

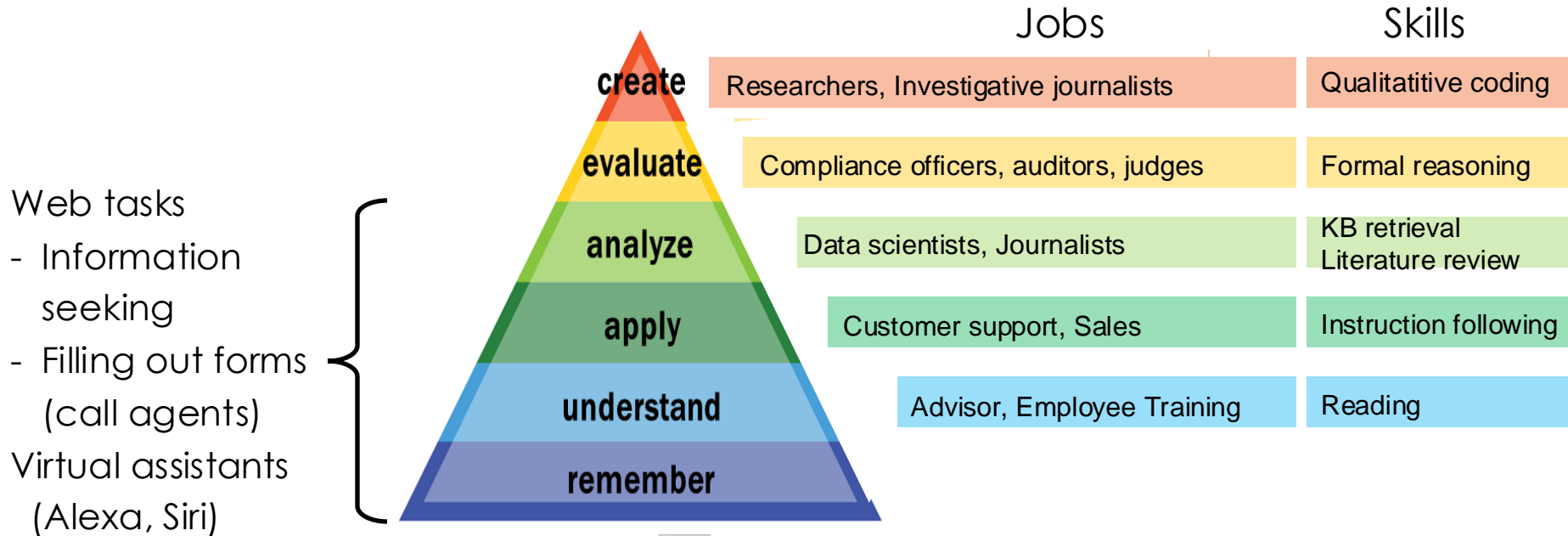
**CS224v**

**Conversational Virtual Assistants  
with Deep Learning**

# **Lecture 3: An Introduction to Agents**

Monica Lam

# General Assistants



# Lecture Goals

- Knowing the SOTA of knowledge/task agents helps you choose topics
  - Topic for the 2<sup>nd</sup> Assignment
  - Hands on experience in building agents
- Landscape of general assistants
- Overview the technical techniques for creating agents
  - Expose to the high-level concepts  
(Details to come in subsequent lectures)

# Agents at a Glance

Category	Scope	Examples	Technology	Intro
<b>Information Seeking</b>				
- Short form	Free-text	WikiChat	Gen+RAG	L1
	Databases (DB)	Basic YelpBot	Semantic parsing	L3
	Hybrid: DBs + Text	YelpBot, Compmix	SUQL	L3
	Knowledge Graphs (KG)	WikiData	Agentic Approach	L3
- Long form	Free-text	Storm, co-Storm	Multi-agent convos	L2
	Free-text + DB/KG	?	?	
<b>API calling</b>	Simple APIs	Alexa, Siri	Slot filling	L3
	Compound APIs	Almond	Semantic parsing	
<b>Task-Oriented</b> (Mixed initiative)	API-based	MultiWOZ	Neural policy	
	Knowledge + Task	Course Assistant	Genie Worksheet	L3
<b>Social bots</b>	Chitchat	Chirpy	Rule-based	
	Persuasion	Persuabot	Gen+RAG, Gen strategy	

# Outline

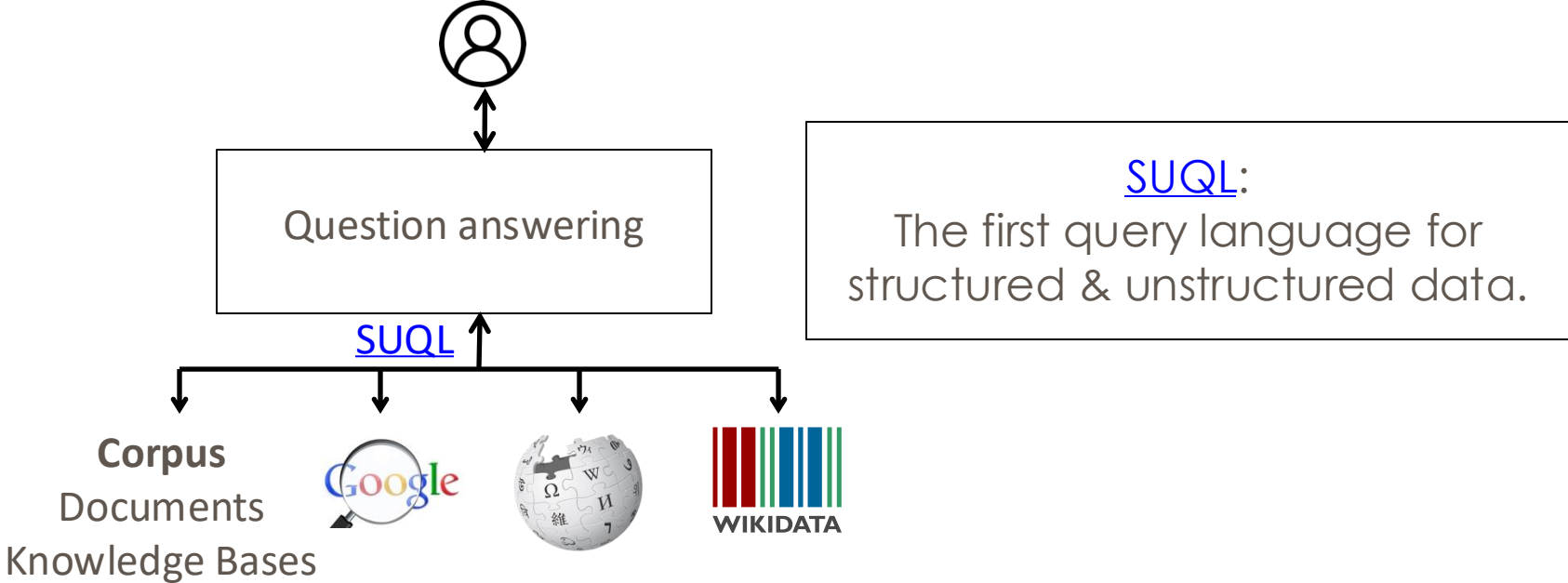
1. Knowledge Assistants
2. API Agents
3. Knowledge + Task-Oriented Agents

# 1. KNOWLEDGE ASSISTANTS

# Outline

1. Knowledge Assistants
  - **Databases**
  - Knowledge graphs
  - Hybrid data
2. API Agents
3. Knowledge + Task-Oriented Agents

# Architecture





# Why Knowledge Bases?

Lots of structured data in the world

- Public databases
  - Schema.org (structured data for the web)
  - Wikidata (knowledge graph with 15 B facts)
- Private databases
  - Every company is a data company [Forbes 2018]
    - Products: Retail (all of ebay), flights, restaurants  
songs, music, books
    - Corporate: People (employees, customers, students, patients)  
Operations (finance, sales, transactions)
    - Personal information: Calendar, emails

# Query Languages

- A **FEW** common query languages:
  - Databases (SQL): Tables with a fixed schema – this lecture
  - Knowledge bases (SPARQL, New4j):  
Graphs with nodes (entities), edges (properties)
- Domains are defined by database **schemas**

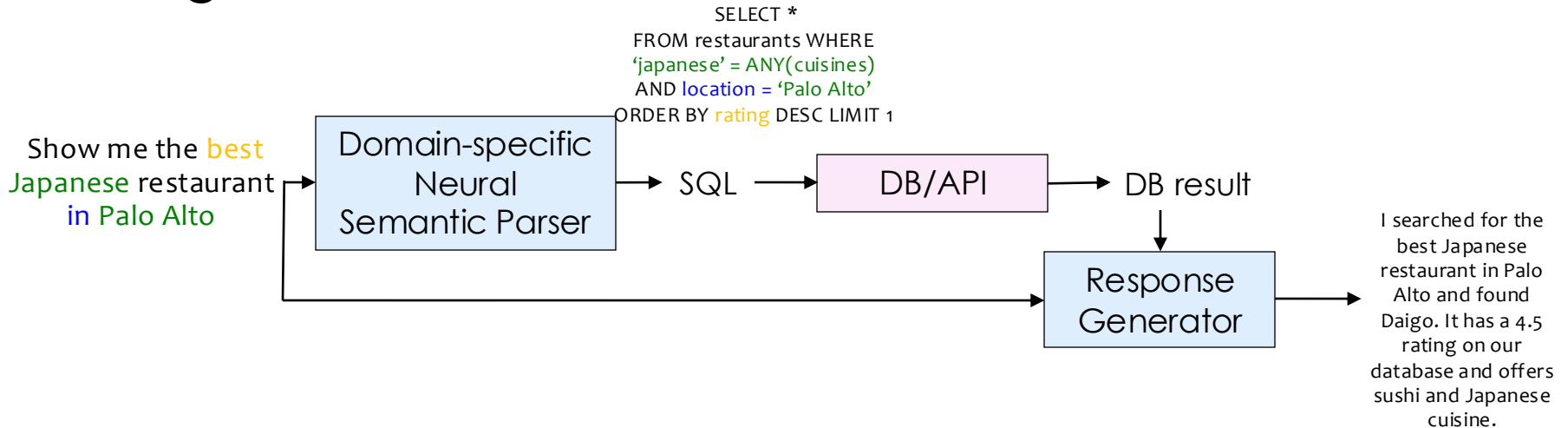
# Power of Query Languages

- Domain agnostic
- All queries of any domain are compositions of a FEW relational algebra operations
  - Basic: Selection, Projection, Cartesian product (Join), Union, Set Difference
  - Extended: Sort, Aggregate Operators (Sum, Max, Avg, ...)
- Expressive, succinct, well-defined

Amazing  
CS Idea

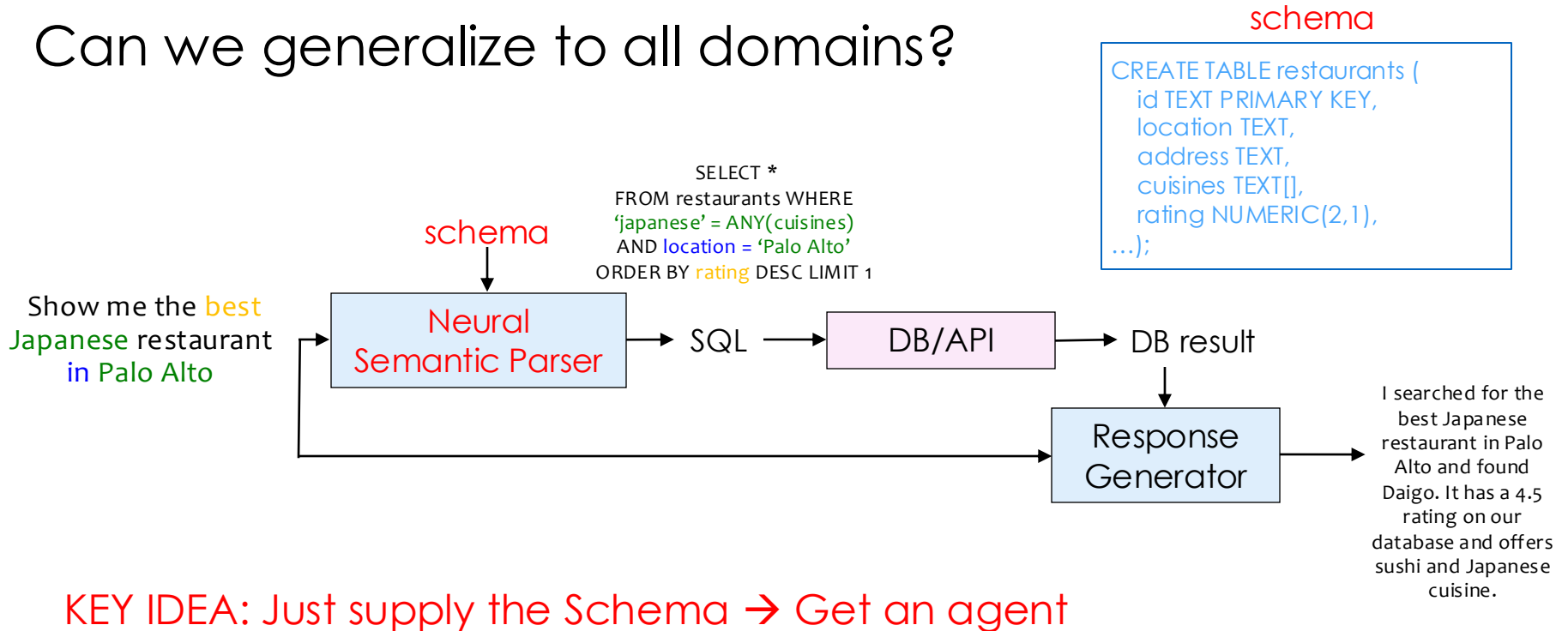
# Semantic Parsing: NL $\rightarrow$ Formal Query

For a given domain:



# Semantic Parsing: NL $\rightarrow$ Formal Query

Can we generalize to all domains?



