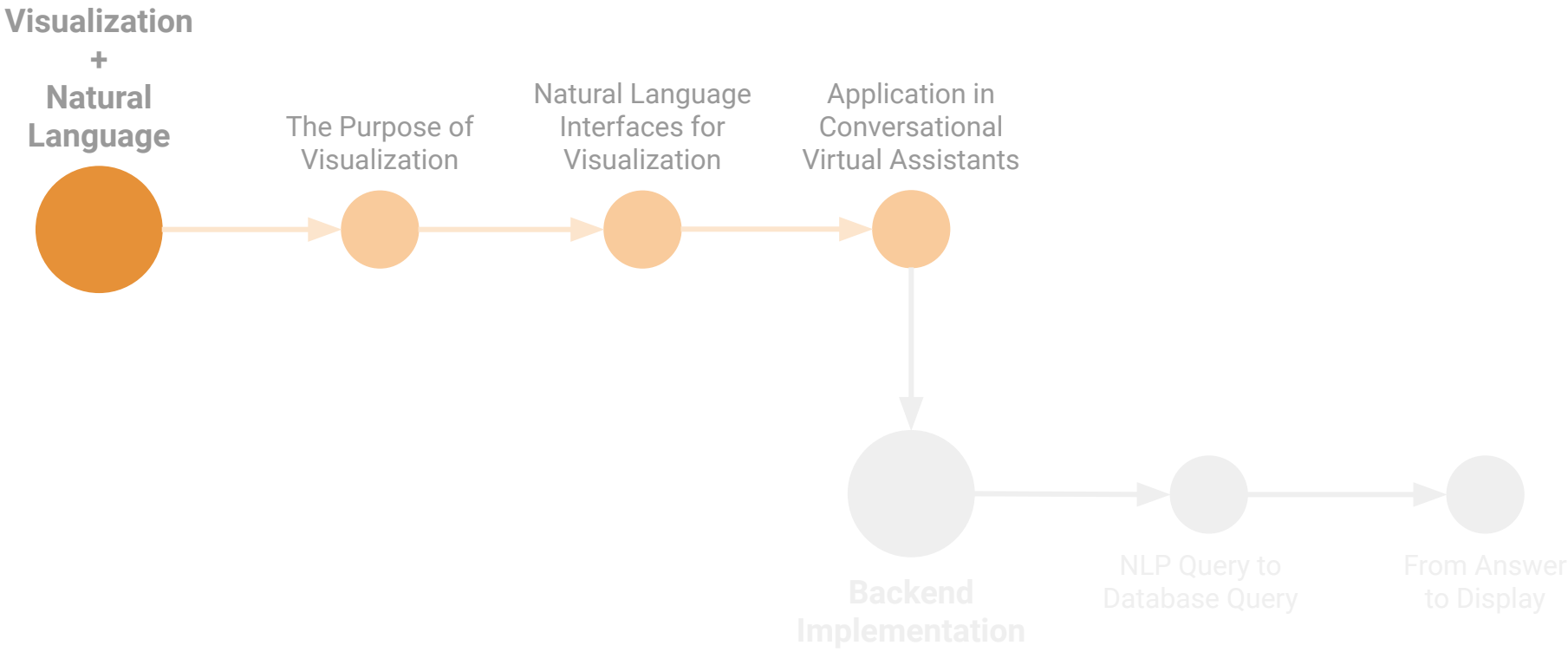
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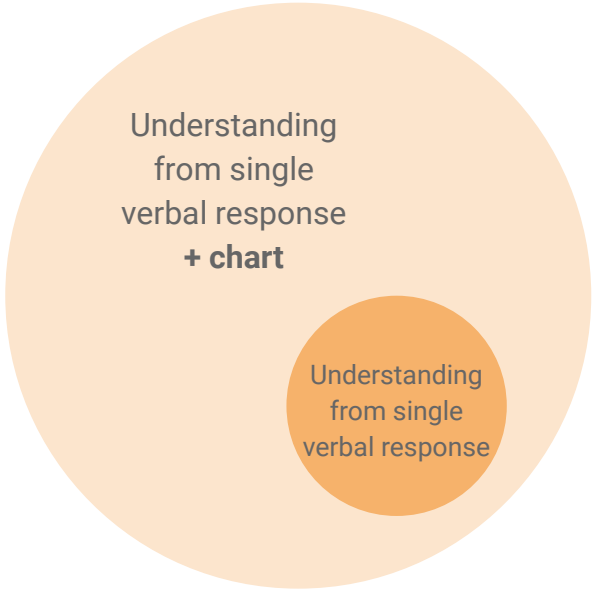
Motivation

- Current tools created for data analysts, not the general, curious public
- "**Amplify cognition**" (Card, Mackinlay, and Shneiderman 1999)
- Provide **context** to numerical responses to increase comprehension
- Encourage **curiosity** and "see what else is there" (Anscombe 1973)



Challenges

- Ambiguity
  - What is the user asking for specifically?
- Inferring **when** to include a chart in the response
  - When does a user benefit from viewing a chart?
- Determining **what** to display
  - What kind of additional data should be displayed?
  - What kind of chart is most effective?
- CUI vs GUI

Question #1

Besides standard graphs, what other types of visualizations do you think would be helpful to integrate into a virtual assistant?

For what domain(s)?

