Humanize Web APIs, without the headache

By Team: Red
Old Dominion University
CS 410
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Team Bios - 1/3

John Hicks

A part-time Computer Science Major at ODU, transfer student from Tidewater Community College (TCC) where he earned his Associate of Science with a specialization in Computer Science. John has been employed full-time in software development and IT roles during most of his time in school. John began his journey into software development when his parents' small business needed a website upgrade from Microsoft Frontpage to WordPress. On understanding WordPress's hook and filter mechanism, John's imagination was kindled in wondering what other ways of writing software there might be. That curiosity turned to flame and was formed into skill with the help of many friends, family, internet contributors, workplace mentors and school faculty.

Freddie Boateng

A Computer Science major with a minor in Cybersecurity. He is from Northern Virginia and currently working as a Cybersecurity Engineer with Zachary Piper Solutions. He strives to always improve and stay updated to the world of technology, enabling him to reach his goals

Team Bios - 2/3

Kobe Franssen

Full time Computer Science major at ODU while also working part time as System Administrator at the ODU Computer Science Consultant Group. Experienced in Java, Python, C++ and API handling such as with Discord Bots. Love working on cars and has 3 cats.

Diya Patel

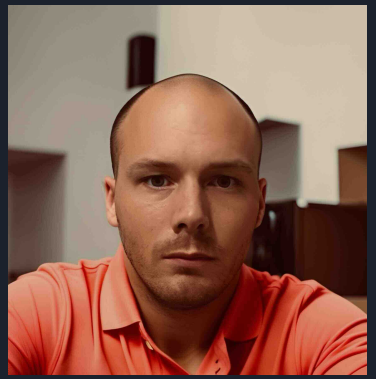
A Junior at ODU, pursuing a Bachelor's degree in Computer Science. She is interested in learning about the newest advancements in web development and artificial intelligence. She has an ongoing desire to take on new tasks and expand her skill set.

Andrew Bausas

I am a computer science major from Virginia Beach. I am to improve my skills and eventually use them to make games.

Team Bios - 3/3

Sean Baker



Sean's journey into computer science has been unconventional and spans both time and institutions. A transfer student from Piedmont Virginia Community College (PVCC), Sean earned his associate degree in computer science in 2016, but his tech journey began much earlier. At 14, he built his first WordPress site to supplement hsi allowance, which led to articles like "Ten reasons this IPhone will succeed". Since then, rather than pursuing a conventional corporate path, Sean has prioritized creativity and innovation, which has led him to work on projects that push technological boundaries, including contributing to self-driving car technologies with Edison2 and developing die cast automation software for VisiTrak Worldwide and Rockwell Automation. His self-taught, autodidactic learning approach has defined his career. Set to graduate this spring, Sean hopes to pursue a masters degree.

Chase Wallace

A Computer Science and Biomedical Sciences double major from Norfolk with a strong interest in neuroscience and artificial intelligence. He is always ready to learn new skills and broaden his horizons with challenging new projects.

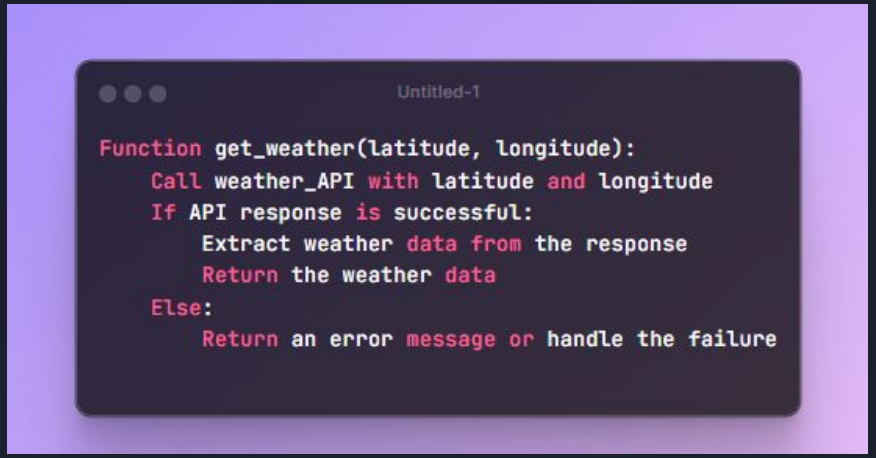
The Societal Problem

- User interfaces don’t speak the user’s language, but users rely on apps to make things happen.
- Developers are motivated to add Natural Language Processing (NLP) features to their apps, but doing so is painstaking.
- Things happen in Web apps through Web APIs.
- We need a way to turn natural language into Web Application Programming Interface (API) calls.

Elevator Pitch

- CueCode lets a Web application generate API calls from natural language with minutes of development time. “I booked an appointment for Patricia Davis for Thursday at 2pm” can become an API call to your appointment booking backend with little additional programming effort.
- A good API specification and a few key questions are all CueCode needs to start generating API requests.
- This allows rapid development of natural language processing features typical of those created during the Generative AI boom, without having to risk taking humans or business rules out of the loop. CueCode can add AI features to your app without any backend code changes or specialized NLP or large language model (LLM) skills.
- CueCode is easy to integrate with existing applications, making a better experience for users and developers alike.

Review of existing AI tools And How They Work



What is AI Function Calling?

A common misconception is that AI itself is making function calls.

However, the model(s) never actually executes functions themselves, instead they model simply generate parameters that can be used to call your function, and executes the function if you allow it. *OpenAI Platform*. (n.d.)

How do we give AI Models Access to Functions?