# Basic Idea: Zero-Shot Prompt with LLMs

You are a semantic parser. Generate a query for a restaurant database with the following signature:

```
CREATE TABLE restaurants (  
  name TEXT,  
  address TEXT,  
  location TEXT,  
  phone_number TEXT,  
  opening hours TEXT,  
  cuisines TEXT[],  
  price ENUM ('cheap', 'moderate', 'expensive', 'luxury'),  
  rating NUMERIC(2,1),  
  num_review NUMBER,  
);
```



How to create effective semantic parsers with LLMs?

# Restaurant Assistant



```
CREATE TABLE restaurants (  
  name          TEXT,  
  address       TEXT,  
  location      TEXT,  
  phone_number  TEXT,  
  opening_hours TEXT,  
  cuisines      TEXT[],  
  price         ENUM ('cheap', 'moderate', 'expensive', 'luxury'),  
  rating        NUMERIC(2,1),  
  num_reviews   NUMBER,  
  reviews       FREE_TEXT,  
  popular_dishes FREE_TEXT,  
);
```

NUMERIC(2,1) means 2-digit precision, 1 digit after decimal

# Queries in a Conversation (Yelp)

My dad is visiting me in Mountain View. What do you think about dinner choices?

I found Cascal, a moderate Spanish restaurant with great tapas platters, appetizers, and drinks. It has a great ambience with live music on the weekends and both indoor and outdoor seating with heat lamps to keep guests warm.

Generated SQL:

```
SELECT * FROM restaurants  
WHERE location = "Mountain View"
```

How about Italian instead? I really like the food there when I visited Florence last year.

I found Vaso Azzurro Ristorante, a moderate Italian restaurant near Mountain View. It has a lively atmosphere and offers excellent customer service. Reviews say their pasta is authentic and perfectly seasoned.

Generated SQL:

```
SELECT * FROM restaurants  
WHERE location = "Mountain View"  
AND cuisines = ANY("Italian")
```

Oh, what is the ham called in Italian?

Prosciutto is the Italian word for ham.

GPT responds directly

Thanks. We'll be visiting Stanford. How about in Palo Alto?

I found Terún, a 4 star Italian and Pizza restaurant near Stanford in Palo Alto. Reviews say the pizza is great and they can seat customers outside without a reservation.

Generated SQL:

```
SELECT * FROM restaurants  
WHERE location = "Palo Alto"  
AND cuisines = ANY("Italian")
```



# Outline

1. Knowledge Assistants
  - Databases
  - **Knowledge graphs**
  - Hybrid data
2. API Agents
3. Knowledge + Task-Oriented Agents

# Wikidata: Largest, Live Knowledge Graph

- 15B facts, 100M entities, 10K properties, 25K contributors
  - Every Wikipedia article has a corresponding entity in Wikidata
  - **Dataset for research in life sciences, digital humanity, etc.**
- Representation: Semantic web (triples)
  - Query with SPARQL

Who founded Stanford?

```
SELECT ?x WHERE
```

```
{ wd:Q41506 wdt:P112 ?x. }
```

Stanford Founded by

# But Querying Wikidata is difficult

Forums exist to help Wikidata users write SPARQLs

---

**Question:** Who are the doctoral advisors of Leonhard Euler, and their advisors, and so on? In addition, who are his doctoral student, grand-student, great-grand-student, and great-great-grand-students? Each tuple in the result should contain both the student and the doctoral advisor.

---

```
SPARQL: SELECT ?doctor ?doctorMaster WHERE {  
  { ?root (wdt:P184*) ?doctor. }  
  UNION  
  { ?root (wdt:P185/(wdt:P185?)/(wdt:P185?)/(wdt:P185?)) ?doctor. }  
  ?doctor wdt:P184 ?doctorMaster.  
  VALUES ?root {  
    wd:Q7604  
  }  
}
```

---

A natural language interface can greatly expand access

# **SPINACH: SPARQL-Based Information Navigation for Challenging Real-World Questions**

**Shicheng Liu**<sup>†\*</sup>   **Sina J. Semnani**<sup>†\*</sup>   **Harold Triedman**<sup>§</sup>   **Jialiang Xu**<sup>†</sup>  
**Isaac Dan Zhao**<sup>†</sup>   **Monica S. Lam**<sup>†</sup>  
<sup>†</sup> Stanford University   <sup>§</sup> Wikimedia Foundation

Agentic approach to imitate the expert worker

1. Try out possibly a simpler query
2. Evaluate the query
3. Revise the query based on the result
4. Repeat

Live demo: <https://spinach.genie.Stanford.edu>

- Release on Wikidata in July 2024

# Outline

1. Knowledge Assistants
  - Databases
  - Knowledge graphs
  - **Hybrid data**
2. API Agents
3. Knowledge + Task-Oriented Agents

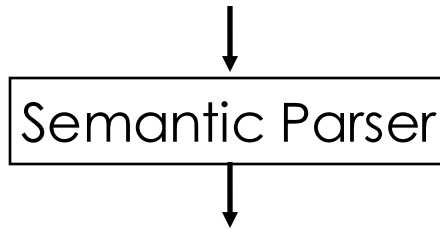
# We Need Hybrid Data

	<b>Structured</b>	<b>Free Text</b>
Restaurants	Cuisines, opening hours, address, rating	Reviews, popular dishes
Products	Product ID, cost, ratings, sizes, physical dimensions, color	Descriptions, reviews
Courses	Class number, time offered, instructor, building, pre-requisites	Descriptions, reviews
Business processes	Receipts, statements	Regulations
Medical	Patient demographics Prescription	Diagnosis history

# SUQL

- Extend SQL with two free-text LLM functions: `summary`, `answer`

“I want a family-friendly restaurant in Palo Alto”



```
SELECT *, summary(reviews) FROM restaurants  
WHERE location = 'Palo Alto'
```

```
AND answer(reviews, 'is it a family friendly restaurant') = 'Yes' LIMIT 1;
```



# Experiment: Yelp



## RestaurantGenie

I'd like some spicy Szechuan food in Palo Alto, can you help?

I searched for restaurants that serve spicy Szechuan food in Palo Alto. I found Taste, a Chinese restaurant located at 423 University Ave, Palo Alto, CA 94301. They have a rating of 4.0 and offer a variety of Szechuan dishes. Some popular dishes mentioned in reviews include Dumpling, Tofu, Spicy Fish Fillet in Flaming Red Oil, Hot and Sour Soup with Pork, Numbing Spicy Beef Tripe, Tea Flavored Duck, Beef Chow Fun, Chongqing Numbing Spicy Noodle, Honey Walnut Shrimp, Sizzling Cumin Lamb, Stir Fried Pea Sprouts with Garlic, Shrimp Dumpling, Mongolian Beef, BBQ Pork Bun, Sweet and Sour Chicken, Crispy Sweet & Sour Fish, Lanzhou Beef Ramen, and Dry Braised Pork Intestine. The restaurant's phone number is (650) 323-6488.

That sounds delicious. Would my friend who does not like spicy food like it too?

I searched for information about Taste in Palo Alto. According to reviews, Taste offers non-spicy options such as Broccoli with Beef and Stir fry Chinese Greens with Garlic. So, your friend who does not like spicy food should be able to find something they enjoy as well.

## SUQL

"SELECT \*, **summary(reviews)**  
FROM restaurants WHERE  
'szechuan' = ANY (cuisines) AND  
location = "Palo Alto" AND  
**answer(reviews, 'does this restaurant  
serve spicy food?') = 'Yes' LIMIT 1;"**

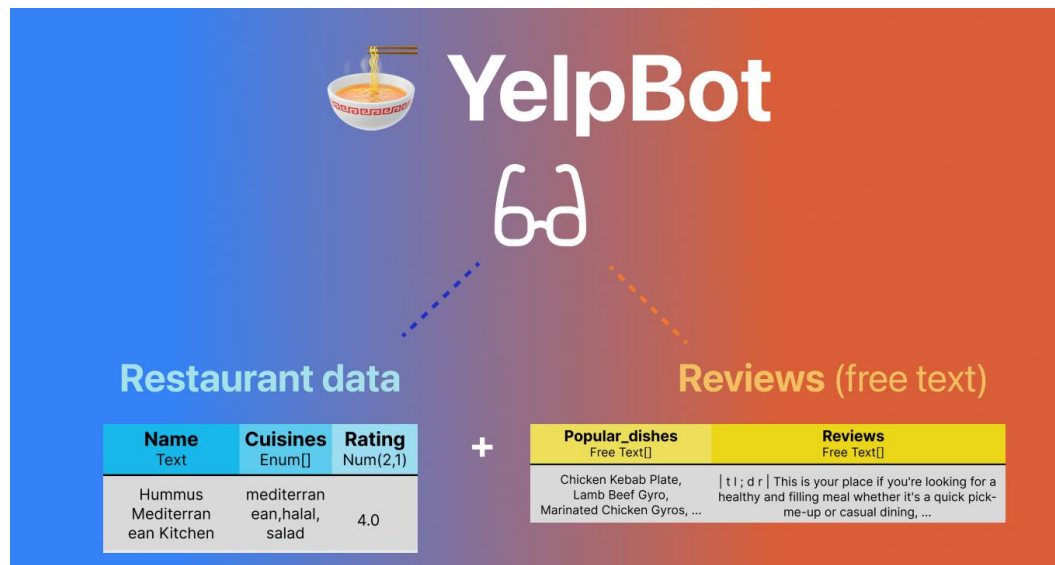
"SELECT **answer(reviews, 'does this  
restaurant have non-spicy options?')**  
FROM restaurants WHERE  
name ILIKE 'Taste' AND  
location = 'Palo Alto';"

# Evaluation of YelpBot

- Dataset
  - 55 of 100 questions need SUQL (structured & unstructured)
- Query *precision*: #correct results / #results
- Optimizing compiler implemented

	100 Questions	20 Conversations 96 turns
Linearization (1 result)	57.0%	63.4%
Linearization (3 results)	49.7 %	61.9%
SUQL (up to 3 results)	<b>93.8%</b>	<b>90.3%</b>

Live Demo: <https://yelpbot.genie.stanford.edu/>



# 1. KNOWLEDGE ASSISTANTS

Data can be accessed with Query Languages  
(SQL, SPARQL, SUQL for free-text+KB)

Semantic parsing translates NL to formal QL

Schema-parameterized semantic parsing  
translates NL to QL for given schema

## 2. API CALLS

# Semantic Parsing: NL $\rightarrow$ API Call

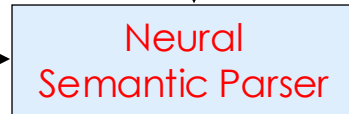
Signature

```
enum GradeType {Letter, Credit,};  
Enroll (  
  str student_id.  
  str course_name,  
  GradeType grade_type,  
  int num_units  
);
```

```
Enroll (student_id="123456",  
        course_name="CS224V",  
        grade_type=Letter,  
        num_units=4)
```

signature

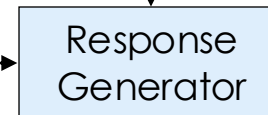
My ID is 123456,  
I want to enroll in CS224v  
for a letter grade,  
and for 4 units



API



Result



You are enrolled  
successfully.