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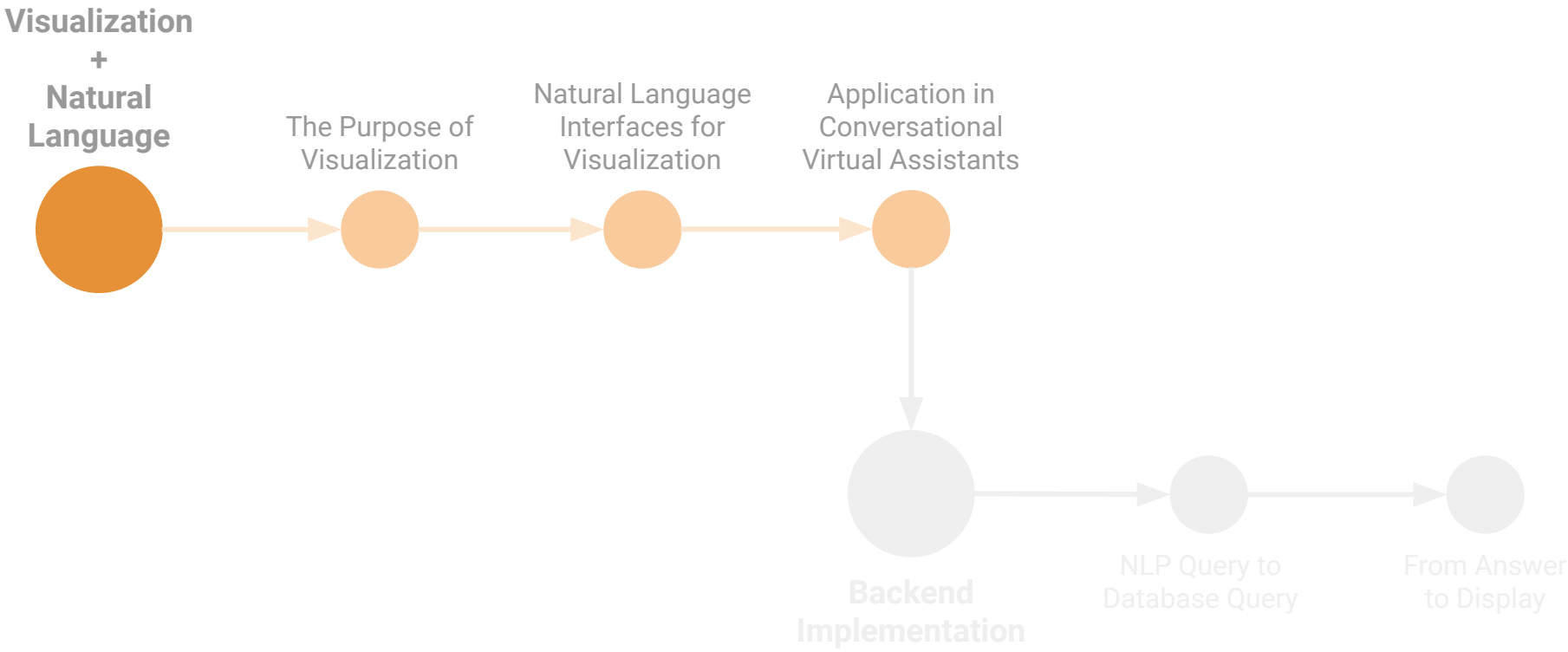
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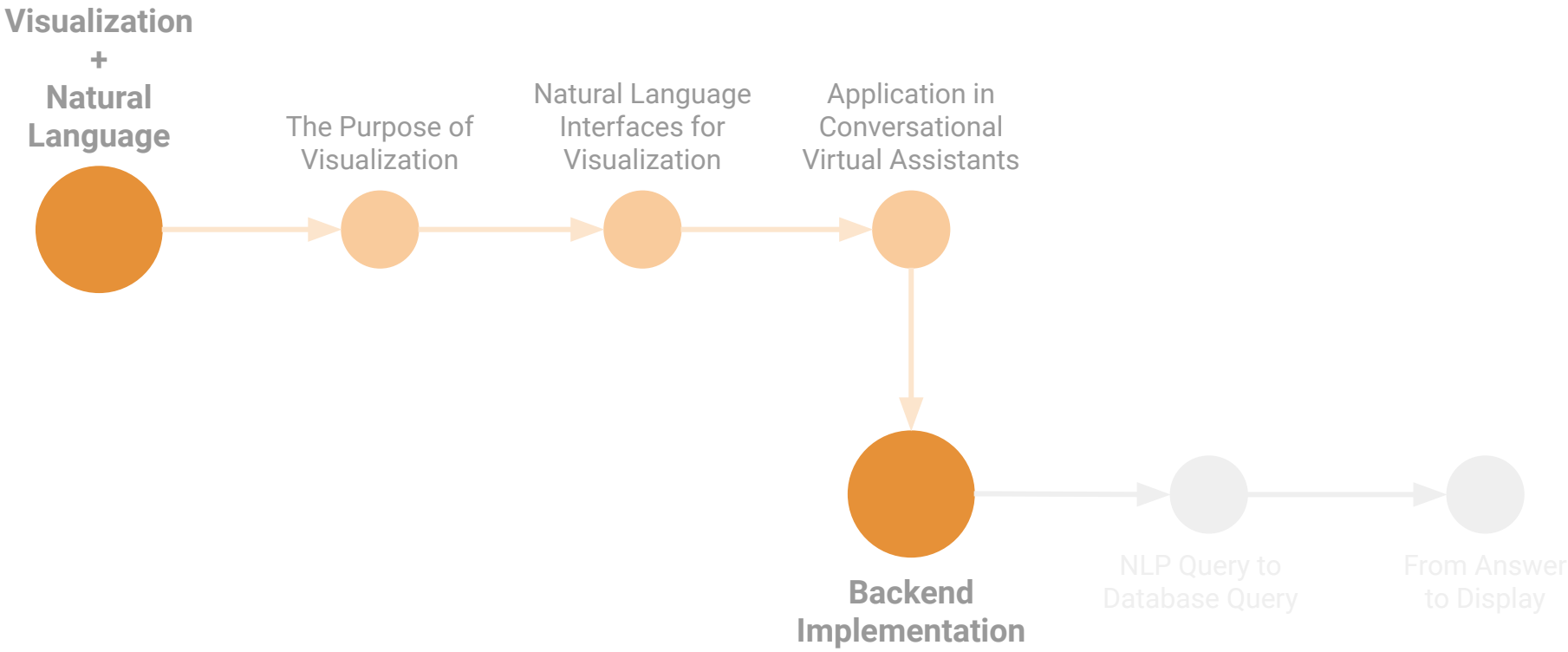
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