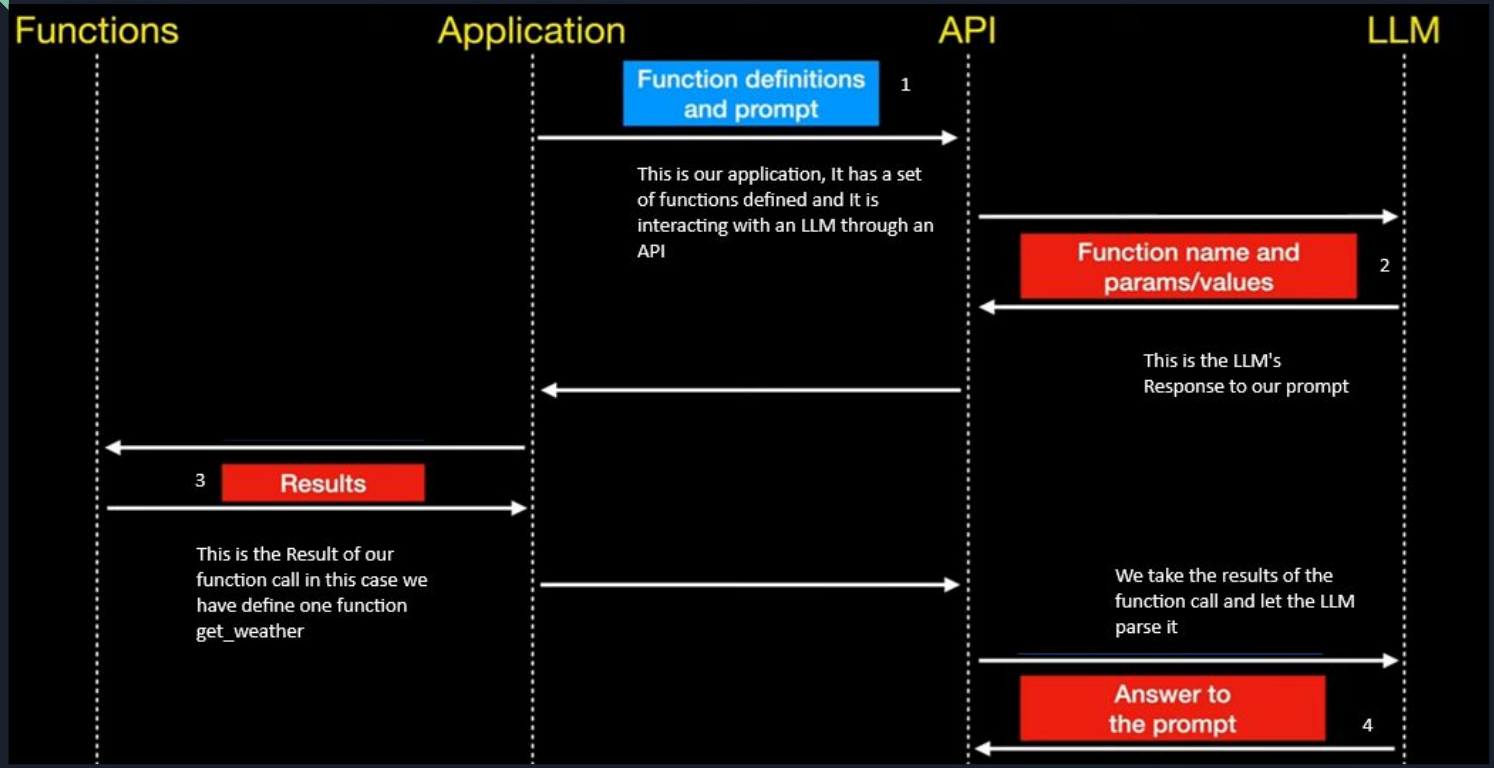
```
function_calling_dictionary {
  "get_weather": get_weather
}
```

```
Tools =
[
   {
    "type": "function",
    "function": {
        "name": "get_weather",
        "description": "Fetches the temperature for a given location.",
        "parameters": {
            "type": "object",
            "properties": {
                "latitude": { "type": "number", "description": "Latitude of the
location" },
                "longitude": { "type": "number", "description": "Longitude of the
location" }
            },
            "required": ["latitude", "longitude"]
        }
    }
}
]
```

We give it a list of functions assigned to a string and a JSON Object Identifying Each Function:

1. **Name**: Identifier of the function.
2. **Description**: A brief overview of the function's purpose.
3. **Parameters**: Defines the expected input parameters, including type (in this case number), whether they are required, and other details.

What Does the Function Calling Process flow look like?



Function Definitions and Prompt

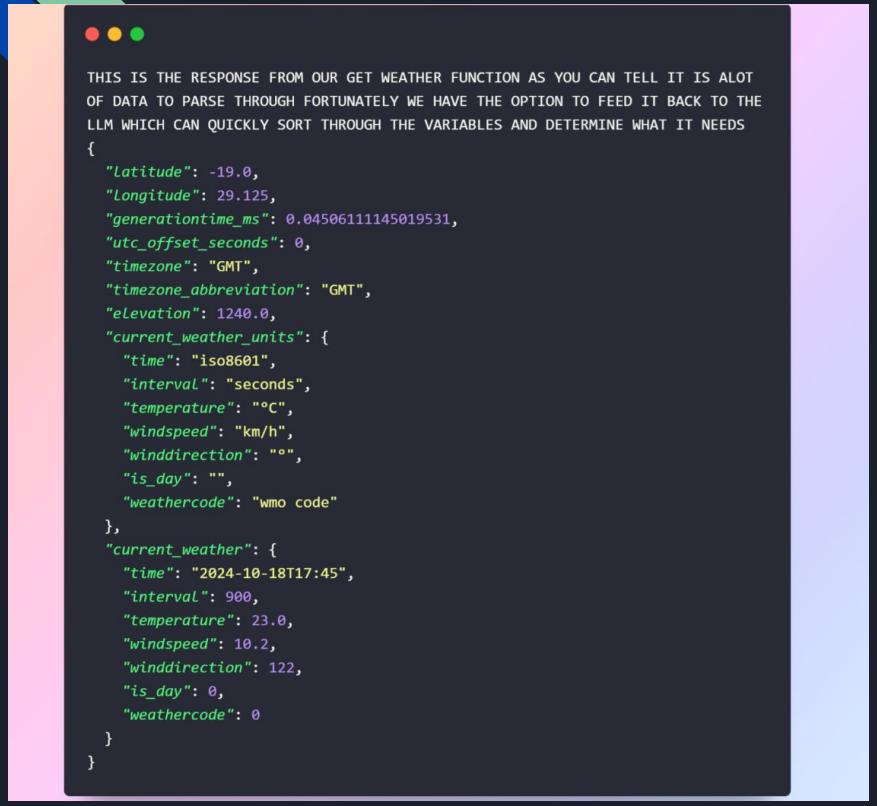
```
{
  "type": "function",
  "function": {
    "name": "get_temperature",
    "description": "Gives the temperature",
    "parameters": {
      "type": "object",
      "properties": {
        "Latitude": {
          "type": "number",
          "description": "The latitude"
        },
        "Longitude": {
          "type": "number",
          "description": "The longitude"
        }
      },
      "required": ["latitude", "longitude"]
    }
  },
  "prompt": "You assist me with calling specific tools.",
  "kwargs": {
    "prompt": "Based on the temperature in Zimbabwe, what month is it?"
  }
}
```