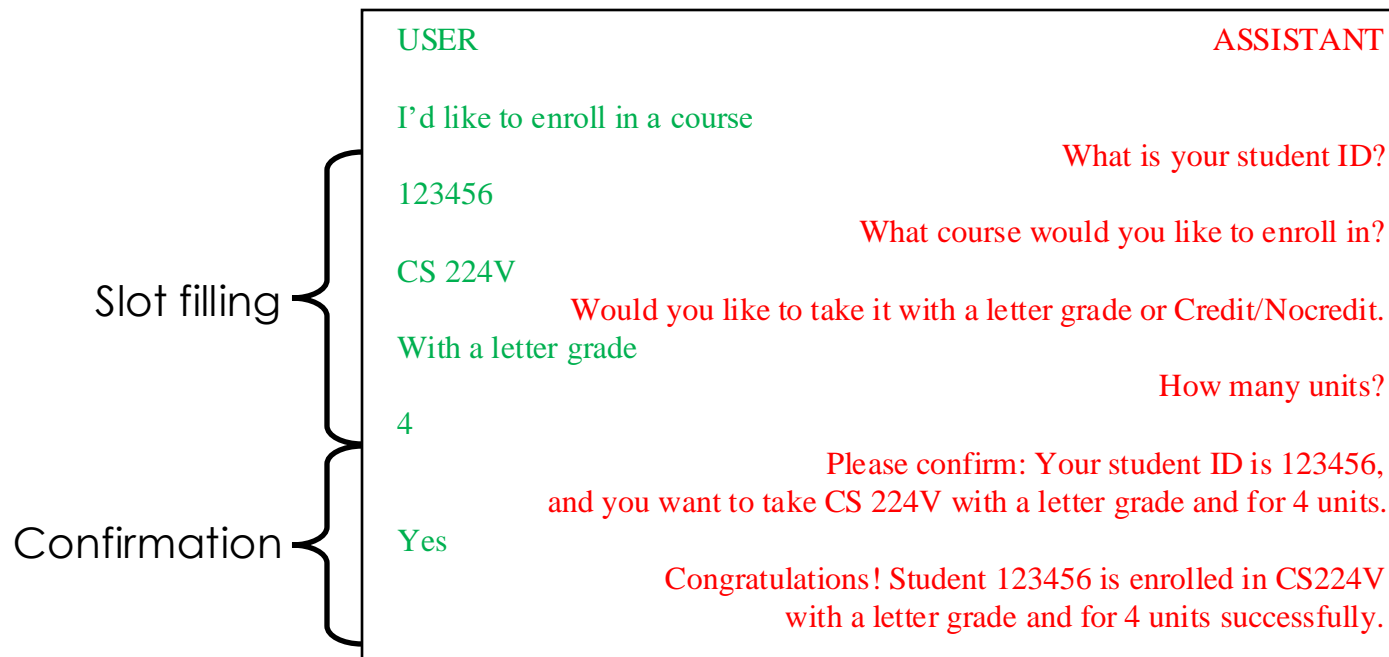
KEY IDEA: Just supply the Signature  $\rightarrow$  Get an agent

# Conversational Agent for API calls

A conversation is needed typically

- Slot filling
  - Ask for missing arguments of the API  
e.g. “I want to enroll in a course”
- Confirm before API execution:
  - Because APIs have side effects

# A Simple Enrollment Dialogue





## 2. API CALLS

Signature-parameterized semantic parsing  
translates NL to QL for a given set of API signatures

### 3. KNOWLEDGE + TASK-ORIENTED AGENTS

# Outline

1. Knowledge Assistants
  - Databases
  - Knowledge graphs
  - Hybrid data
2. API Agents
3. Knowledge + Task-Oriented Agents
  - **Motivation: a Case Study**
  - Design of the Genie WorkSheet
  - Genie Runtime System

# Task Assistants

	<b>Tasks</b>
Restaurants	Book restaurant
Products	Purchasing Ordering food
Courses	Enrolling in courses
Business processes	Filing taxes Reimbursements Customer support
Medical	Making diagnoses Insurance claims

# Task Assistants Should also Provide Knowledge

	<b>Tasks</b>	<b>Structured</b>	<b>Free Text</b>
Restaurants	Book restaurant	Cuisines, opening hours, address, phone number	Reviews, popular dishes
Products	Purchasing Ordering food	Product ID, cost, ratings, sizes, color, physical dimensions	Descriptions, reviews
Courses	Enrolling in courses	Class number, time offered, instructor, building, pre-requisites	Descriptions, reviews
Business processes	Filing taxes Reimbursements Customer support	Receipts, statements	Regulations
Medical	Making diagnoses Insurance claims	Patient demographics Prescription	Diagnosis history

# A Case Study

## Course Enrollment at Stanford

Let's consider a CS MS student

**DEPARTMENT OF COMPUTER SCIENCE****MSCS Program Sheet (2023-24)****Artificial Intelligence Specialization**

Name: \_\_\_\_\_ Advisor: \_\_\_\_\_ Date: \_\_\_\_\_

Student ID#: \_\_\_\_\_ Email: \_\_\_\_\_ Proposed date for  
degree conferral: \_\_\_\_\_ HCP? \_\_\_\_\_ Coterm? \_\_\_\_\_

**GENERAL INSTRUCTIONS:** Before the end of your first quarter, complete a program sheet by filling in the number, name and units of each course you intend to take for your degree. Program sheets, as well as foundation course waiver forms, may be submitted electronically on the Gates Information Network at <http://gin.stanford.edu>, using your CS ID and password (click on the 'Dashboard' link). See <http://cs.stanford.edu/degrees/mcs/programsheets/psguide2324.pdf> for detailed instructions.

**FOUNDATIONS REQUIREMENT:** You must satisfy the requirements listed in each of the following areas; all courses taken elsewhere must be approved by your advisor via the foundation course waiver form. Do not enter anything in the "Units" column for courses taken elsewhere or for Stanford courses counted towards your undergraduate degree.

Required:	Equivalent elsewhere (course numbers/titles/institution)	Grade	Units
Logic, Automata & Complexity (CS103)			
Probability (CS109, Stat116, CME106, MS&E 220, or EE178)			
Algorithmic Analysis (CS161)			
Computer Organ & Sys (CS107 or 107E)			
Principles of Computer Systems (CS111)			

TOTAL UNITS USED TO SATISFY FOUNDATIONS REQUIREMENT (May not exceed 10 units.) 

**SIGNIFICANT IMPLEMENTATION REQUIREMENT:** At least one course in your MS program should be designated as satisfying the Significant Implementation Requirement. Note that this course will also be used to satisfy some other requirement (i.e., Depth or Elective). Must be taken for a letter grade.\* Must be taken at Stanford. Coterm students who took two of these courses at Stanford as undergraduates may waive this requirement. Deviations must be approved by the faculty director of the MS program, Cynthia Lee.

Course Number:	Title:	Grade

*Courses that may be used to satisfy the significant implementation requirement include:* CS 140, 140E, 143, 144, 145, 148, 151, 190, 210B, 212, 224R, 227B, 231N, 239, 243, 248A, 248B, 330, and 341.

**BREADTH REQUIREMENT:** Three courses, with each course chosen from a different Breadth area A, B, C or D. Breadth courses may not be waived, must be taken for at least 3 units each, and must be completed for a letter grade.\* Each of the three Breadth courses must be from different Areas. Note that these courses will also be used to satisfy some other requirement (i.e., Depth or Elective). Letter grade only.\*

Course Number:	Title:	Grade

**Area A. Formal Foundations:** CS 154, 157, 166, 168, 205L, 229T, 250, 254, 254B, 255, 256, 257, 258, 259Q, 261, 263, 265, 269I, 328, 331, 334A, 354, 355, 359D, 369Q; EE 364A, 364B; Phil 251

**Area B. Learning and Modeling:** CS 173A, 205L, 221, 223A, 224N, 224R, 224S, 224U, 224V, 224W, 227B, 228, 229, 229B, 229T, 230, 231A, 231N, 233, 234, 236, 237A, 237B, 248A, 248B, 271, 272, 273A, 273B, 274, 279, 281, 326, 329D, 329X, 330, 332, 333, 348A, 348B, 348C, 348E, 348I, 348N, 371, 373

**Area C. Systems:** CS 112 (with CS111 as prereq), 140E, 143, 144, 145, 149, 155, 212, 240, 240LX, 242, 243, 244, 244B, 245, 246, 249I, 316, 348K, 356, 358; EE 180, 282, 382E

**Area D. People and Society:** CS 147, 148, 152, 181/W, 182/W, 194H, 206, 247 (any suffix), 256, 269I, 278, 281, 329T, 329X, 347, 377 (any suffix), 384, 448B; AMSTUD 145; ANTHRO 132C, 132D; COMM 254, 266, 286, 324; DESIGN 255; EARTHSYS 213; EDUC 315A; ENGLISH 184D; HISTORY 244F; INTLPOL 268; LAW 4039; ME 177; MS&E 193, 231, 234, 254; POLISCI 150A; PUBLPOL 103F for 3 units, 353B

**ARTIFICIAL INTELLIGENCE DEPTH**

All depth courses must be taken for a letter grade\* for 3 or more units. A maximum of 6 units of CS 399 Independent Study may be counted towards the depth. Any deviations from the stated requirements must be noted and approved by your advisor in the Advisor Notes box provided (maximum of one advisor-approved deviation allowed). Courses taken for your Stanford undergraduate degree do not need to be repeated. Enter course selection in the table below:

- a) CS 221 (students with equivalent course work may waive with advisor approval)
- b) At least four of: CS 223A, 224N, 224R, 224S, 224U, 224V, 224W, 228, 229, 231A, 231N, 234, 237A, 237B, 238
- c) A total of at least 21 units from categories (a), (b) and the following: CS 205L, 224C, 224R, 225A, 227B, 229B, 229S, 229T, 230, 233, 235, 236, 239, 246, 257, 270, 271, 173A/273A, 273B, 274, 275, 279, 281, 293, 322, 324, 324H, 325B, 326, 327A, 328, 329 (any suffix), 330, 331, 332, 333, 336, 348L, 348N, 353, 361, 368, 371, 375, 377† (any suffix), 379† (any suffix), 398, 399†, 428A, 428B, 432; EE 263, 276, 278, 364A, 364B, 377; ENGR 205, 209A; MS&E 226, 252; PSYCH 209; STATS 202, 315A, 315B (courses with † notation require approval of MS advisor)

**Advisor Notes**

Course number	Title (Depth courses must be taken for at least 3 units.)	Grade	Units
<b>TOTAL DEPTH UNITS APPLIED TO MSCS (must total at least 21 units) Letter grades only.*</b>			

**ELECTIVES**

List here any additional courses used to complete the 45-unit requirement for the MSCS degree. You may count up to a maximum of 3 units of 1-2 unit seminars offered in the School of Engineering. All other electives must be taken for 3 or more units. CS courses numbered above 111, excluding CS 161A, 196, CS198, and CS390A/B/C, can be used as MS electives. Non-CS courses must be technical courses numbered above 100, related to the degree program, and approved by the advisor and the MS program administrator. Note that CS 129 may not be counted towards the MS if CS 229 is being counted towards any BS or MS requirement.

Course number	Title	Grade	Units
<b>TOTAL ELECTIVE UNITS APPLIED TO MSCS</b>			

**TOTAL UNITS APPLIED TO MSCS** **ADDITIONAL REQUIREMENTS**

- All courses submitted for the MSCS degree must be numbered 100 or greater.
- At most 10 units of Foundations requirement courses may be counted toward your 45 units.
- At most 3 units of 1-2 unit seminars may be counted toward your 45 units.
- At least 36 units submitted for the MSCS degree, including all courses taken for breadth and depth, must be taken for a letter grade.\*
- The average grade in the courses submitted for the MSCS must be at least a B (3.0 in Stanford's GPA scale).
- Units previously applied toward BS requirements may not also be counted toward the MSCS.
- You must complete at least 45 graduate units at Stanford before receiving the MSCS degree.