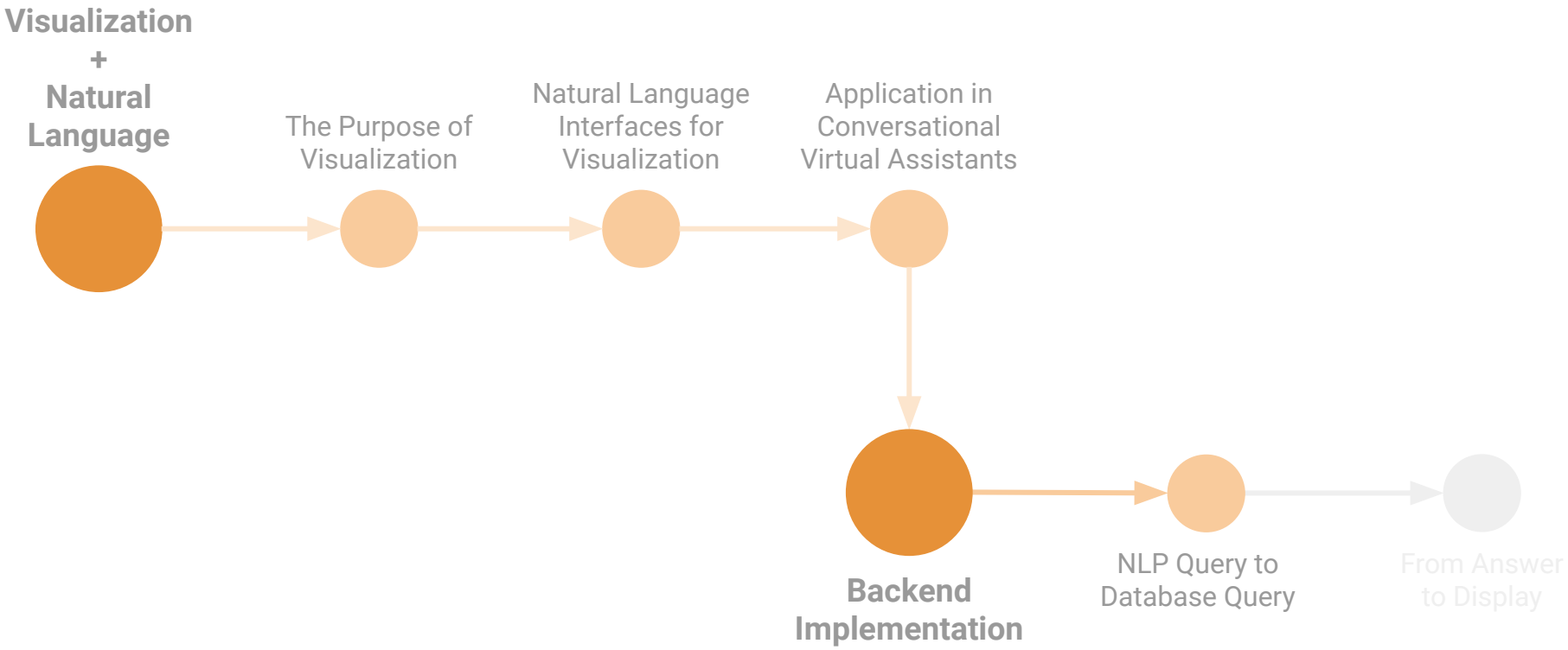
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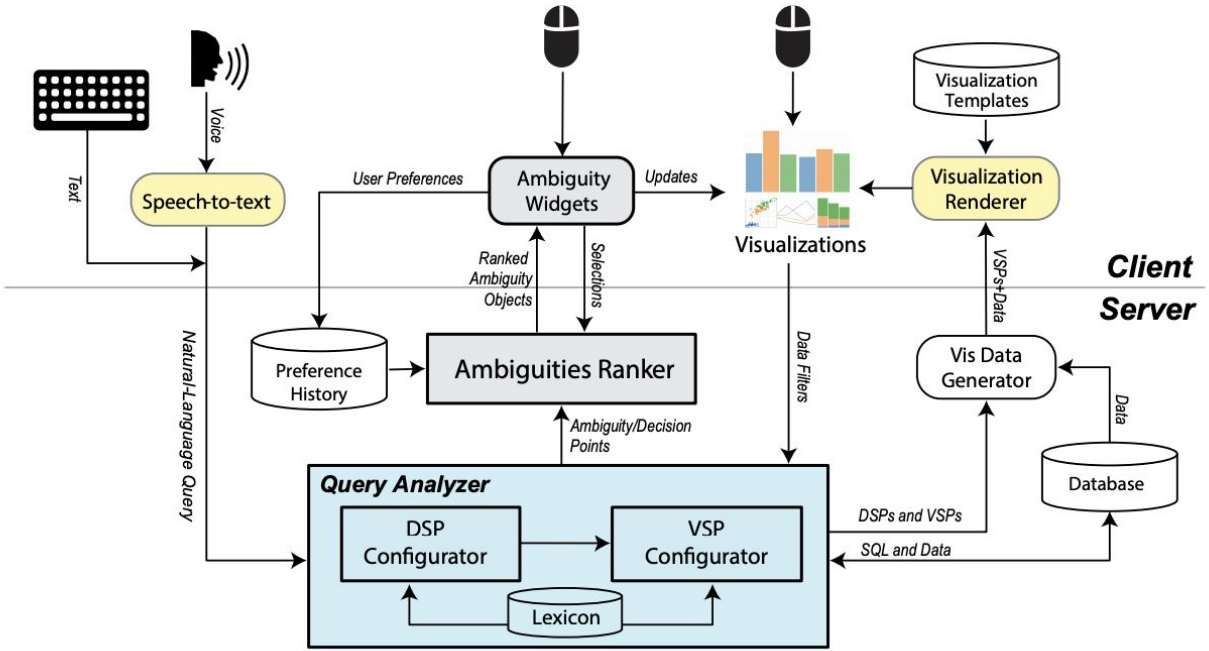
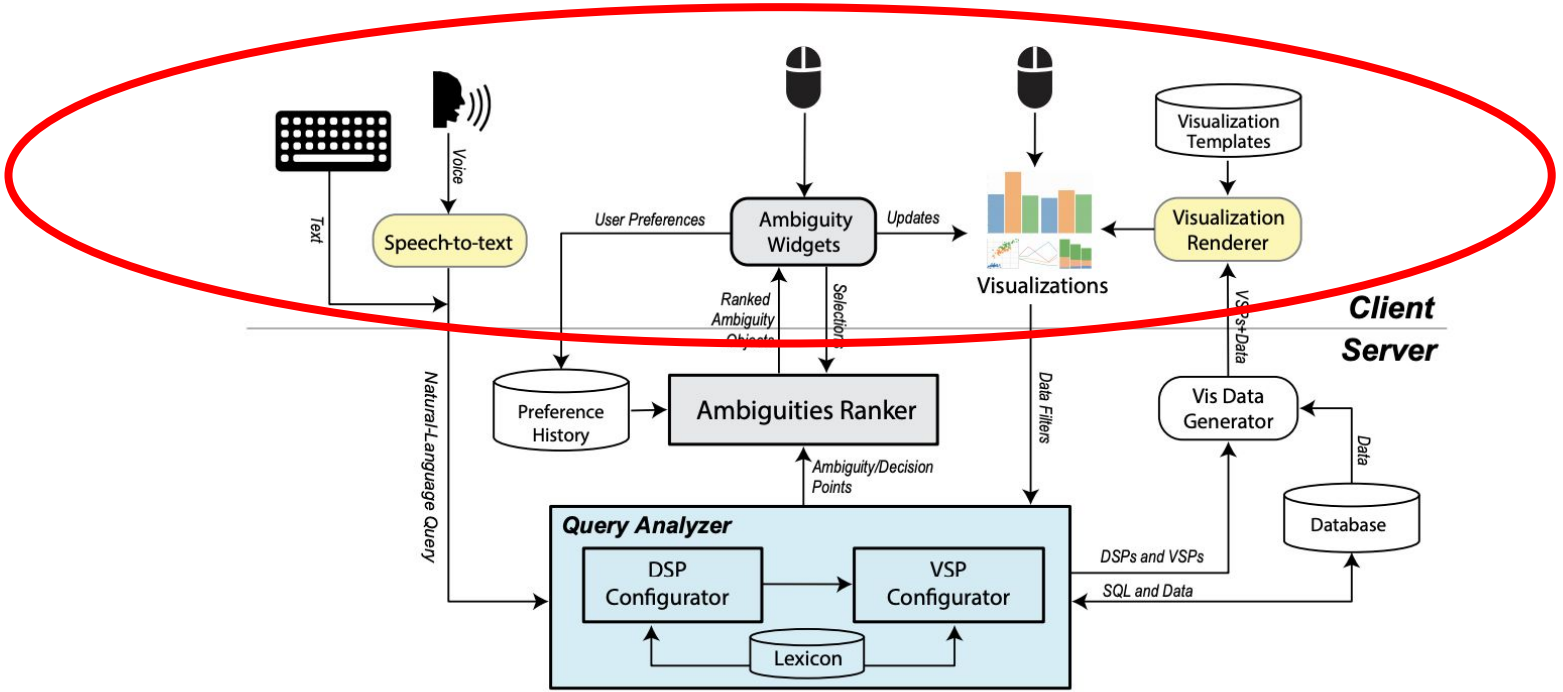
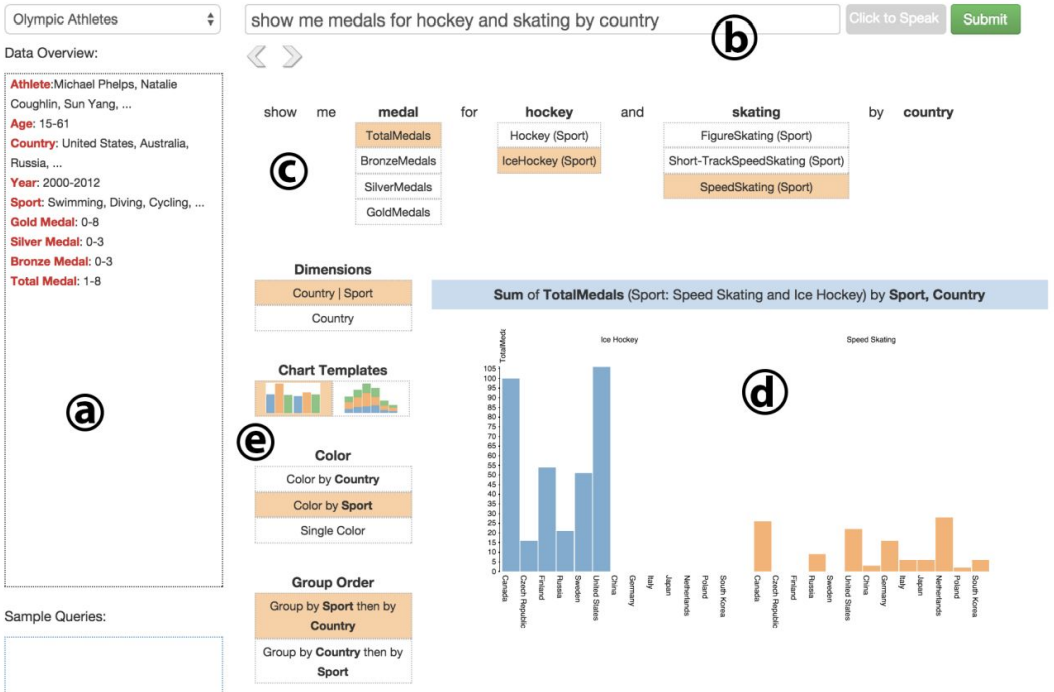
DataTone System Architecture