EXAMPLE PROMPT: “Based on the temperature in Zimbabwe, what month is it?”

Function Names and Parameter Values

The model realizes to get the temperature in Zimbabwe, it needs to call the get_weather function.

The LLM looks at the tools we provided and examines the required fields. It then realizes it needs the latitude and longitude for Zimbabwe, , that data is available to the model without needing to make another function call.

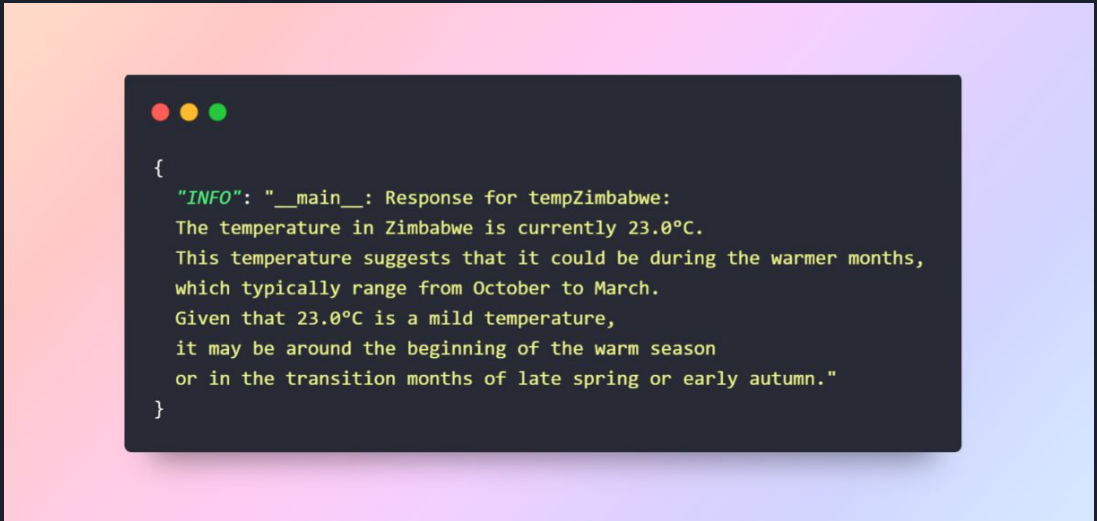


Getting the Results

The Get Weather Function is Called, and the result is passed back to the LLM.

This is the actual data received from a function call (again this function was defined in our code, the LLM decided to call get weather and we are now sending that data back to the LLM)

Giving the Results Back to the LLM



The Model Gets The Response and parses it and Finally Returns an Answer To the Prompt

Untitled-1

```python
# Define some sample functions
def greet():
    return "Hello, world!"

def add(a, b):
    return a + b

def multiply(a, b):
    return a * b

# Store functions in a dictionary
dynamic_function_calling_dictionary = {
    "greet": greet,
    "add": add,
    "multiply": multiply
}

# Call functions dynamically from the dictionary
# Example 1: Call greet function
result = dynamic_function_calling_dictionary ["greet"]()
print(result)  # Output: Hello, world!

# Example 2: Call add function with arguments
result = dynamic_function_calling_dictionary ["add"](3, 5)
print(result)  # Output: 8

# Example 3: Call multiply function with arguments
result = dynamic_function_calling_dictionary ["multiply"](4, 6)
print(result)  # Output: 24
```

How are Models Able To Call Functions?

Simple Example of Chaining Function Calls

Question 1: Find a 3 day period during which Tesla's stock price was at its lowest point near the end of the year 2022. For that same time period, retrieve the daily weather data in Palo Alto, California, and compare the temperature patterns with the changes in Natural Gas prices.

Question 2: show me a correlation between the stock price of tesla the price of natural gas and the temperature from december 25th 2022 to january 31st 2023

2.1 Problem Statement

No framework exists for making Natural Language to API-call generation simple for fullstack and Web developers.

Existing approaches:

- Microsoft created a paper describing their approach to using natural language to operate on the Microsoft Graph API (Su et al., 2017). But that is just for the Graph API.
- Zafin claims to have built a system that does uniquely well at identifying which API endpoint to call due to an embedding strategy for API calls (Zafin, 2023). The solution focused on chatbot integration more than data entry.
- LLM Function Calling is promising, but it requires LLM prompt engineering and backend programming to turn natural language to API calls, vs. the normal chatbot use-case (Against LLM Maximalism · Explosion, 2023; Function Calling, n.d.; Tool/Function Calling | LangChain, n.d.; Su et al., 2017).

=> Demand for API-call generation, but no simple, operationalized, and risk-aware tooling for it.

2.2 Problem Characteristics - use of API specs

- To solve the problems, we must commoditize the process of turning natural language into API calls against a large number of existing existing Web APIs.
- Since APIs are commonly described with specifications, why not use those?
  - (Keep a clean contract between system components.)
- OpenAPI is the leading industry standard way to describe REST (REpresentational State Transfer) APIs.
- However, there are no complete frameworks that leverage OpenAPI specifications when turning natural language to REST API calls.