\*All classes taken Spring 19-20 and Fall through Summer 20-21 for a CR or S grade will satisfy MSCS requirements as if taken for a letter grade.

Advisor's signature: \_\_\_\_\_ Date: \_\_\_\_\_

# Computational Biology

## DEPARTMENT OF COMPUTER SCIENCE MSCS Program Sheet (2023-24) Computational Biology Specialization

Name: \_\_\_\_\_ Advisor: \_\_\_\_\_ Date: \_\_\_\_\_

Student ID#: \_\_\_\_\_ Email: \_\_\_\_\_ Proposed date for degree conferral: \_\_\_\_\_ HCP? \_\_\_\_\_ Coterm? \_\_\_\_\_

**GENERAL INSTRUCTIONS:** Before the end of your first quarter, complete a program sheet by filling in the number, name and units of each course you intend to take for your degree. Program sheets, as well as foundation course waiver forms, may be submitted electronically on the Gates Information Network at <http://gin.stanford.edu/> using your CS ID and password (click on the 'Dashboard' link). See <http://cs.stanford.edu/degrees/mscs/programsheets/psguide2324.pdf> for detailed instructions.

**FOUNDATIONS REQUIREMENT:** You must satisfy the requirements listed in each of the following areas; all courses taken elsewhere must be approved by your advisor via the foundation course waiver form. Do not enter anything in the "Units" column for courses taken elsewhere or for Stanford courses counted towards your undergraduate degree.

Required:	Equivalent elsewhere (course numbers/titles/institution)	Grade	Units
Logic, Automata & Complexity (CS103)			
Probability (CS109, Stat116, CME106, MS&E220, or EE178)			
Algorithmic Analysis (CS161)			
Computer Organ & Sys (CS107 or 107E)			
Principles of Computer Systems (CS111)			

TOTAL UNITS USED TO SATISFY FOUNDATIONS REQUIREMENT (May not exceed 10 units.)

**SIGNIFICANT IMPLEMENTATION REQUIREMENT:** At least one course in your MS program should be designated as satisfying the Significant Implementation Requirement. Note that this course will also be used to satisfy some other requirement (i.e., Depth, or Elective). Must be taken for a letter grade,\* must be taken at Stanford. Coterm students who took two of these courses at Stanford as undergraduates may waive this requirement. Deviations must be approved by the faculty director of the MS program, Cynthia Lee.

Course Number:	Title:	Grade

*Courses that may be used to satisfy the significant implementation requirement include:* CS 140, 140E, 143, 144, 145, 148, 151, 190, 210B, 212, 224R, 227B, 231N, 239, 243, 248A, 248B, 330, and 341.

**BREADTH REQUIREMENT:** Three courses, with each course chosen from a different Breadth area A, B, C or D. Breadth courses may not be waived, must be taken for at least 3 units each, and must be completed for a letter grade.\* Each of the three Breadth courses must be from different Areas. Note that these courses will also be used to satisfy some other requirement (i.e., Depth or Elective). Letter grade only.\*

Course Number:	Title:	Grade

**Area A.** Formal Foundations: CS 154, 157, 166, 168, 205L, 229T, 250, 254, 254B, 255, 256, 257, 258, 259Q, 261, 263, 265, 269L, 328, 331, 334A, 354, 355, 359D, 369Q; EE 364A, 364B; Phil 251

**Area B.** Learning and Modeling: CS 173A, 205L, 221, 223A, 224N, 224R, 224S, 224U, 224V, 224W, 227B, 228, 229, 229B, 229T, 230, 231A, 231N, 233, 234, 236, 237A, 237B, 248A, 248B, 271, 272, 273A, 273B, 274, 279, 281, 326, 329D, 329X, 330, 332, 333, 348A, 348B, 348C, 348E, 348I, 348N, 371, 373

**Area C.** Systems: CS 112 (with CS111 as prereq), 140E, 143, 144, 145, 149, 155, 212, 240, 240LX, 242, 243, 244, 244B, 245, 246, 249L, 316, 348K, 356, 358, EE 180, 282, 382E

**Area D.** People and Society: CS 147, 148, 152, 181/W, 182/W, 194H, 206, 247 (any suffix), 256, 269L, 278, 281, 329T, 329X, 347, 377 (any suffix), 384, 448B; AMSTUD 145; ANTHRO 132C, 132D; COMM 254, 266, 286, 324; DESIGN 255; EARTHSYS 213; EDUC 315A, ENGLISH 184D, HISTORY 244F, INTLPOL 268; LAW 4039; ME 177; MS&E 193, 231, 234, 254; POLISCI 150A; PUBLPOL 103F for 3 units, 353B

### COMPUTATIONAL BIOLOGY DEPTH

All depth courses must be taken for a letter grade\* for 3 or more units. A maximum of 6 units of CS 399 Independent Study may be counted towards the depth. Any deviations from the stated requirements must be noted and approved by your advisor in the Advisor Notes box provided (maximum of one advisor-approved deviation allowed). Courses taken for your Stanford undergraduate degree do not need to be repeated. Enter course selection in the table below:

- One of: CS 173A, 273A (students with equivalent coursework may waive with the approval of their advisor)
- CS221
- At least two of: CS 142 (or 147L or 193X), 145, 246, 448B
- At least three of: CS 279, 371, BIOMEDIN 210, 214, 215, 217, 219, 220, 222, 260, 273B, IMMUNOL 207
- A total of at least 21 units from categories (a), (b), (c), (d) and the following: CS 124, 131, 147, 148, 154, 166, 168, 185, 224N, 224W, 228, 229, 229B, 229S, 229T1, 230, 231N, 234, 238, 248/248A, 353, 399; BIO 183, 187; STATS 215, 256

#### Advisor Notes

Course number	Title (Depth courses must be taken for at least 3 units.)	Grade	Units

TOTAL SPECIALIZATION UNITS APPLIED TO MSCS (must total at least 21 units) Letter grades only.\*

### ELECTIVES

List here any additional courses used to complete the 45-unit requirement for the MSCS degree. You may count up to a maximum of 3 units of 1-2 unit seminars offered in the School of Engineering. All other electives must be taken for 3 or more units. CS courses numbered above 111, excluding CS 161A, 196, CS198, and CS390A/B/C, can be used as MS electives. Non-CS courses must be technical courses numbered above 100, related to the degree program, and approved by the advisor and the MS program administrator. Note that CS 129 may not be counted towards the MS if CS 229 is being counted towards any BS or MS requirement.

Course number	Title	Grade	Units

TOTAL ELECTIVE UNITS APPLIED TO MSCS

TOTAL UNITS APPLIED TO MSCS

### ADDITIONAL REQUIREMENTS

- All courses submitted for the MSCS degree must be numbered 100 or greater.
- At most 10 units of Foundations requirement courses may be counted toward your 45 units.
- At most 3 units of 1-2 unit seminars may be counted toward your 45 units.
- At least 36 units submitted for the MSCS degree, including all courses taken for breadth and depth, must be taken for a letter grade.\*
- The average grade in the courses submitted for the MSCS must be at least a B (3.0 in Stanford's GPA scale).
- Units previously applied toward BS requirements may not also be counted toward the MSCS.
- You must complete at least 45 graduate units at Stanford before receiving the MSCS degree.

\*All classes taken Spring 19-20 and Fall through Summer 20-21 for a CR or S grade will satisfy MSCS requirements as if taken for a letter grade.

Advisor's signature: \_\_\_\_\_ Date: \_\_\_\_\_



# Computer and Network Security

DEPARTMENT OF COMPUTER SCIENCE  
MSCS Program Sheet (2023-24)  
Computer and Network Security Specialization

Name: \_\_\_\_\_ Advisor: \_\_\_\_\_ Date: \_\_\_\_\_

Student ID#: \_\_\_\_\_ Email: \_\_\_\_\_ Proposed date for degree conferral: \_\_\_\_\_ HCP?: \_\_\_\_\_ Coterm?: \_\_\_\_\_

**GENERAL INSTRUCTIONS:** Before the end of your first quarter, complete a program sheet by filling in the number, name and units of each course you intend to take for your degree. Program sheets, as well as foundation course waiver forms, may be submitted electronically on the GSI Information Network at <http://gin.stanford.edu/> using your CS ID and password (click on the 'Dashboard' link). See <http://cs.stanford.edu/degrees/mscs/programsheets/psguide2324.pdf> for detailed instructions.

**FOUNDATIONS REQUIREMENT:** You must satisfy the requirements listed in each of the following areas; all courses taken elsewhere must be approved by your advisor via the foundation course waiver form. Do not enter anything in the "Units" column for courses taken elsewhere or for Stanford courses counted towards your undergraduate degree.

Required:	Equivalent elsewhere (course numbers/titles/institution)	Grade	Units
Logic, Automata & Complexity (CS103)			
Probability (CS109, Stat116, CME106, MS&E220, or EE178)			
Algorithmic Analysis (CS161)			
Computer Organ & Sys (CS107 or 107E)			
Principles of Computer Systems (CS111)			

TOTAL UNITS USED TO SATISFY FOUNDATIONS REQUIREMENT (May not exceed 10 units.)

**SIGNIFICANT IMPLEMENTATION REQUIREMENT:** At least one course in your MS program should be designated as satisfying the Significant Implementation Requirement. Note that this course will also be used to satisfy some other requirement (i.e., Depth, or Elective). Must be taken for a letter grade,\* must be taken at Stanford. Coterm students who took two of these courses at Stanford as undergraduates may waive this requirement. Deviations must be approved by the faculty director of the MS program, Cynthia Lee.

Course Number:	Title:	Grade

**Courses that may be used to satisfy the significant implementation requirement include:** CS 140, 140E, 143, 144, 145, 148, 151, 190, 210B, 212, 224R, 227B, 231N, 239, 243, 248A, 248B, 330, and 341.

**BREADTH REQUIREMENT:** Three courses, with each course chosen from a different Breadth area A, B, C or D. Breadth courses may not be waived, must be taken for at least 3 units each, and must be completed for a letter grade.\* Each of the three Breadth courses must be from different Areas. Note that these courses will also be used to satisfy some other requirement (i.e., Depth or Elective). Letter grade only.\*

Course Number:	Title:	Grade

**Area A. Formal Foundations:** CS 154, 157, 166, 168, 205L, 229T, 250, 254, 254B, 255, 256, 257, 258, 259Q, 261, 263, 265, 269I, 328, 331, 334A, 354, 355, 359D, 3690; EE 364A, 364B; Phil 251

**Area B. Learning and Modeling:** CS 173A, 205L, 221, 223A, 224N, 224R, 224S, 224U, 224V, 224W, 227B, 228, 229, 229B, 229T, 230, 231A, 231N, 233, 234, 236, 237A, 237B, 248A, 248B, 271, 272, 273A, 273B, 274, 279, 281, 326, 329D, 329X, 330, 332, 333, 348A, 348B, 348C, 348E, 348I, 348N, 371, 373

**Area C. Systems:** CS 112 (with CS111 as prereq), 140E, 143, 144, 145, 149, 155, 212, 240, 240LX, 242, 243, 244, 244B, 245, 246, 249I, 316, 348K, 356, 358; EE 180, 282, 382E

**Area D. People and Society:** CS 147, 148, 152, 181/W, 182/W, 194H, 206, 247 (any suffix), 256, 269I, 278, 281, 329T, 329X, 347, 377 (any suffix), 384, 448B; AMSTUD 145; ANTHRO 132C, 132D; COMM 254, 266, 286, 324; DESIGN 255; EARTHYSYS 213; EDUC 315A; ENGLISH 184D, HISTORY 244F; INTLPOL 268; LAW 4039; ME 177; MS&E 193, 231, 234, 254; POLISCI 150A; PUBLPOL 103F for 3 units, 353B

COMPUTER AND NETWORK SECURITY DEPTH

All depth course must be taken for a letter grade\* for 3 or more units. A maximum of 6 units of CS 399 Independent Study may be counted towards the depth. Any deviations from the stated requirements must be noted and approved by your advisor in the Advisor Notes box provided (maximum of one advisor-approved deviation allowed). Courses taken for your Stanford undergraduate degree do not need to be repeated. Enter course selection in the table below:

- All of: CS 140/212 (or 140U or 112),† 144†, 155, 255, 356 (students with equivalent course work may waive † flagged courses with advisor approval)
- At least three of: CS 142, 152, 190, 240 (any suffix), 244, 244B, 249I, 253, 261, 265, 340 (any suffix), 355
- A total of at least 21 units from categories (a), (b) and the following: CS 245, 251, 294S†, 399†; EE 384S (courses with † notation require approval of MS advisor)

Advisor Notes

Course number	Title (Depth courses must be taken for at least 3 units.)	Grade	Units
TOTAL SPECIALIZATION UNITS APPLIED TO MSCS (must total at least 21 units) Letter grades only.*			<input type="text"/>

ELECTIVES

List here any additional courses used to complete the 45-unit requirement for the MSCS degree. You may count up to a maximum of 3 units of 1-2 unit seminars offered in the School of Engineering. All other electives must be taken for 3 or more units. CS courses numbered above 111, excluding CS 161A, 196, CS198, and CS390A/B/C, can be used as MS electives. Non-CS courses must be technical courses numbered above 100, related to the degree program, and approved by the advisor and the MS program administrator. *Note that CS 129 may not be counted towards the MS if CS 229 is being counted towards any BS or MS requirement.*

Course number	Title	Grade	Units
TOTAL ELECTIVE UNITS APPLIED TO MSCS			<input type="text"/>

TOTAL UNITS APPLIED TO MSCS

ADDITIONAL REQUIREMENTS

- All courses submitted for the MSCS degree must be numbered 100 or greater.
- At most 10 units of Foundations requirement courses may be counted toward your 45 units.
- At most 3 units of 1-2 unit seminars may be counted toward your 45 units.
- At least 36 units submitted for the MSCS degree, including all courses taken for breadth and depth, must be taken for a letter grade.\*
- The average grade in the courses submitted for the MSCS must be at least a B (3.0 in Stanford's GPA scale).
- Units previously applied toward BS requirements may not also be counted toward the MSCS.
- You must complete at least 45 graduate units at Stanford before receiving the MSCS degree.

\*All classes taken Spring 19-20 and Fall through Summer 20-21 for a CR or S grade will satisfy MSCS requirements as if taken for a letter grade.

Advisor's signature: \_\_\_\_\_ Date: \_\_\_\_\_

# Software Theory

## DEPARTMENT OF COMPUTER SCIENCE MSCS Program Sheet (2023-24) Software Theory Specialization

Name: \_\_\_\_\_ Advisor: \_\_\_\_\_ Date: \_\_\_\_\_

Student ID#: \_\_\_\_\_ Email: \_\_\_\_\_ Proposed date for degree conferral: \_\_\_\_\_ HCP? \_\_\_\_\_ Coterm? \_\_\_\_\_

**GENERAL INSTRUCTIONS:** Before the end of your first quarter, complete a program sheet by filling in the number, name and units of each course you intend to take for your degree. Program sheets, as well as foundation course waiver forms, may be submitted electronically on the Gates Information Network at <http://gin.stanford.edu/> using your CS ID and password (click on the "Dashboard" link). See <http://cs.stanford.edu/degrees/mscs/programsheets/pguide2324.pdf> for detailed instructions.

**FOUNDATIONS REQUIREMENT:** You must satisfy the requirements listed in each of the following areas; all courses taken elsewhere must be approved by your advisor via the foundation course waiver form. Do not enter anything in the "Units" column for courses taken elsewhere or for Stanford courses counted towards your undergraduate degree.

Required:	Equivalent elsewhere (course numbers/titles/institution)	Grade	Units
Logic, Automata & Complexity (CS103)			
Probability (CS109, Stat116, CME106, MS&H220, or EE178)			
Algorithmic Analysis (CS161)			
Computer Organ & Sys (CS107 or 107E)			
Principles of Computer Systems (CS111)			

**TOTAL UNITS USED TO SATISFY FOUNDATIONS REQUIREMENT** (May not exceed 10 units.)

**SIGNIFICANT IMPLEMENTATION REQUIREMENT:** At least one course in your MS program should be designated as satisfying the Significant Implementation Requirement. Note that this course will also be used to satisfy some other requirement (i.e., Depth, or Elective). Must be taken for a letter grade.\* must be taken at Stanford. Coterm students who took two of these courses at Stanford as undergraduates may waive this requirement. Deviations must be approved by the faculty director of the MS program, Cynthia Lee.

Course Number:	Title:	Grade

*Courses that may be used to satisfy the significant implementation requirement include:* CS 140, 140E, 143, 144, 145, 148, 151, 190, 210B, 212, 224R, 227B, 231N, 239, 243, 248A, 248B, 330, and 341.

**BREADTH REQUIREMENT:** Three courses, with each course chosen from a different Breadth area A, B, C or D. Breadth courses may not be waived, must be taken for at least 3 units each, and must be completed for a letter grade.\* Each of the three Breadth courses must be from different Areas. Note that these courses will also be used to satisfy some other requirement (i.e., Depth or Elective). Letter grade only.\*

Course Number:	Title:	Grade

**Area A. Formal Foundations:** CS 154, 157, 166, 168, 205L, 229T, 250, 254, 254B, 255, 256, 257, 258, 259Q, 261, 263, 265, 269I, 328, 331, 334A, 354, 355, 359D, 369O; EE 364A, 364B, Phil 251

**Area B. Learning and Modeling:** CS 173A, 205L, 221, 223A, 224N, 224R, 224S, 224U, 224V, 224W, 227B, 228, 229, 229B, 229T, 230, 231A, 231N, 233, 234, 236, 237A, 237B, 248A, 248B, 271, 272, 273A, 273B, 274, 279, 281, 326, 329D, 329X, 330, 332, 333, 348A, 348B, 348C, 348E, 348I, 348N, 371, 373

**Area C. Systems:** CS 112 (with CS111 as prereq), 140E, 143, 144, 145, 149, 155, 212, 240, 240LX, 242, 243, 244, 244B, 245, 246, 249I, 316, 348K, 356, 358; EE 180, 282, 382E

**Area D. People and Society:** CS 147, 148, 152, 181/W, 182/W, 194H, 206, 247 (any suffix), 256, 269I, 278, 281, 329T, 329X, 347, 377 (any suffix), 384, 448B; AMSTUD 145; ANTHRO 132C, 132D; COMM 254, 266, 286, 324; DESIGN 255; EARTHSYS 213; EDUC 315A, ENGLISH 184D, HISTORY 244F; INTLPOL 268; LAW 4039; ME 177; MS&E 193, 231, 234, 254; POLISCI 150A; PUBLPOL 103F for 3 units, 353B

### SOFTWARE THEORY DEPTH

All depth course must be taken for a letter grade\* for 3 or more units. A maximum of 6 units of CS399 Independent Study may be counted towards the depth. Any deviations from the stated requirements must be noted and approved by your advisor in the Advisor Notes box provided (maximum of one advisor-approved deviation allowed). Courses taken for your Stanford undergraduate degree do not need to be repeated. Enter course selection in the table below:

- CS 242, 243
- At least one of: CS 221, 244, 245, 341
- At least one of: CS 255, 350, 355, 356
- A total of at least 21 units chosen from categories (a), (b), (c) or the following: CS 151, 250, 261, 265, 294S, 295, 315B, 349H, 357, 357S, 399T (courses with † notation require approval of MS advisor)

### Advisor Notes

Course number	Title (Depth courses must be taken for at least 3 units.)	Grade	Units
<b>TOTAL SPECIALIZATION UNITS APPLIED TO MSCS (must total at least 21 units) Letter grades only.*</b> <input type="text"/>			

### ELECTIVES

List here any additional courses used to complete the 45-unit requirement for the MSCS degree. You may count up to a maximum of 3 units of 1-2 unit seminars offered in the School of Engineering. All other electives must be taken for 3 or more units. CS courses numbered above 111, excluding CS 161A, 196, CS198, and CS390A/B/C, can be used as MS electives. Non-CS courses must be technical courses numbered above 100, related to the degree program, and approved by the advisor and the MS program administrator. *Note that CS 129 may not be counted towards the MS if CS 229 is being counted towards any BS or MS requirement.*

Course number	Title	Grade	Units
<b>TOTAL ELECTIVE UNITS APPLIED TO MSCS</b> <input type="text"/>			

**TOTAL UNITS APPLIED TO MSCS**

### ADDITIONAL REQUIREMENTS

- All courses submitted for the MSCS degree must be numbered 100 or greater.
- At most 10 units of Foundations requirement courses may be counted toward your 45 units.
- At most 3 units of 1-2 unit seminars may be counted toward your 45 units.
- At least 36 units submitted for the MSCS degree, including all courses taken for breadth and depth, must be taken for a letter grade.\*
- The average grade in the courses submitted for the MSCS must be at least a B (3.0 in Stanford's GPA scale).
- Units previously applied toward BS requirements may not also be counted toward the MSCS.
- You must complete at least 45 graduate units at Stanford before receiving the MSCS degree.

\*All classes taken Spring 19-20 and Fall through Summer 20-21 for a CR or S grade will satisfy MSCS requirements as if taken for a letter grade.

Advisor's signature: \_\_\_\_\_ Date: \_\_\_\_\_

**DEPARTMENT OF COMPUTER SCIENCE**  
**MSCS Program Sheet (2023-24)**  
**Systems Specialization**

Name: \_\_\_\_\_ Advisor: \_\_\_\_\_ Date: \_\_\_\_\_

Student ID#: \_\_\_\_\_ Email: \_\_\_\_\_ Proposed date for degree conferral: \_\_\_\_\_ HCP? \_\_\_\_\_ Coterm? \_\_\_\_\_

**GENERAL INSTRUCTIONS:** Before the end of your first quarter, complete a program sheet by filling in the number, name and units of each course you intend to take for your degree. Program sheets, as well as foundation course waiver forms, may be submitted electronically on the Gates Information Network at <http://gin.stanford.edu/> using your CS ID and password (click on the 'Dashboard' link). See <http://cs.stanford.edu/degrees/mscs/programsheets/pguide2324.pdf> for detailed instructions.

**FOUNDATIONS REQUIREMENT:** You must satisfy the requirements listed in each of the following areas; all courses taken elsewhere must be approved by your advisor via the foundation course waiver form. Do not enter anything in the "Units" column for courses taken elsewhere or for Stanford courses counted towards your undergraduate degree.

Required:	Equivalent elsewhere (course numbers/titles/institution)	Grade	Units
Logic, Automata & Complexity (CS103)			
Probability (CS109, Stat116, CME106, MS&E220, or EE178)			
Algorithmic Analysis (CS161)			
Computer Organ & Sys (CS107 or 107E)			
Principles of Computer Systems (CS111)			

**TOTAL UNITS USED TO SATISFY FOUNDATIONS REQUIREMENT** (May not exceed 10 units.)

**SIGNIFICANT IMPLEMENTATION REQUIREMENT:** At least one course in your MS program should be designated as satisfying the Significant Implementation Requirement. Note that this course will also be used to satisfy some other requirement (i.e., Depth, or Elective). Must be taken for a letter grade,\* must be taken at Stanford. Coterm students who took two of these courses at Stanford as undergraduates may waive this requirement. Deviations must be approved by the faculty director of the MS program, Cynthia Lee.

Course Number:	Title:	Grade

*Courses that may be used to satisfy the significant implementation requirement include:* CS 140, 140E, 143, 144, 145, 148, 151, 190, 210B, 212, 224R, 227B, 231N, 239, 243, 248A, 248B, 330, and 341.