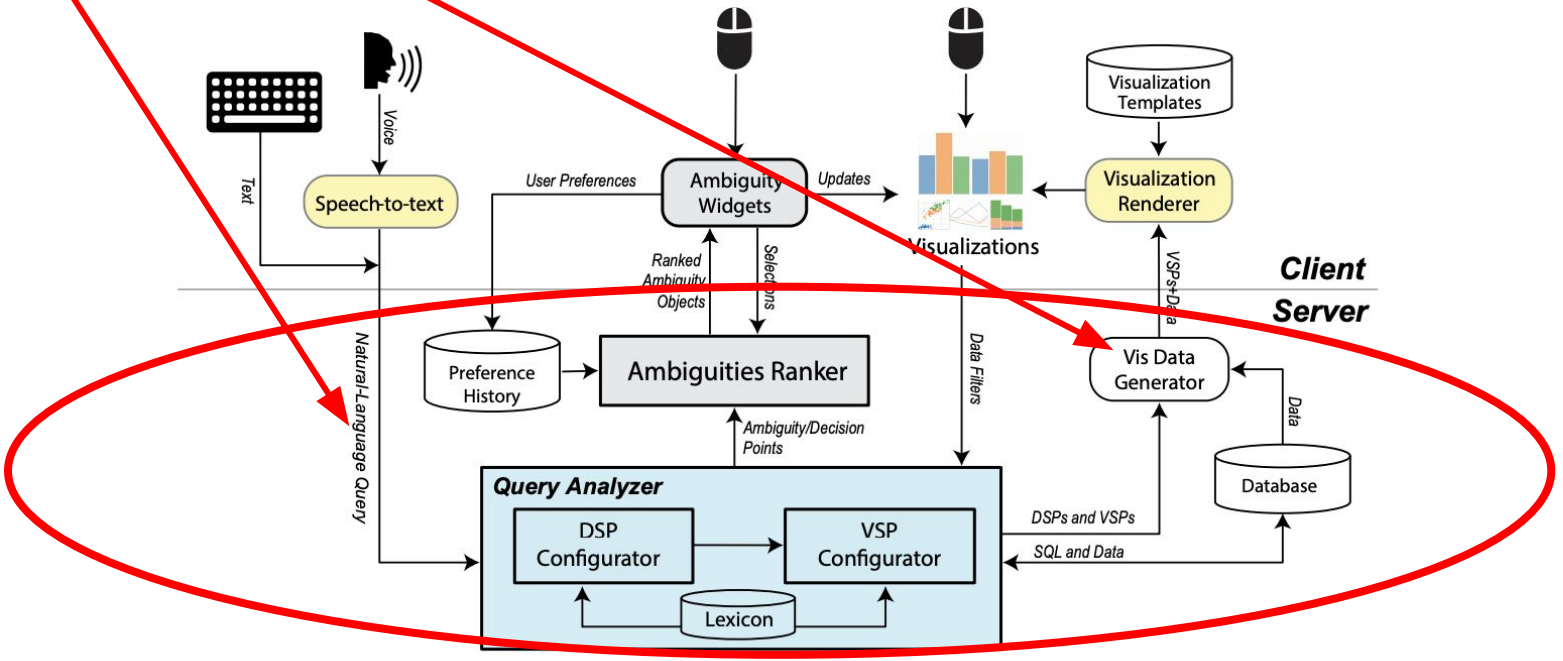
Client Side: Web-based interface that operates in standard web browsers