2.2 Problem Characteristics - NLP/LLM challenges

Problems with current NLP/LLM processing for creating API calls:

- Require awareness of prompt engineering and other more complex AI techniques
  - => Time/money upskilling fullstack and Web developers.
- The NLP tools for generating API calls today are stand-alone programs and libraries that don't present a unified, opinionated solution.
  - => Developers are left building one-off solutions.
  - => Heavy boilerplate/in-house frameworks.
- Humans and application logic are kept out of the loop in other approaches; this is high-risk.

2.2 Problem Characteristics - NLP/LLM challenges

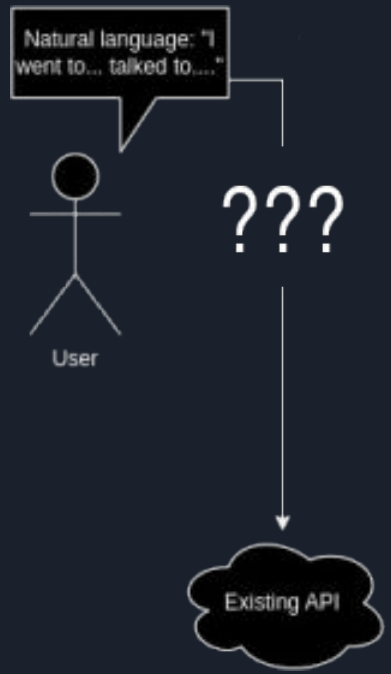
Problems with current NLP/LLM processing for creating API calls:

- Limiting Responses to fit an API Structure Is Difficult
- Lack of Understanding of Entity Relationships
- Absence of a Consistent Framework for Web Developers

2.3 Current Process Flow

A solution for generating API calls would ideally address the following points.

- Design the interface between the customer's application and the API call generation code.
- Encode the Web API structure for validation and generation. Options:
  - In Langchain, build Python classes that define the expected structure of the LLM response (Tool/Function Calling | LangChain, n.d.).
  - OpenAI, use Function Calling schema specification and hope for the best. (OpenAI Platform, n.d.; Tool/Function Calling | LangChain, n.d.)
- Tag entities and their relationships in the natural language input.
- For JSON, the format that is standard for API calls across the web, prompt the LLM to use a certain JSON format.
- Tell the LLM about the API structure:
  - One-shot prompt is common in examples, but LLMs struggle to consistently generate responses that are conformant to the spec (Microsoft/Prompt-Engine, 2022/2024).
- Make the existing application aware of LLM API call suggestions:
  - For interactive apps, show the suggestions to the user.
  - For batch processing, push the generated API calls through business logic.
- Validation (see next slide)



2.3 Current Process Flow (Validation)

- Verify output is in JSON format (LangChain [9], Guidance AI [6])
- Once an API call is generated, confirm its structure conforms to the schema defined in the OpenAPI spec.
- Confirm that the sequence of data manipulations is consistent with the new/modified entities' relationships.
- For interactive applications confirm the generated API call with the user, and for batch applications, validate the generated API call using business logic.

No single application or framework on the market addresses all of these concerns, and implementing these solutions manually for each application that wants these features is tedious and requires expertise in using LLMs.

3 Solution

CueCode will provide a comprehensive service for creating Web API calls from natural language input in a risk-aware, accurate manner that puts developers - and, by extension, users - in control of when API calls are invoked.

3.1 Solution Statement

What that means:

Developers will be able to use existing API specifications, which CueCode makes understandable by LLMs, to generate the content of their API calls in conformance with their API spec.

So, our client service representative can provide input to a booking application using CueCode in natural language, “I called Patricia Davis and rescheduled her appointment from August 1st to August 16th.” The application can then use CueCode’s libraries, which have been configured using documentation about the structure of their data, to generate the following Web API request with a JSON request body:

```
POST https://the-appointment-app.com/api/v1/appointments/

{"request":{"reschedule":{"last": "Davis", "first":"Patricia", "from":{"month":8,
"day":1,"year":2024}, "to":{"month":8, "day":1,"year":2024}}}}
```

Which would then be used by the booking application to perform the API call, which will change the appointment date in their database, or prompt the user for additional information.

3.2 Solution Characteristics

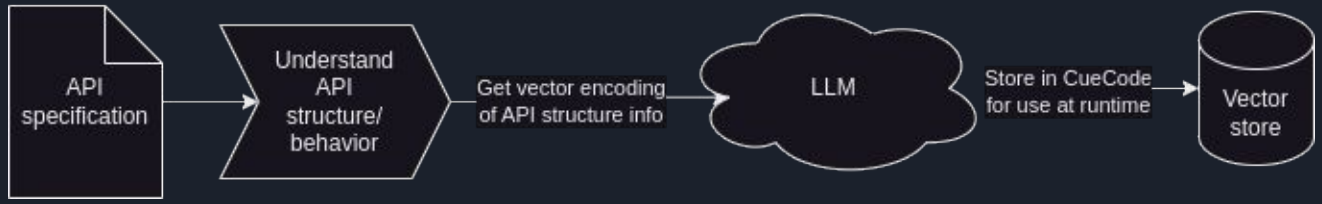
Problem Characteristics

- Forcing end users to fill out lots of forms for input is both limiting and tedious
- There is no easy way to implement using NLP to parse user input for existing applications
- It is difficult to make LLMs aware of the structure of data expected from a natural language prompt
- There is no standardized solution for translating natural language into structured data
- Translating natural language into structured data requires prompt engineering and other skill sets that do not belong to a typical front end or full stack developer
- LLM integration can cause data mutation and incorrect parsing of information

Solution Characteristics

- CueCode leverages LLM technology to parse natural language into structured data to generate API calls, simplifying the process of data entry.
- CueCode provides libraries to front end and full stack developers to easily integrate NLP into their existing applications
- Existing API specifications provide machine-readable input to guide LLMs into parsing user input from natural language, saving developers time and resources
- CueCode facilitates Human-in-the-Loop feedback to allow the end user to review the generated data in the existing user interface