**BREADTH REQUIREMENT:** Three courses, with each course chosen from a different Breadth area A, B, C or D. Breadth courses may not be waived, must be taken for at least 3 units each, and must be completed for a letter grade.\* Each of the three Breadth courses must be from different Areas. Note that these courses will also be used to satisfy some other requirement (i.e., Depth or Elective). Letter grade only.\*

Course Number:	Title:	Grade

**Area A. Formal Foundations:** CS 154, 157, 166, 168, 205L, 229T, 250, 254, 254B, 255, 256, 257, 258, 259Q, 261, 263, 265, 269I, 328, 331, 334A, 354, 355, 359D, 369O; EE 364A, 364B; Phil 251

**Area B. Learning and Modeling:** CS 173A, 205L, 221, 223A, 224N, 224R, 224S, 224U, 224V, 224W, 227B, 228, 229, 229B, 229T, 230, 231A, 231N, 233, 234, 236, 237A, 237B, 248A, 248B, 271, 272, 273A, 273B, 274, 279, 281, 326, 329D, 329X, 330, 332, 333, 348A, 348B, 348C, 348E, 348I, 348N, 371, 373

**Area C. Systems:** CS 112 (with CS111 as prereq), 140E, 143, 144, 145, 149, 155, 212, 240, 240LX, 242, 243, 244, 244B, 245, 246, 249I, 316, 348K, 356, 358, EE 180, 282, 382E

**Area D. People and Society:** CS 147, 148, 152, 181/W, 182/W, 194H, 206, 247 (any suffix), 256, 269I, 278, 281, 329T, 329X, 347, 377 (any suffix), 384, 448B; AMSTUD 145; ANTHRO 132C, 132D; COMM 254, 266, 286, 324; DESIGN 255; EARTHSYS 213; EDUC 315A; ENGLISH 184D; HISTORY 244E; INTLPOL 268; LAW 4039; ME 177; MS&E 193, 231, 234, 254; POLISCI 150A; PUBLPOL 103F for 3 units, 353B

**SYSTEMS DEPTH**

All depth course must be taken for a letter grade\* for 3 or more units. A maximum of 6 units of CS399 Independent Study may be counted towards the depth. Any deviations from the stated requirements must be noted and approved by your advisor in the Advisor Notes box provided (maximum of one advisor-approved deviation allowed). Courses taken for your Stanford undergraduate degree do not need to be repeated. Enter course selection in the table below:

**Advisor Notes**

- All of: CS140/212 (or 140E or 112 or 112E) †, CS 144‡, 240
- At least four of: CS 190, 242, 243, 244, 245, 248/248A, 348B; EE 271, 282
- A total of at least 21 units from categories (a), (b) and the following: CS 149, 217, 229S, 241, 244B, 246, 251, 255, 270, 272, 294S†, 295, 315B, 316, 340 (any suffix), 343D, 344 (any suffix), 348A, 348C, 348E, 348I, 348K, 349 (any suffix and 3 or more units), 356, 357S, 399†, 448 (any suffix); EE 267, 273, 382C, 384A, 384C, 384S (courses with † notation require approval of MS advisor)

Course number	Title (Depth courses must be taken for at least 3 units.)	Grade	Units
<b>TOTAL SPECIALIZATION UNITS APPLIED TO MSCS (must total at least 21 units) Letter grades only.*</b>			

**ELECTIVES**

List here any additional courses used to complete the 45-unit requirement for the MSCS degree. You may count up to a maximum of 3 units of 1-2 unit seminars offered in the School of Engineering. All other electives must be taken for 3 or more units. CS courses numbered above 111, excluding CS 161A, 196, CS198, and CS390A/B/C, can be used as MS electives. Non-CS courses must be technical courses numbered above 100, related to the degree program, and approved by the advisor and the MS program administrator. *Note that CS 129 may not be counted towards the MS if CS 229 is being counted towards any BS or MS requirement.*

Course number	Title	Grade	Units
<b>TOTAL ELECTIVE UNITS APPLIED TO MSCS</b>			

**TOTAL UNITS APPLIED TO MSCS**

**ADDITIONAL REQUIREMENTS**

- All courses submitted for the MSCS degree must be numbered 100 or greater.
- At most 10 units of Foundations requirement courses may be counted toward your 45 units.
- At most 3 units of 1-2 unit seminars may be counted toward your 45 units.
- At least 36 units submitted for the MSCS degree, including all courses taken for breadth and depth, must be taken for a letter grade.\*
- The average grade in the courses submitted for the MSCS must be at least a B (3.0 in Stanford's GPA scale).
- Units previously applied toward BS requirements may not also be counted toward the MSCS.
- You must complete at least 45 graduate units at Stanford before receiving the MSCS degree.

\*All classes taken Spring 19-20 and Fall through Summer 20-21 for a CR or S grade will satisfy MSCS requirements as if taken for a letter grade.

Advisor's signature: \_\_\_\_\_

Date: \_\_\_\_\_

**DEPARTMENT OF COMPUTER SCIENCE**  
**MSCS Program Sheet (2023-24)**  
**Theoretical Computer Science Specialization**

Name: \_\_\_\_\_ Advisor: \_\_\_\_\_ Date: \_\_\_\_\_  
 Student ID#: \_\_\_\_\_ Email: \_\_\_\_\_ Proposed date for degree conferral: \_\_\_\_\_ HCP? \_\_\_\_\_ Coterm? \_\_\_\_\_

**GENERAL INSTRUCTIONS:** Before the end of your first quarter, complete a program sheet by filling in the number, name and units of each course you intend to take for your degree. Program sheets, as well as foundation course waiver forms, may be submitted electronically on the Gates Information Network at <http://gin.stanford.edu> using your CS ID and password (click on the 'Dashboard' link). See <http://cs.stanford.edu/degrees/mscs/programsheets/pguide2324.pdf> for detailed instructions.

**FOUNDATIONS REQUIREMENT:** You must satisfy the requirements listed in each of the following areas; all courses taken elsewhere must be approved by your advisor via the foundation course waiver form. Do not enter anything in the "Units" column for courses taken elsewhere or for Stanford courses counted towards your undergraduate degree.

Required:	Equivalent elsewhere (course numbers/titles/institution)	Grade	Units
Logic, Automata & Complexity (CS103)			
Probability (CS109, Stat116, CME106, MS&E220, or EE178)			
Algorithmic Analysis (CS161)			
Computer Organ & Sys (CS107 or 107E)			
Principles of Computer Systems (CS111)			

**TOTAL UNITS USED TO SATISFY FOUNDATIONS REQUIREMENT** (May not exceed 10 units.)

**SIGNIFICANT IMPLEMENTATION REQUIREMENT:** At least one course in your MS program should be designated as satisfying the Significant Implementation Requirement. Note that this course will also be used to satisfy some other requirement (i.e., Depth, or Elective). Must be taken for a letter grade,\* must be taken at Stanford. Coterm students who took two of these courses at Stanford as undergraduates may waive this requirement. Deviations must be approved by the faculty director of the MS program, Cynthia Lee.

Course Number:	Title:	Grade

*Courses that may be used to satisfy the significant implementation requirement include:* CS 140, 140E, 143, 144, 145, 148, 151, 190, 210B, 212, 224R, 227B, 231N, 239, 243, 248A, 248B, 330, and 341.

**BREADTH REQUIREMENT:** Three courses, with each course chosen from a different Breadth area A, B, C or D. Breadth courses may not be waived, must be taken for at least 3 units each, and must be completed for a letter grade.\* Each of the three Breadth courses must be from different Areas. Note that these courses will also be used to satisfy some other requirement (i.e., Depth or Elective). Letter grade only.\*

Course Number:	Title:	Grade

- Area A. Formal Foundations:** CS 154, 157, 166, 168, 205L, 229T, 250, 254, 254B, 255, 256, 257, 258, 259Q, 261, 263, 265, 269I, 328, 331, 334A, 354, 355, 359D, 369O; EE 364A, 364B, Phil 251
- Area B. Learning and Modeling:** CS 173A, 205L, 221, 223A, 224N, 224R, 224S, 224U, 224V, 224W, 227B, 228, 229, 229B, 229T, 230, 231A, 231N, 233, 234, 236, 237A, 237B, 248A, 248B, 271, 272, 273A, 273B, 274, 279, 281, 326, 329D, 329X, 330, 332, 333, 348A, 348B, 348C, 348E, 348I, 348N, 371, 373
- Area C. Systems:** CS 112 (with CS111 as prereq), 140E, 143, 144, 145, 149, 155, 212, 240, 240LX, 242, 243, 244, 244B, 245, 246, 249I, 316, 348K, 356, 358; EE 180, 282, 382E
- Area D. People and Society:** CS 147, 148, 152, 181/W, 182/W, 194H, 206, 247 (any suffix), 256, 269I, 278, 281, 329T, 329X, 347, 377 (any suffix), 384, 448B; AMSTUD 145; ANTHRO 132C, 132D; COMM 254, 266, 286, 324; DESIGN 255; EARTHSYS 213; EDUC 315A, ENGLISH 184D, HISTORY 244F; INTLPOL 268; LAW 4039; ME 177; MS&E 193, 231, 234, 254; POLISCI 150A; PUBLPOL 103F for 3 units, 353B

**THEORETICAL COMPUTER SCIENCE DEPTH**

All depth course must be taken for a letter grade\* for 3 or more units. A maximum of 6 units of CS 399 Independent Study may be counted towards the depth. Any deviations from the stated requirements must be noted and approved by your advisor in the Advisor Notes box provided (maximum of one advisor-approved deviation allowed). Courses taken for your Stanford undergraduate degree do not need to be repeated. Enter course selection in the table below:

**Advisor Notes**

- CS 154<sup>‡</sup>, 261 (students with equivalent course work may waive † courses with advisor approval)
- A total of at least 21 units from category (a) and the following: CS 151, 163, 166, 168, 228, 229T, 233, 236, 246, 250, 251, 254, 254B, 255, 256, 257, 259Q, 263, 265, 269I, 328, 331, 351, 354, 355, 358, 359 (any suffix)†, 368, 369 (any suffix)†, 399†, 468†; EE 364A; MS&E 310, 319 (courses with † notation require approval of MS advisor)

Note: Multiple CS359, CS369, and/or CS468 courses may be taken as long as they are each on different topics (denoted by different letter suffixes).

Course number	Title (Depth courses must be taken for at least 3 units.)	Grade	Units
<b>TOTAL SPECIALIZATION UNITS APPLIED TO MSCS</b> (must total at least 21 units) <i>Letter grades only.*</i>		<input type="text" value=""/>	

**ELECTIVES**

List here any additional courses used to complete the 45-unit requirement for the MSCS degree. You may count up to a maximum of 3 units of 1-2 unit seminars offered in the School of Engineering. All other electives must be taken for 3 or more units. CS courses numbered above 111, excluding CS 161A, 196, CS198, and CS390A/B/C, can be used as MS electives. Non-CS courses must be technical courses numbered above 100, related to the degree program, and approved by the advisor and the MS program administrator. *Note that CS 129 may not be counted towards the MS if CS 229 is being counted towards any BS or MS requirement.*

Course number	Title	Grade	Units
<b>TOTAL ELECTIVE UNITS APPLIED TO MSCS</b>		<input type="text" value=""/>	

**TOTAL UNITS APPLIED TO MSCS**

**ADDITIONAL REQUIREMENTS**

- All courses submitted for the MSCS degree must be numbered 100 or greater.
- At most 10 units of Foundations requirement courses may be counted toward your 45 units.
- At most 3 units of 1-2 unit seminars may be counted toward your 45 units.
- At least 36 units submitted for the MSCS degree, including all courses taken for breadth and depth, must be taken for a letter grade.\*
- The average grade in the courses submitted for the MSCS must be at least a B (3.0 in Stanford's GPA scale).
- Units previously applied toward BS requirements may not also be counted toward the MSCS.
- You must complete at least 45 graduate units at Stanford before receiving the MSCS degree.

\*All classes taken Spring 19-20 and Fall through Summer 20-21 for a CR or S grade will satisfy MSCS requirements as if taken for a letter grade.

Advisor's signature: \_\_\_\_\_ Date: \_\_\_\_\_

## Course Enrollment Agent

What course would you like to enroll in?

User:

I am studying computer science.  
I want to complete the significant  
implementation requirement.  
What are some of the options that require the  
least amount of work?

# A Course Enrollment Assistant

Course Enrollment Agent

What course would you like to enroll in?