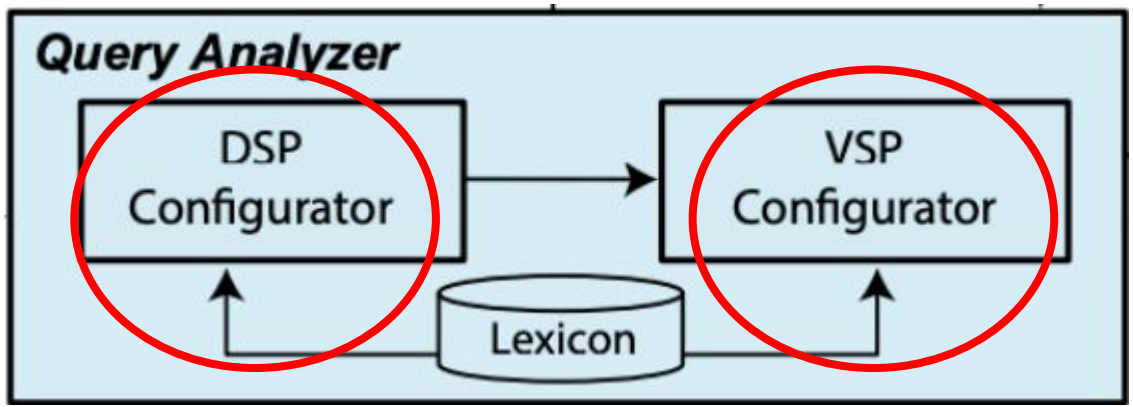
Client Side Example



Server Side: handles translation of
user input to a visualization



Query Analyzer



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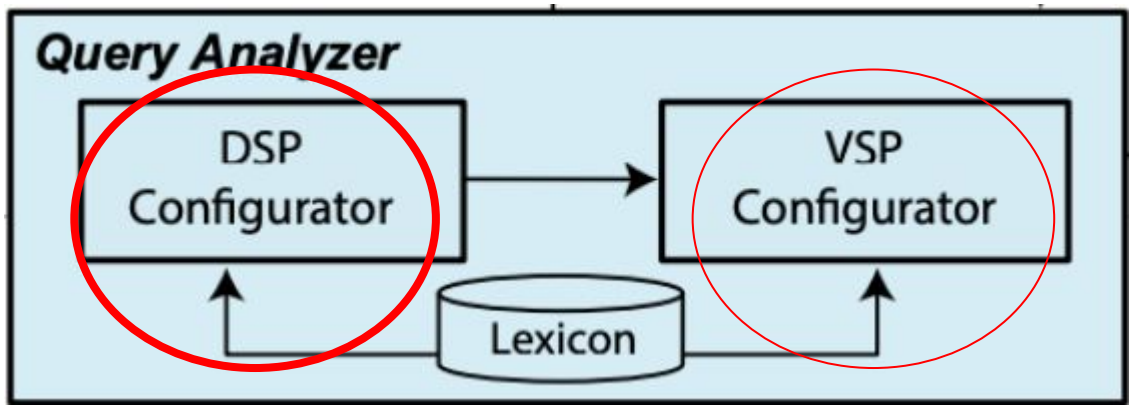

Tokenization

- Identify low-level language features (words and phrases) that have meaning within the context of the dataset and analysis tasks
  - Example: words that identify column names

1. Construct set of possible phrases
   - Extract all n-grams, ranging from 1 (single words) to k, the sentence length
   - Example: This is a sentence. => {this, is, a, sentence, this is, is a, a sentence, this is a, is a sentence, this is a sentence }
2. Identify n-grams with relevance to dataset/query
   - comparing each n-gram to a set of regular expressions and a lexicon consisting of general phrases
   - tag each matched n-gram with one of eight category labels

Category Labels

1. database attributes (i.e., column names)
2. database cell values
3. numerical values
4. time expressions
5. data operators and functions (greater than, less than, equal, sum, average, sort)
6. visualization key phrases (trend, correlation, relationship, distribution, time series, bars, stacked bars, line graph)
7. boolean operators (e.g., and, or),
8. “direct manipulation” terms (e.g., color)

Example

Query: What is the relationship between unemployment and family income for those families earning more than 20000 and less than 150000 between 2007 and 2010 for California and Michigan?

1. Break into N-grams
2. Identify relevant N-grams by matching to categories

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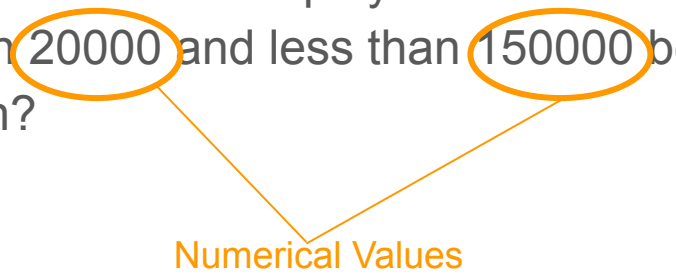

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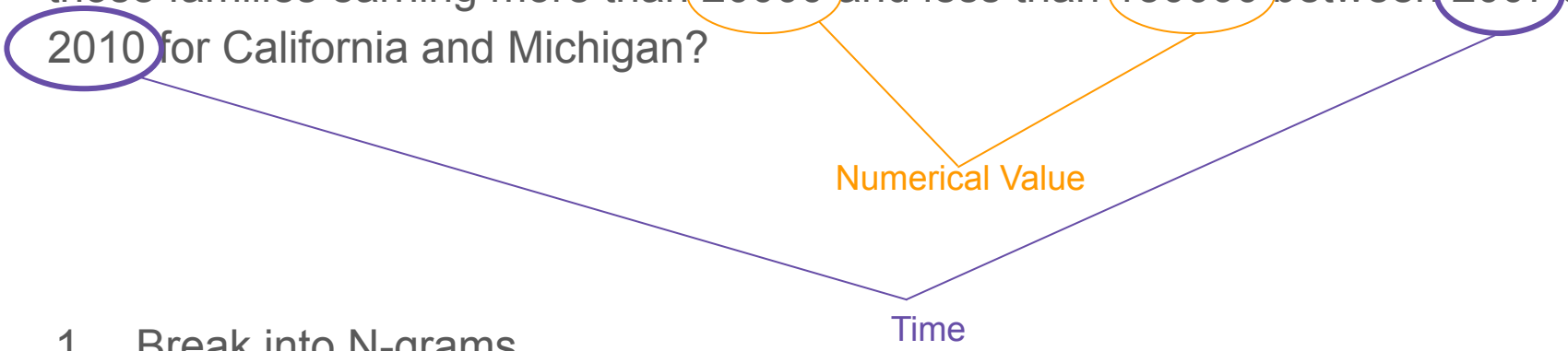

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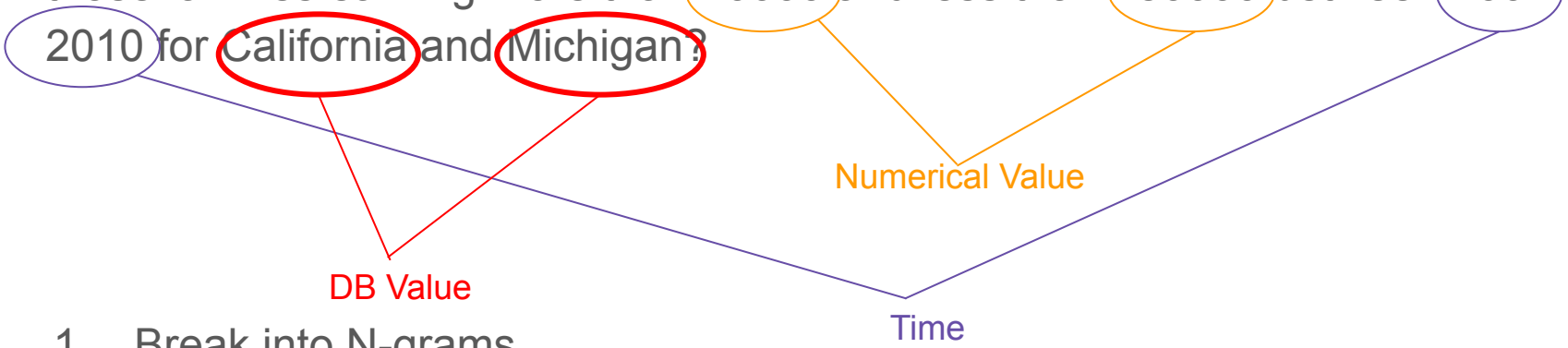