3.3 Solution Process Flow (configuration)



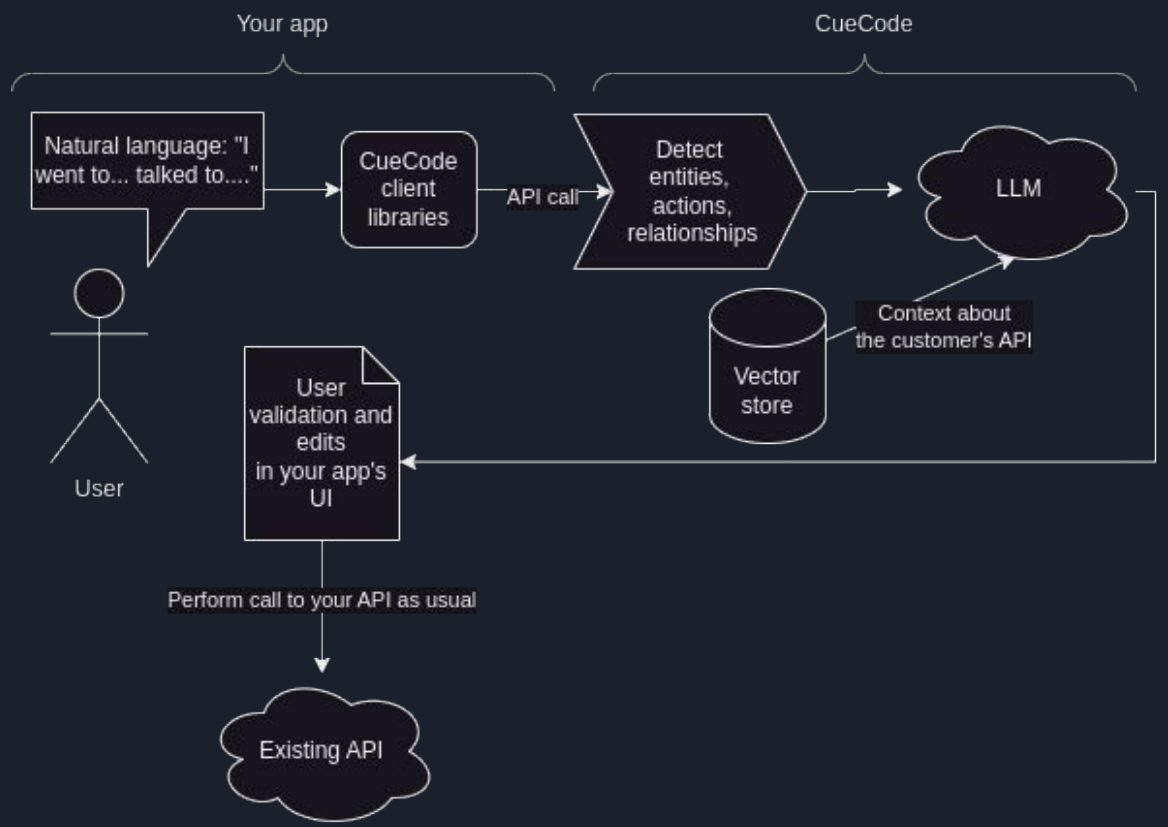
At configuration time:

- Developers ensure their API specification is accurate.
- Developer uploads their API specification to CueCode.
- Developer answer a few configuration questions.
- CueCode stores the structure and requirements for the API to aid the LLM in generating responses at runtime.
- All of this is transparent to the Developer's customers/end-users.

3.3 Solution Process Flow (runtime)

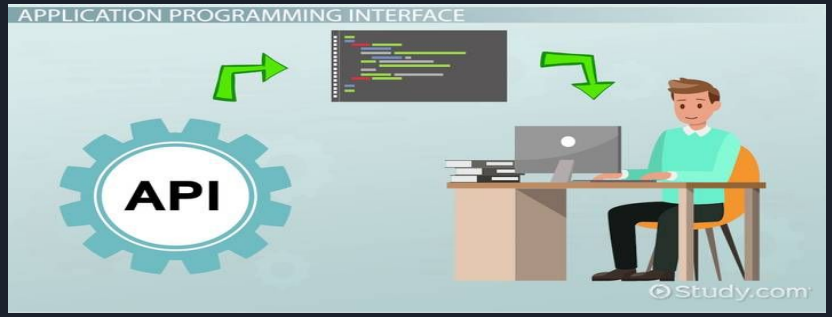
Use CueCode in the developer's app:

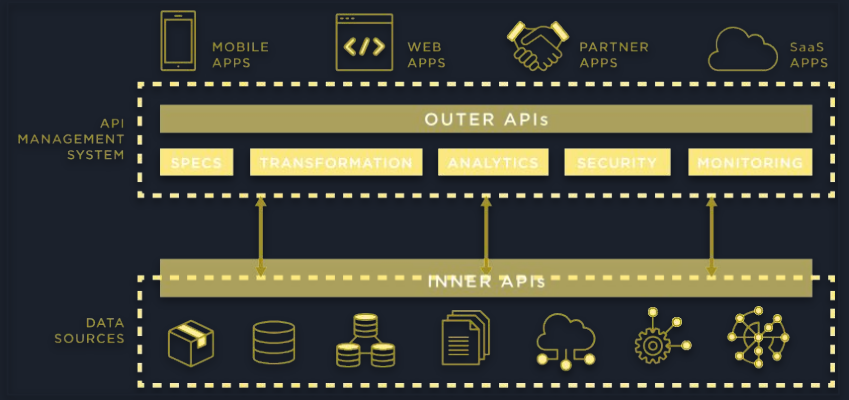
- Program your app to pass natural language text to CueCode libraries.
- Let the CueCode service figure out the structured data contained in the text.
- Use CueCode's extracted structured data within the existing application's data model. e.g.:
  - Show suggestions to the user
  - Perform API calls in a batch job
  - Validate through business rules
  - Whatever the use case requires



3.4 What it Will Do

- Will implement NLP capabilities to enable and understand natural language
- Will offer a user friendly interface (API) that developers can use
- Will provide a developer portal web application, where developers can upload API specifications
- Will provide tools for customizing NLP models to fit specific domains/industries ensuring better performance for unique use cases.
- Will include documentation and support resources to help developers implement and troubleshoot various systems effectively.
- Will use API specifications, enabling context-aware replies that complement the distinct functionality and data structure of each application.
- Will allow for real time analysis and response generation, enhancing user experience through immediate feedback and interactions.