Students need to consult:

## Degree Requirements

- Unique to each department and specialization
- Program sheets

Stanford | Bulletin  
ExploreCourses

- All offered courses
- Description, instructors, offerings, and units

CARTA

- Ratings, reviews, hours of work, enrollment outcomes, and sequencing

# CS 144: Introduction to Computer Networking

← SUMMER 23-24 →

Results for: CS 140

▼ AT A GLANCE

▼ EVALUATIONS

PINNED CLASSES  
Pin a course to your calendar

QUARTER OVERVIEW

Mo	Tu	We	Th	Fr	Sa	Su
8 am						
9 am						
10 am						
11 am						
12 pm						
1 pm						
2 pm						
3 pm						
4 pm						

Pinned Units:  
Weekly Time t

Results for: CS 145

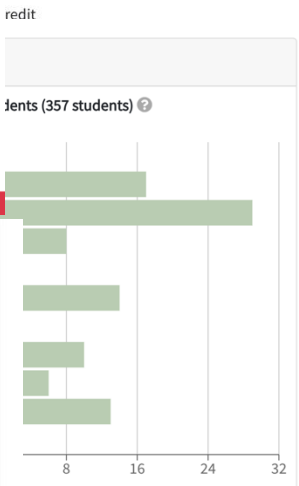
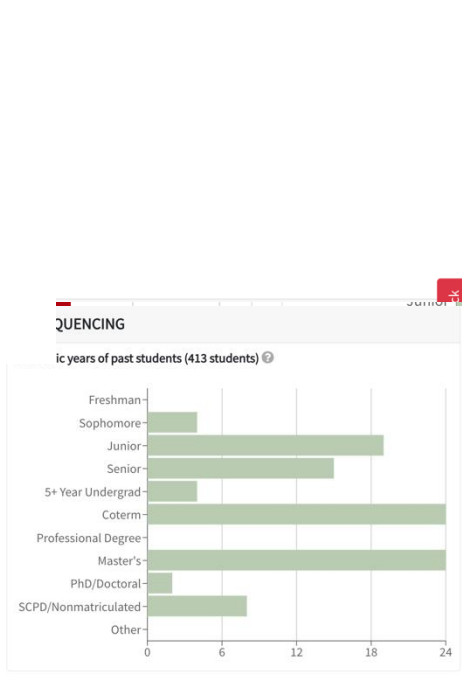
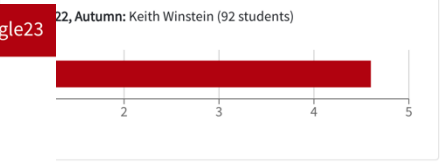
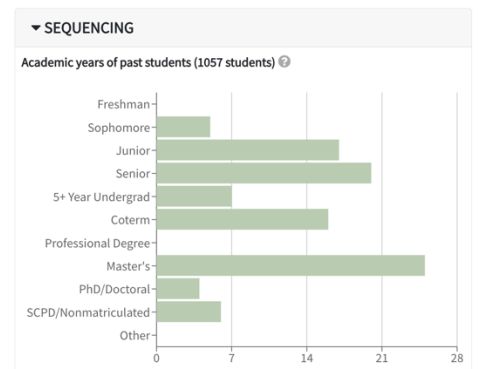
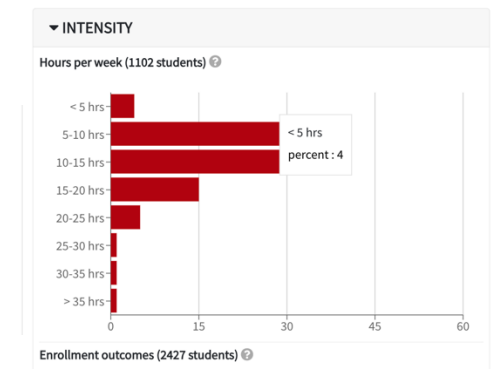
Units ▼ Days ▼ WAYS ▼ Quarters ▼

## CS 145: Data Management and Data Systems

Introduction to the use, design, and implementation of database and data-intensive systems, including data models; schema design; data storage; query processing, query optimization, and cost estimatio...[Read more](#)

[Show Schedule](#)

**Term:** AUT  
**Units:** 3-4  
**Grading:** Letter or Credit/No Credit  
**Instructors:** Shivakumar, N.



# 1. Stanford Course Enrollment Form

Form Name	Predicate	Kind	Type	Name	Enum Values	Description
Main		WS		course_enrollment		
		input	CourseToTake	course_to_take		The course to enroll
		input	StudentInfo	student_info_details		Information on the student
StudentInfo			worksheet			
		input	str	student_name		Name of the student
		input	str	student_id		Student's ID number
		input	str	student_email_address		Student's email address
CourseToTake			worksheet			
		input	str	course_name		Name of the course
		input	Enum	grade_type		The desired grading basis
					Credit/No Credit	
					Letter	
		input	int	num_units		The number of units taken
		input	confirm	confirm		Confirm the course




# 2. Course Assistant Knowledge Corpus

courses DB				
internal; primary	int	course_id		
offerings DB				
programs DB				
ratings DB				
	internal; primary	int	rating_id	
	internal	int	course_id	
	internal	List[str]	instructor_names	
	internal	int	average_rating	
	internal	int	num_ratings	
	internal	int	term_id	
	internal	int	start_year	
	internal	int	end_year	
	internal	Enum	season	
				autumn
				winter
				spring
				summer
	internal	List[str]	reviews	
	internal	str	sheet_requirements	

# Translates Questions into SUQL

I am a sophomore studying computer science. I want to complete the significant implementation requirement. What are some of the options that require the least amount of work?



```
SELECT title, course_codes, description,  
average_hours_spent  
FROM courses WHERE  
significant_implementation_requirement = TRUE  
ORDER BY average_hours_spent LIMIT 5;
```



You 01:01 AM

Hi, I want to complete the significant implementation requirement. What courses would you suggest me to take?

Took 3 steps ▾



Course Enrollment Assistant 01:01 AM


I found some courses that fulfill the significant implementation requirement. Here are a few suggestions along with their average hours spent per week:

1. **General Game Playing (CS 227B)**: A general game playing system accepts a formal description of a game to play it without human intervention or algorithms designed for specific games. Hands-on introduction to these systems and artificial intelligence techniques such as knowledge representation, reasoning, learning, and rational behavior. Students create GGP systems to compete with each other and in external competitions. Prerequisite: programming experience. Recommended: 103 or equivalent. *Average hours spent per week: 7.48.*
2. **Logic Programming (CS 151)**: Logic Programming is a style of programming based on symbolic logic. In writing a logic program, the programmer describes the application area of the program (as a set of logical sentences) without reference to the internal data structures or operations of the system executing the program. This course introduces basic logic programming theory, current technology, and examples of common applications. Prerequisite: CS 106B or equivalent. *Average hours spent per week: 7.5.*
3. **Introduction to Computer Graphics and Imaging (CS 148)**: This introductory course in the computer graphics sequence introduces students to the technical concepts behind creating computer-generated images. Topics include the mathematical concepts of synthetic imagery, fundamentals of light and color, rasterization, and ray tracing technology. Prerequisite: Linear Algebra and familiarity with Python and debugging. *Average hours spent per week: 8.79.*

Could you please provide me with the details of the courses you want to take?




# Consideration: Time Offered

 **You** 01:02 AM

Great when are these courses offered?

Took 3 steps ▾

 **Course Enrollment Assistant** 01:02 AM


The courses you're interested in are offered at the following times:

1. **Introduction to Computer Graphics and Imaging (CS 148)** is offered in the **autumn** season on **Tuesday and Thursday** from **12:00 PM to 1:20 PM**.
2. **Logic Programming (CS 227B)** is offered in the **spring** season on **Tuesday and Thursday** from **1:30 PM to 2:50 PM**.
3. **General Game Playing (CS 151)** is offered in the **spring** season on **Wednesday** from **4:30 PM to 6:20 PM**.

Could you please provide me with the details of the courses you would like to take?



# Consideration: Sort by Course Rating

 **You** 01:02 AM

Can you sort them based on rating?

Took 3 steps ▾


 **Course Enrollment Assistant** 01:02 AM

Certainly! Based on their ratings, here are the courses sorted:

1. **Introduction to Computer Graphics and Imaging** with an average rating of 4.04.
2. **Logic Programming** with an average rating of 3.97.
3. **General Game Playing** with an average rating of 3.43.

Could you please provide me with the details of the courses you would like to take?



 **You** 01:03 AM

I will take the top rated one!

Took 3 steps ▾

# Credit or Letter? Depends on the Workload

**C** **Course Enrollment Assistant** 01:03 AM

Great choice! For the course "Introduction to Computer Graphics and Imaging", could you please specify the desired grading basis? The options are: Credit/No Credit or Letter.



**Y** **You** 01:03 AM

How many hours will I have to spend on it?

Took 3 steps ▾

**C** **Course Enrollment Assistant** 01:04 AM

On average, you will have to spend about 8.79 hours per week on the course "Introduction to Computer Graphics and Imaging". Now, could you please specify the desired grading basis for this course? The options are: Credit/No Credit or Letter.



# Pick Max. Number of Units

**Y** You 01:04 AM

Thats low! I will take for letter grade, whats the maximum units I can take it for?

Took 3 steps ▾

**C** Course Enrollment Assistant 01:04 AM

The maximum number of units you can take for the course "Introduction to Computer Graphics and Imaging" is 4 units. How many units would you like to enroll for this course?



**Y** You 01:04 AM

Lets go with 4

Took 3 steps ▾

# Summary

- There are many possible dialogues even for a task with only a few parameters
- Task-oriented agents have mixed initiatives
  - Agent initiative to gather required information
  - User initiative to query related information, change their mind etc.

CLIENT

BANKER

How much money do you wish to transfer?

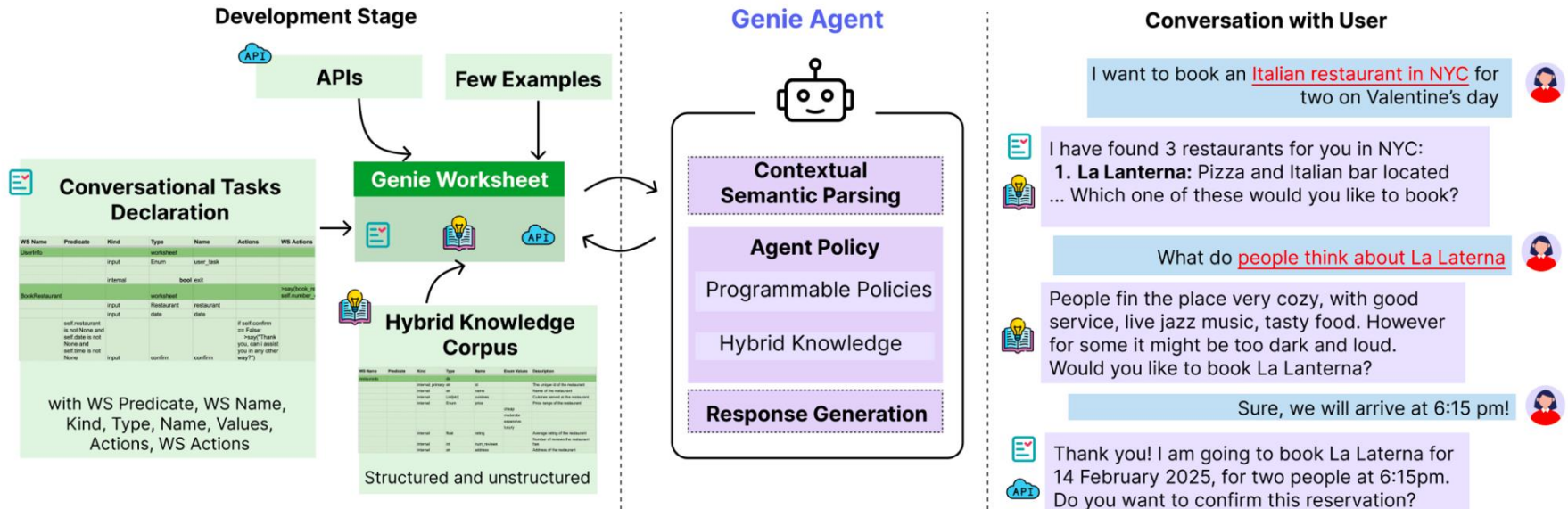
How much money do I have in my account?