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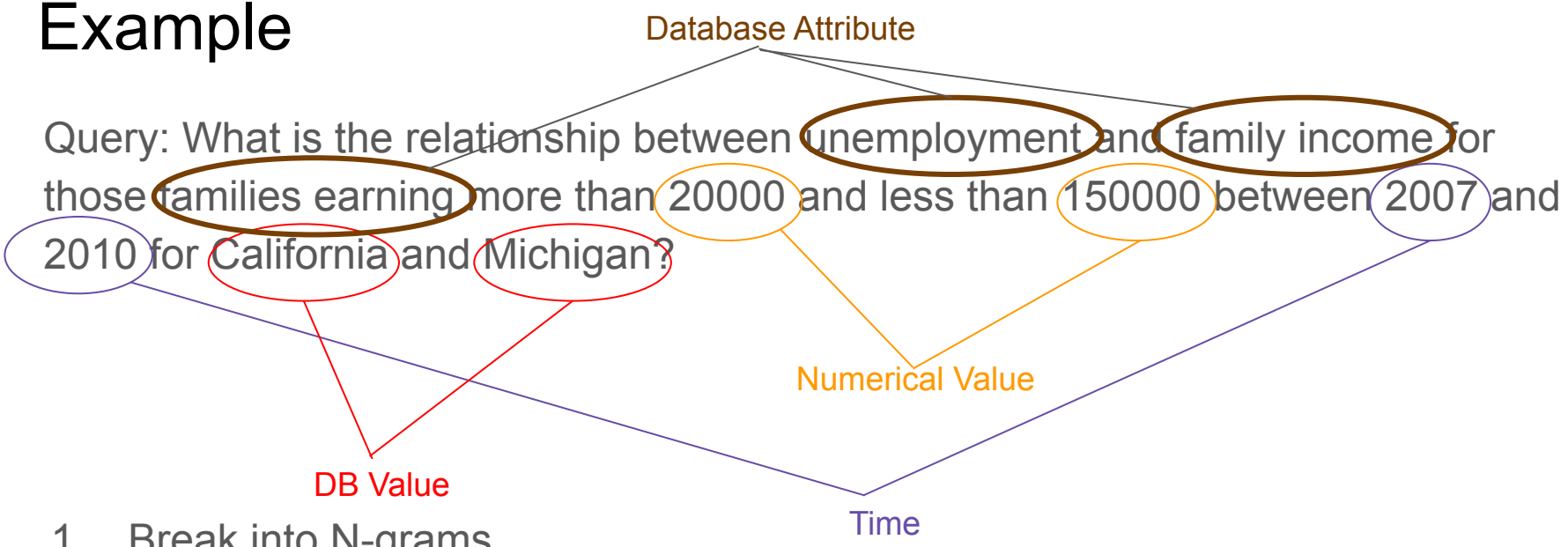

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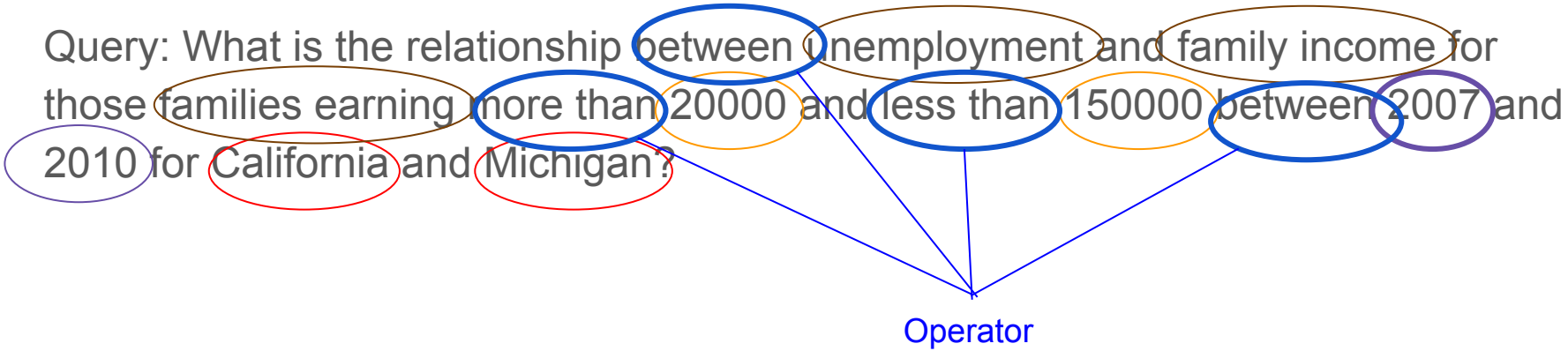

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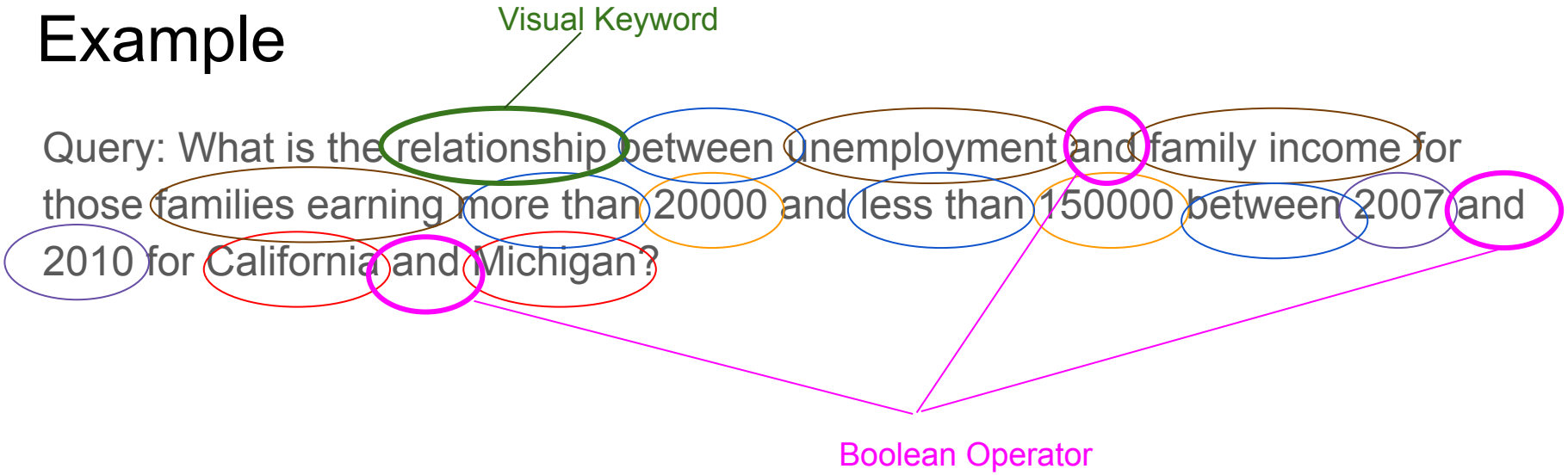