3.5 What it Will Not Do

- Will not replace human judgment when interpreting language in terms of making subjective decisions beyond its programming.
- Will not act as an AI agent
- Will not provide user-facing applications; developers will need to build their own solutions and install any necessary software/applications they need.
- Will not automatically make API calls on users' behalf; requests must first have human permission before being fulfilled.
- Will not have programming tutorials, developers will need to possess knowledge of programming to utilize CueCode effectively.

3.6 Competition Matrix

✔- Full Implementation
P - Partial Implementation

Feature	CueCode	OpenAI Functions	Google Natural Language API	Spacy.io	LangChain	GenKit	Phone AI Alexa, Siri,...
Entity recognition	✔		✔	✔		P	✔
Plug and Play	✔				P	P	P
AI-Initiated actions	✔	P			P		✔
Retrieval Augmented Generation	✔	✔			✔	✔	
API call generation as a service	✔	P	P		P		P
Natural language actions	P						

4 Development Tools

Version Control:

- Git with GitHub

Integrated Development Environment (IDE):

- VS Code

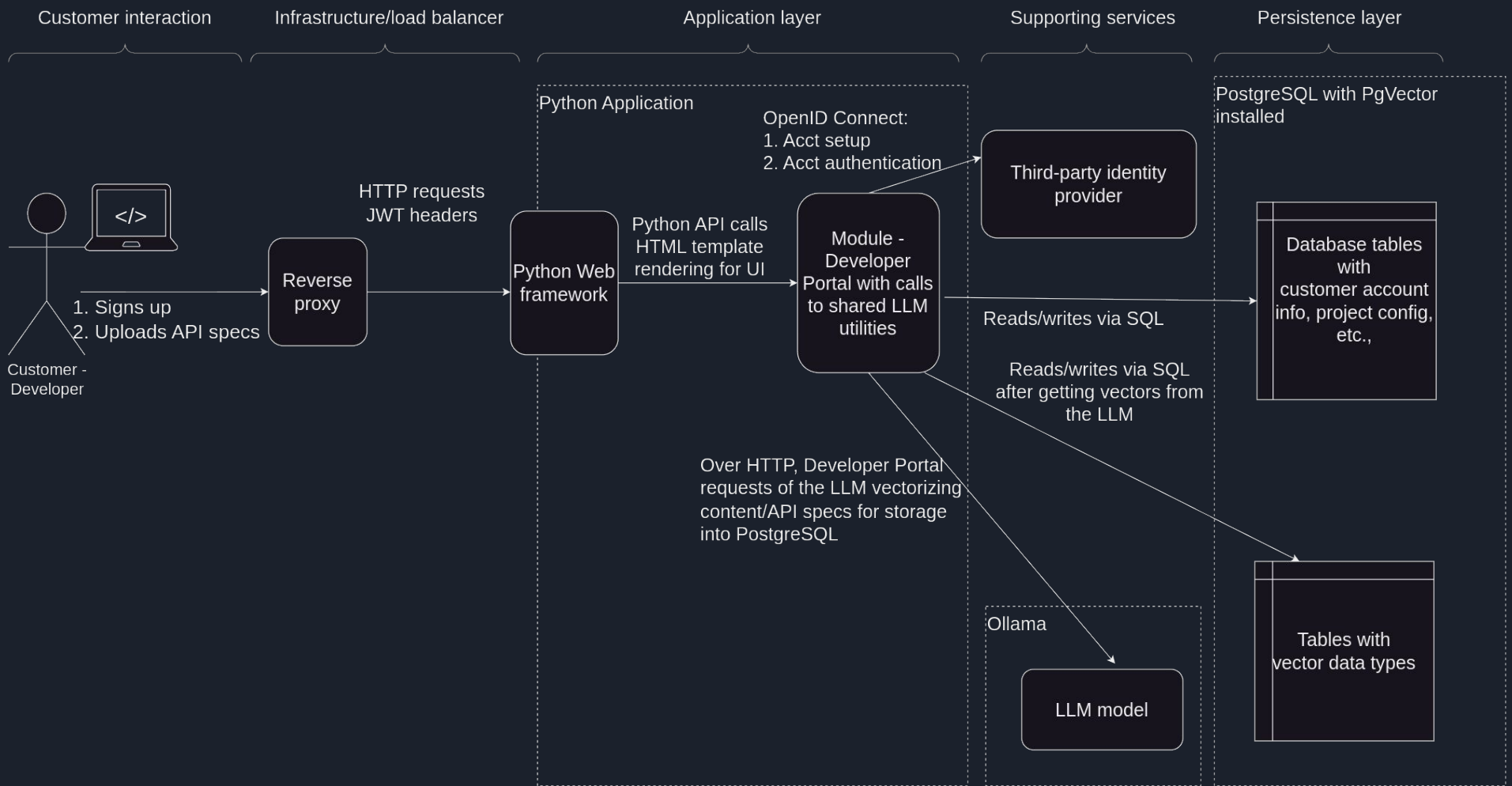
Continuous Integration (CI) & Continuous Deployment (CD):