# Outline

1. Knowledge Assistants
  - Databases
  - Knowledge graphs
  - Hybrid data
2. API Agents
3. Knowledge + Task-Oriented Agents
  - Motivation: a Case Study
  - **Design of the Genie WorkSheet**
  - Genie Runtime System

# Conversational Agent Architecture



# Genie Worksheet

Form Name	Kind	Type	Name	Enum Values	Description	Action
Main	Work sheet		enrollment			Enroll(Student.id, Course.name, Course.grade_type, Course.num_units)
	input	Course	course		The course to enroll	
	input	Student	student		Student info	
Student	Work sheet					
	input	str	name		Name of the student	
	input	str	id		Student's ID number	
	input	str	email		Student's email	
Course	Work sheet					
	input	str	name		Name of the course	
	input	Enum	grade_type		Grading basis	
				Credit	Get a credit/no credit	
				Letter	Get a letter grade	
	input	int	num_units		Number of units taken	
	input	confirm	confirm		Confirm the course	

Succinct / powerful dialogue agent representation

For the programmer

- High-level declarative task specification
- Hyperlinked worksheets
  - Variables: information pertinent to the task
  - Actions when variables are assigned & worksheet filled
  - Expressiveness similar to web forms

For the agent run-time

- Filled-in worksheets serve as the conversational state
- Interpreted easily to implement a flexible **agent policy**
- Succinct context for **contextual semantic parsing**

# Stanford Course Enrollment Form

Form Name	Predicate	Kind	Type	Name	Enum Values	Description
Main		WS		course_enrollment		
		input	CourseToTake	course_to_take		The course to enroll
		input	StudentInfo	student_info_details		Information on the student
StudentInfo			worksheet			
		input	str	student_name		Name of the student
		input	str	student_id		Student's ID number
		input	str	student_email_address		Student's email address
CourseToTake			worksheet			
		input	str	course_name		Name of the course
		input	Enum	grade_type		The desired grading basis
					Credit/No Credit	
					Letter	
		input	int	num_units		The number of units taken
		input	confirm	confirm		Confirm the course

# Required, Enum, Predicated Inputs

Type	Description
Required	Record all relevant info but don't ask for it if not required
Enum	Explain possible values if necessary
Predicated	Needed if predicate is true

USER	ASSISTANT
I'm currently an AllState customer, I am considering changing the provider.	
Great. I need some information. What is your marital status?	
What do you mean by marital status?	
Are you married or single?	
I'm married.	
Got it. What is your spouse's name?	

Form Name	Predicate	Kind	Type	Name	Enum Values	Question	Required
Main			worksheet	Insurance			
		input	str	curr_insurance		Who is your current provider?	no
		input	enum	marital_status		Are you married?	yes
					single		
					married		
	marital_status == married	input	str	spouse_name		What is the name of your spouse?	yes

# Programmable Agent Policies

## Agent Policy

- what the agent says and does

## Runtime system

- When a variable is set,  
corresponding action is executed

STUDENT

ASSISTANT

I want to take CS 224V in the fall quarter

Unfortunately, there are no seats available.  
I can help you find other courses.

Form Name	Name	Description	Action
	course_name	Name of the course that the user wants to take	If not check_availability(course_name): say("Unfortunately, there are no seats available. I can help you find other courses.") self.course_name = None

# Programmable Agent Policies (cont.)

Runtime system

- When a worksheet is completed, execute the worksheet action
- Worksheet variables are referred to as `worksheet_name:variable_name`

<b>Form Name</b>	<b>Worksheet Action</b>
Enrollment	Enroll (student_id = enrollment.student_id, course_name = enrollment.course_name, grade_type = enrollment.grade_type, num_units = enrollment.num_units)

# Set of Built-in Action Primitives

Type	Explanation
say (str)	What the agent says to the user
propose (ws, [fld,val]*)	Propose to open worksheet ws, with initialized values for the different fields
exitws()	Close a worksheet, and the action associated with the worksheet is executed.



# DB Worksheet Contains the Schema

Form Name	Kind	Type	Enum Values
courses		DB	
	internal; primary	int	course_id
	internal	int	max_units
	internal	str	title
	internal	str	grading
	internal	List[str]	course_codes
	internal	List[str]	general_requirements
	internal	int	min_units
	internal	str	description
	internal	int	average_hours_spent
	internal	Enum	foundations_requirements
			logic_automata_and_complexity
			probability
			algorithmic_analysis
			computer_organization_and_systems
			principles_of_computer_systems
	internal	bool	significant_implementation_requirements
	internal	Enum	breadth_requirement
			formal_foundations
			learning_and_modeling
			systems
			people_and_society
	internal	List[str]	prerequisite_course_codes

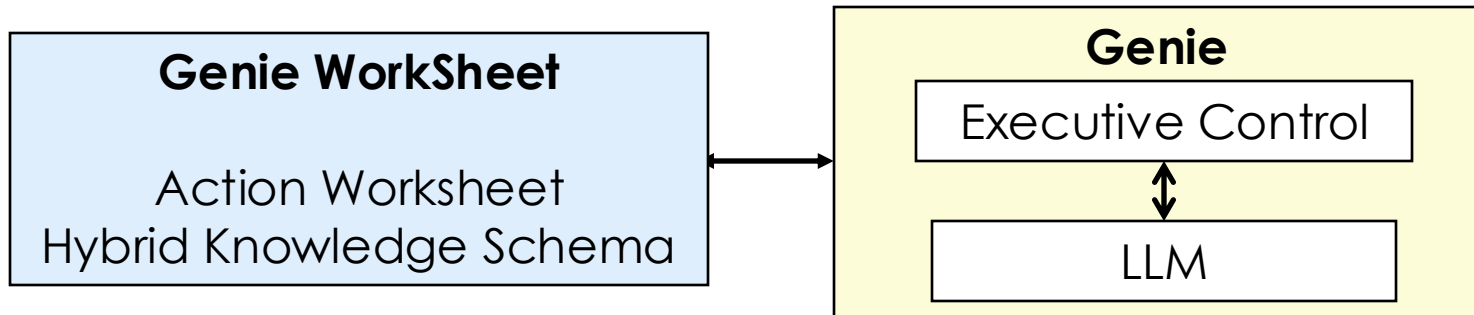
# Outline

1. Knowledge Assistants
  - Databases
  - Knowledge graphs
  - Hybrid data
2. API Agents
3. Knowledge + Task-Oriented Agents
  - Motivation: a Case Study
  - Design of the Genie WorkSheet
  - **Genie Runtime System**

# Run-Time System Architecture

## Executive Control Software

- Interpret & update Genie Worksheet
- Provide turn-specific instruction to LLM  
(Succinct context: Worksheet state + 1 turn of dialogue)



# Semantic Parsing

Assigns variables in the worksheet

“My ID is 123456,  
I want to enroll in CS224v and for 4 units”



```
Enroll: student_id="123456",  
course_name="CS224V",  
num_units=4)
```

# Translates Knowledge Queries

“What is a course that satisfies the significant implementation requirement?”



```
Answer(SELECT * FROM Courses WHERE  
        significant_implementation_requirements == true);
```

# Knowledge + Tasks

“I want to take a course  
that satisfies the significant implementation requirements for 4 units”



Semantic Parser in Run-time

Enroll:

```
course_name= Answer(SELECT * FROM Courses
                    WHERE max_units >= 4 and
                    significant_implementation_requirements == true);
num_units=4;
```

# Run-Time System

## **Contextual Semantic Parser:**

Assign variables to worksheet, generate database queries

**Agent Policy:** Output: Set of agent dialogue acts: A

Query:

- If missing required parameter: Add “ask parameter” to A
- If query is complete, Evaluate query, Update variables

Worksheet:

- If a variable is assigned , Add “ask for confirmation” to A or Execute action
- If a required field is unfilled, Add “ask for field” to A
- If a form is complete, Add “ask for confirmation” to A or Execute action

**Response Generation:** Generate response from A

# The Agent Policy Automatically Handles Many Possible Dialogues

USER:

ASSISTANT

I would like to take CS 224V for letter grade and 3 units.

I am enrolling you in CS 224V for letter grade and 3 units,  
would you like to confirm your enrollment?

Wait, does CS 224V allow for 4 units?

Yes, CS 224V is allowed for 3 – 4 units.

Then make it 4 units.

I am enrolling you in CS 224V for letter grade and 4 units,  
would you like to confirm your enrollment?

Yes!



# Note Conversations Can be Long

USER

I want to take a course for 3 units to fulfill my requirements

ASSISTANT

Sure, I can help you with that.

Here are some of the top rated courses: CS 224V, CS 242, CS 221

I want some easy, undergraduate level courses.

I looked for easy, undergraduate courses.

Here are some of them: CS 106A, CS 108, CS 124

... The student asks for 15 more courses ...

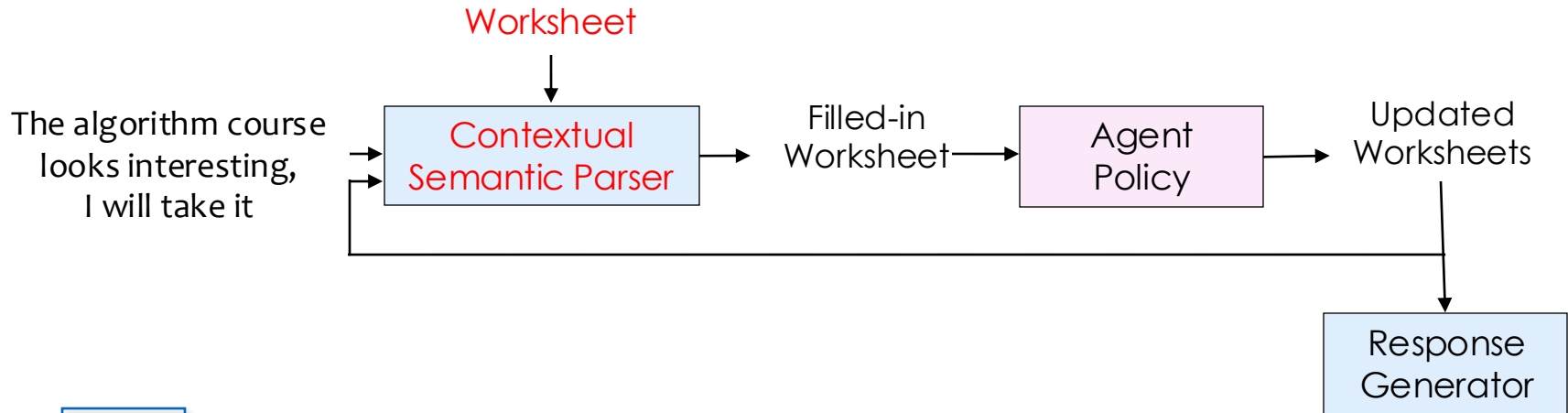
The algorithm course looks interesting, I will take it.

That sounds great. I am enrolling you in CS 163 for 3 units.

Would you like to take it for Pass/No Pass or Letter Grade

# Contextual Semantic Parsing

Use the worksheet state as a concise context



Future  
Topic

How to create effective contextual semantic parsers with LLMs?

# Comparison with GPT (Function Calling)

	SP Acc	Ex Acc	DA Acc	Goal CR
<b>System</b>	<b>All Domains</b>			
GPT 4 (FC)	-	65.4	69.1	21.8
Genie (ours)	91.4	<b>86.5*</b>	<b>89.2*</b>	<b>82.8*</b>
	<b>Restaurant Reservation</b>			
GPT 4 (FC)	-	50.0	57.7	54.54
Genie (ours)	93.8	<b>88.0*</b>	<b>92.5*</b>	<b>91.6</b>
	<b>Ticket Submission</b>			
GPT 4 (FC)	-	58.6	67.6	0.0
Genie (ours)	85.8	<b>80.0*</b>	<b>82.5*</b>	<b>80.0*</b>
	<b>Course Enrollment</b>			
GPT 4 (FC)	-	79.2	77.8	10.0
Genie (ours)	94.1	<b>89.7*</b>	<b>92.9*</b>	<b>80.0*</b>

SP Acc: Semantic Parsing Accuracy

Ex Acc: Execution Accuracy

DA Acc: Agent Act Accuracy

Goal CR: Goal Completion Rate

### 3. KNOWLEDGE + TASK-ORIENTED AGENTS

Genie Worksheet is a Declarative Programming Language

- Worksheet specifies the task at a high level
- Database schemas supply relevant knowledge

The run-time system support rich dialogues automatically

- Interprets the worksheet
- Parses input, performs queries & actions, asks questions

# Assignment 2

- Try out the Genie Worksheet-based course advisor
- Write a simple agent using Genie Worksheet