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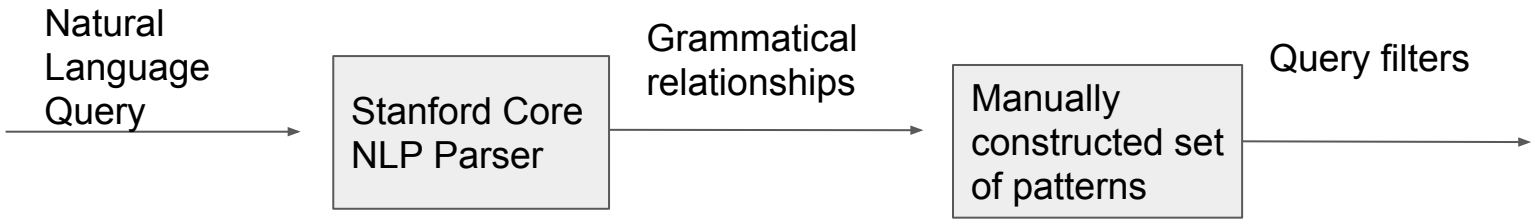
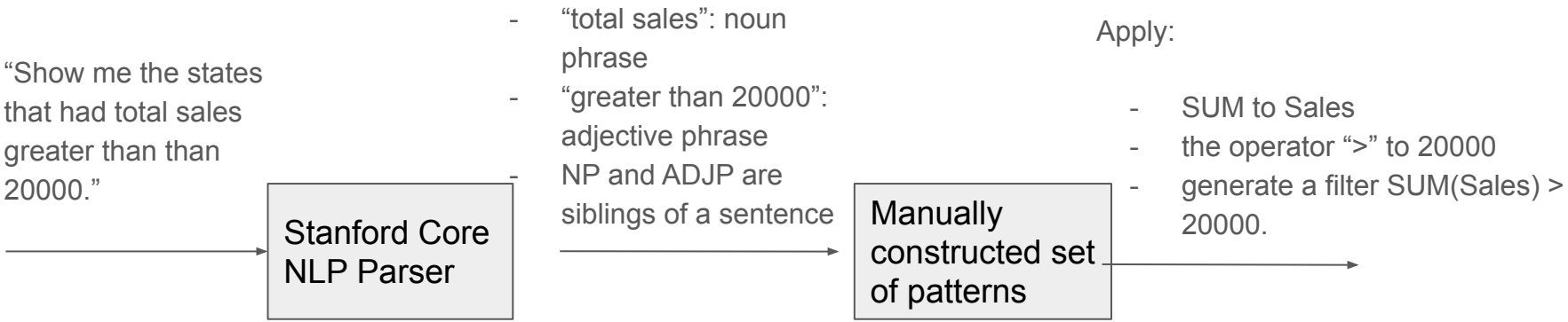
Relation Identification

- We now have a set of tokens with category tags
- We need to define relationships between these tokens in order to construct a query



Relation Identification Example

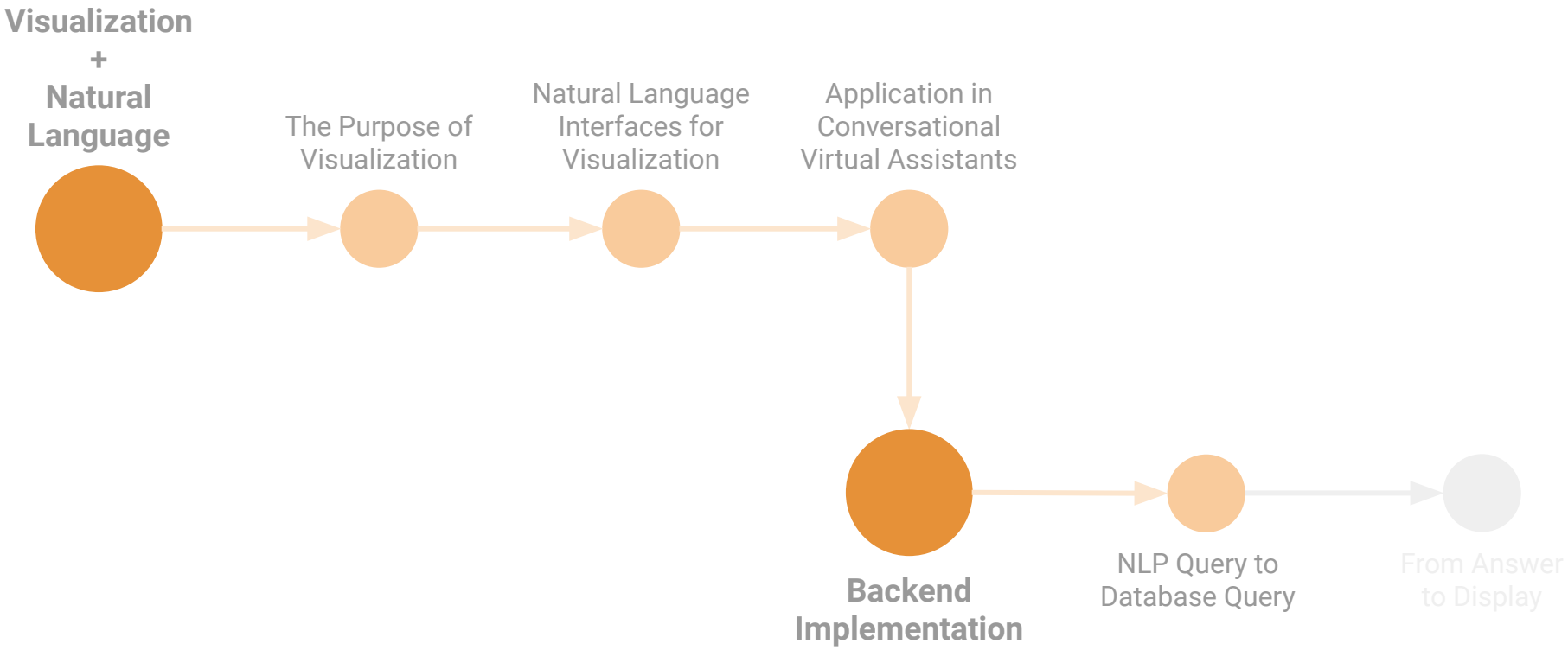


Natural Language Parse ⇒ Data Specification (DSP)

- DSPs contain:
  - **Attributes**: all column names in the original query (ie unemployment, family income)
  - **Values**: all strings, numbers, times (ie California, Michigan, 20000, 150000)
  - **Filters**: as explained in the relation identification
  - **Aggregates**: “Show me average medal count by country per year” → AVG(MedalCount).
  - **Order**: “show me the sorted medal count by country from largest to smallest” → orderBy(MedalCount, DESC)