- GitHub Actions and Workflows

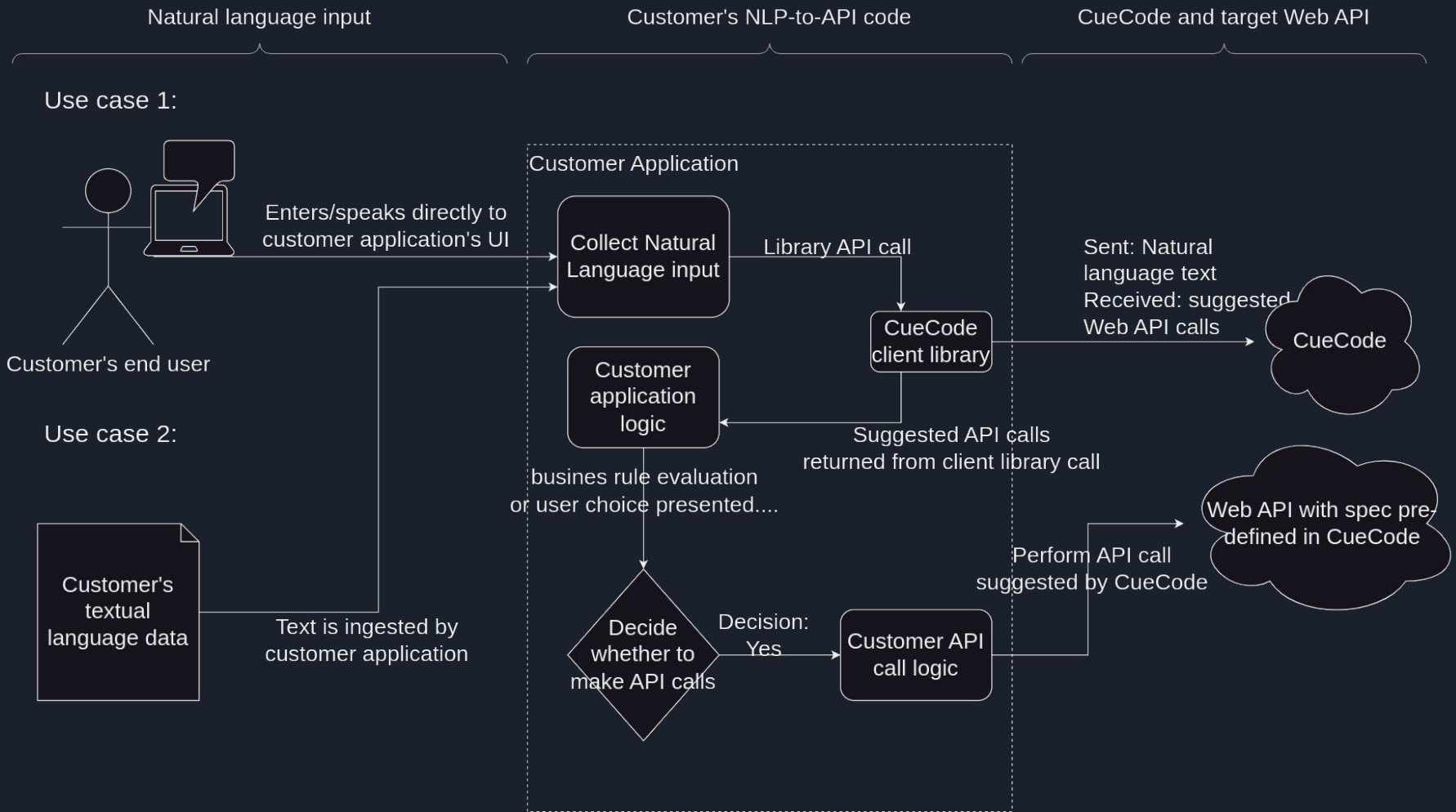
5 Major Functional Components

- Client libraries for customers to use for integrating with CueCode's service
  - Bindings for the CueCode runtime API
- Python modular monolith:
  - All modules exposed via Flask, a Python Web framework
  - Module: Web API Call Generation- receives natural language input and generates Web API calls from it.
  - Module: Developer Portal - account registration/management, API spec upload, configuration, generation audit and monitoring
  - Horizontally scalable via 12-factor app methodology
- PostgreSQL (Postgres) persistence:
  - PgVector extension for storing vectors generated by the LLM
  - Normal Postgre tables for customer accounts, configuration, generation monitoring and audit information
- Ollama:
  - A Web service and set of standardized LLM-call APIs that allows us to swap LLMs used while maintaining the same API contract with our Python backend.
- Third-party identity service:
  - For developer portal
  - TBD on how/whether CueCode runtime API traffic would use the same identity provider for authentication.