- Generate one database query for each DSP

Outline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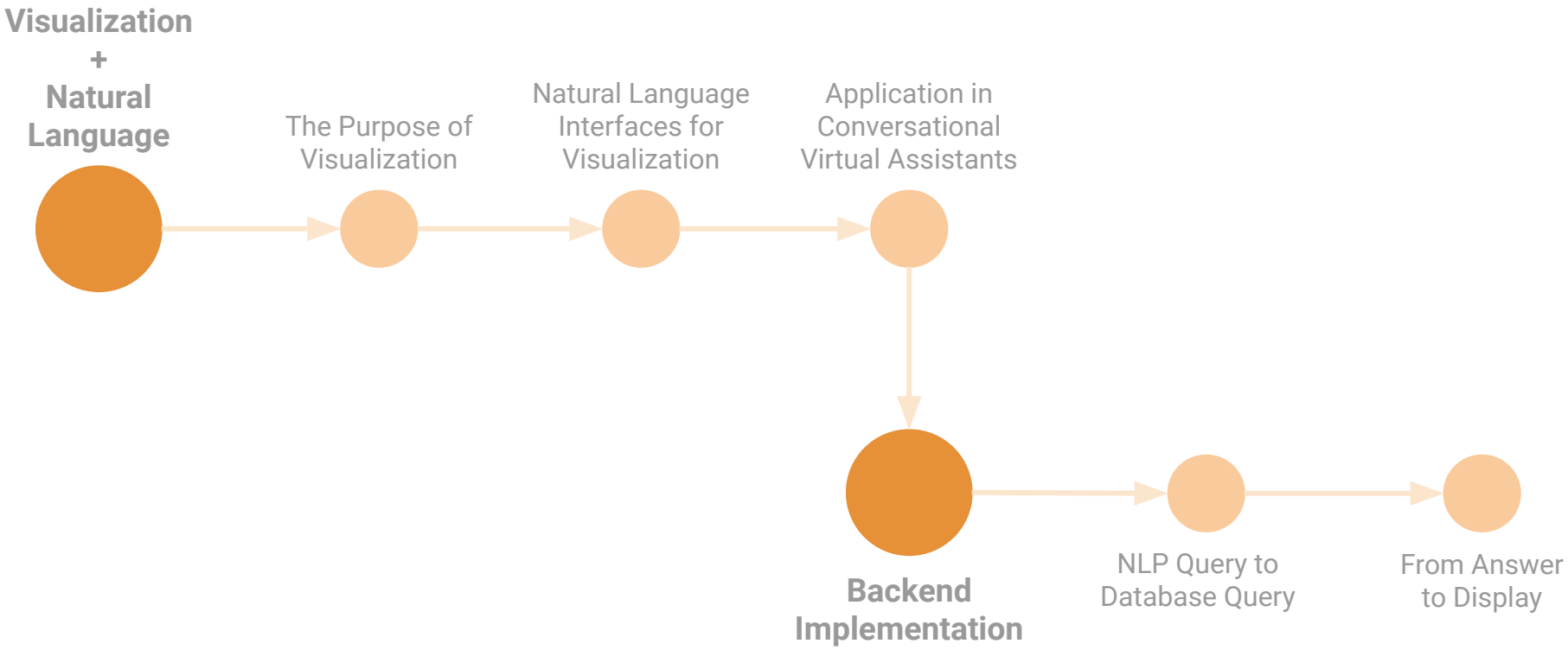
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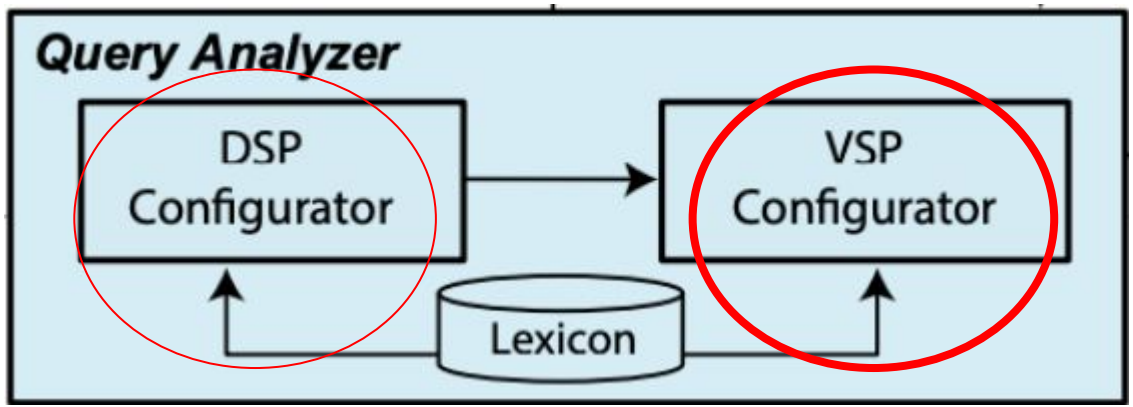
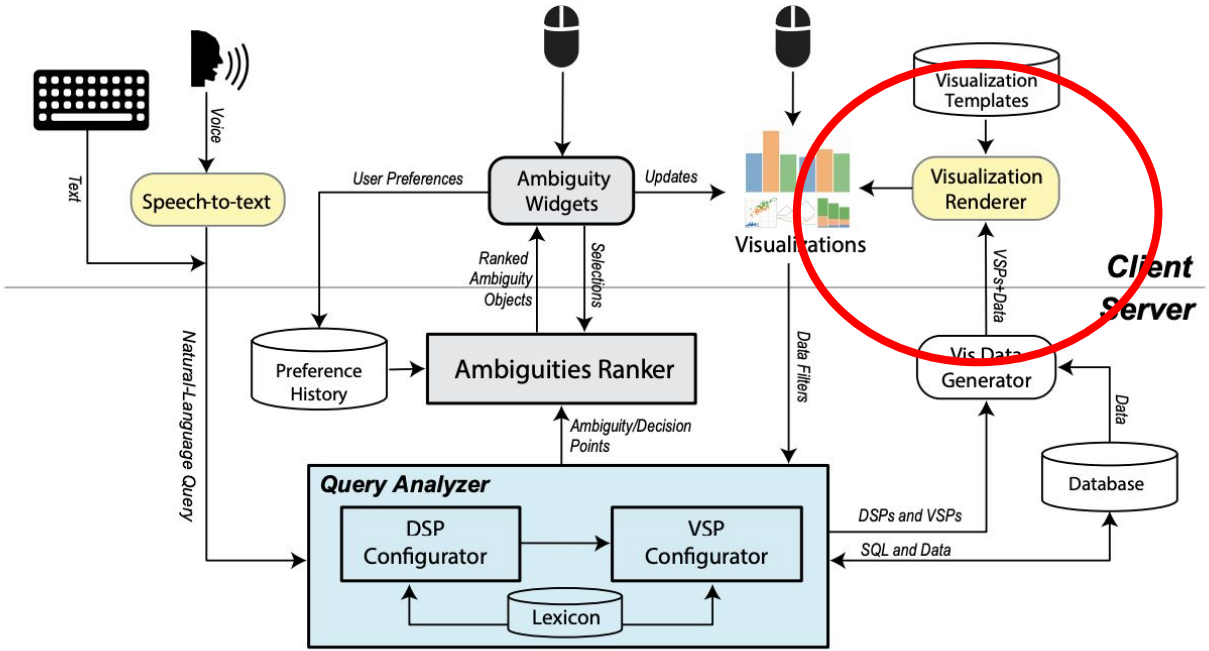


Visual Specification (VSP)

- Template for a graph
- Each template has constraints on how parameters can be filled
  - supported dimension and data types (categorical, quantitative, or time) for each parameter in the graph
- Map each DSP to the VSP template that can accept that specific DSP's configuration
- Bar Chart VSP:
  - x-axis: one categorical dimension
  - y-axis: one quantitative measure
  - color: a color encoding (mapping) of one dimension (optional)
- Given a DSP, there are may be several possible templates

VSP→ Client → D3.js → Image



Question #2

What are some of the category labels for n-grams in this string? What type of graph would you use to represent the answer?

What were the trends of COVID-19 deaths in May between New York and California?

1. database attributes (i.e., column names)
2. database cell values
3. numerical values
4. time expressions
5. data operators and functions (greater than, less than, equal, sum, average, sort)
6. visualization key phrases (trend, correlation, relationship, distribution, time series, bars, stacked bars, line graph),
7. boolean operators (e.g., and, or)
8. “direct manipulation” terms (e.g., color)