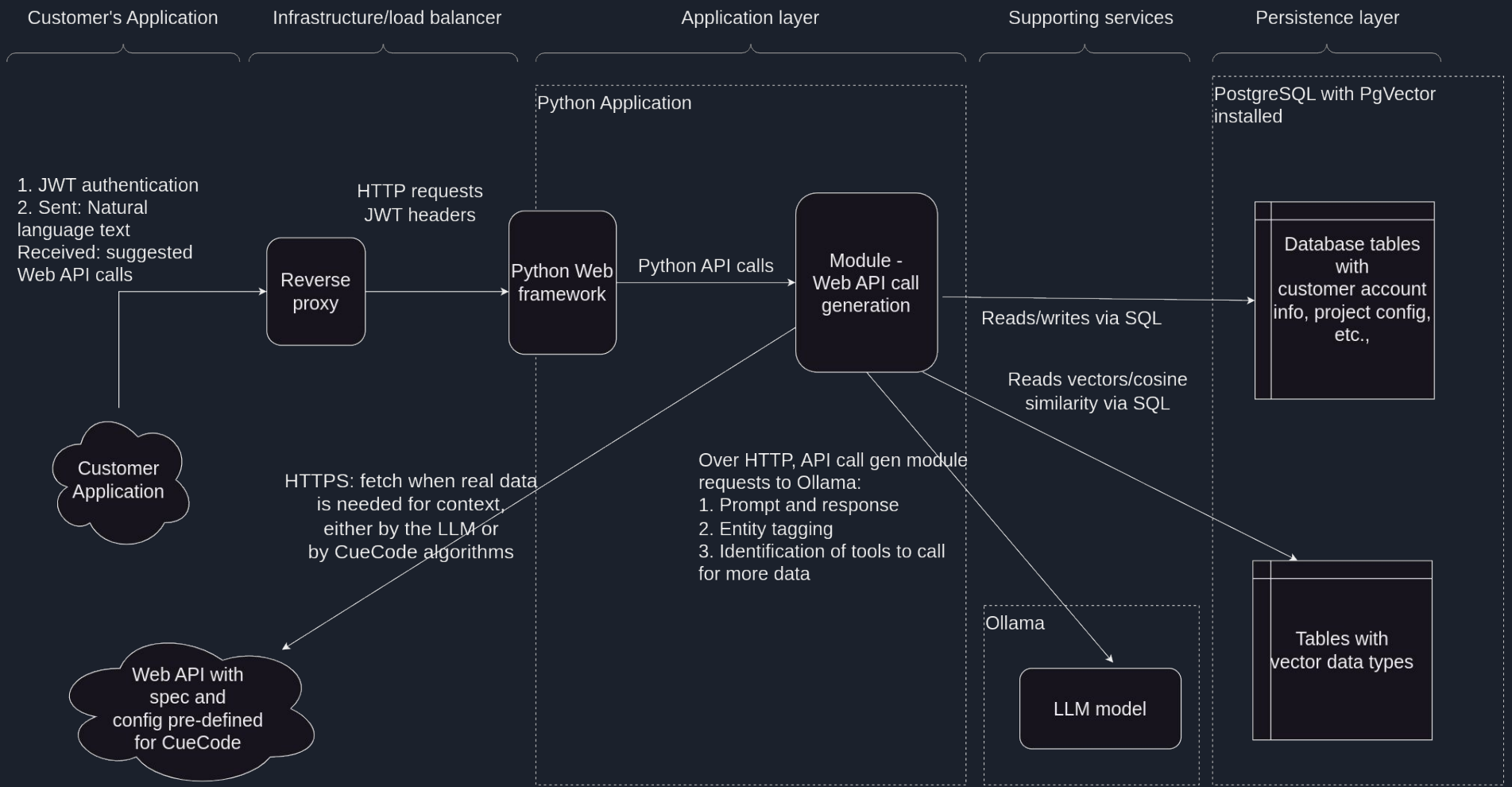
5.1 Major Functional Components Diagram - Configuration



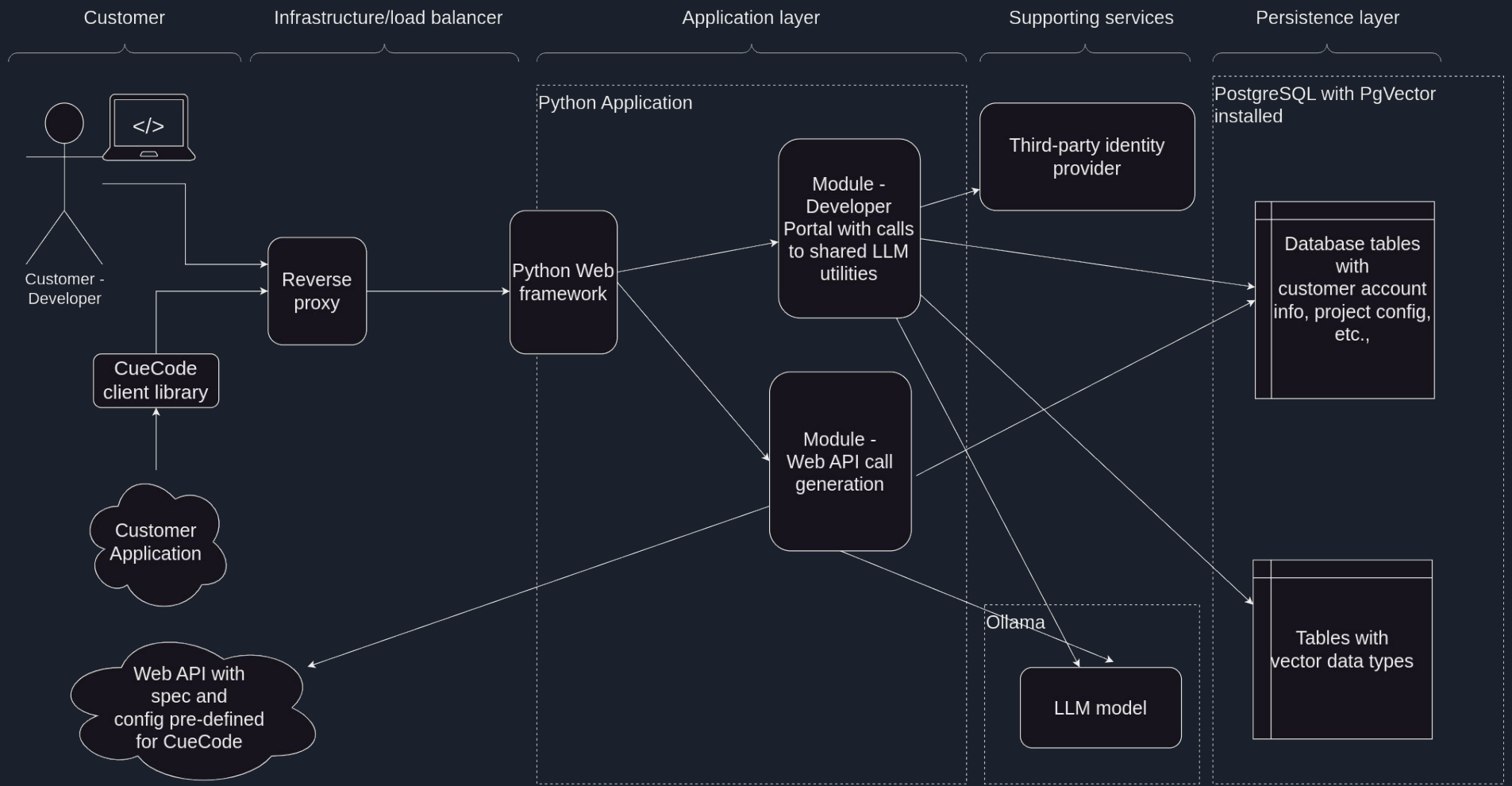
5.1 Major Functional Components Diagram - Runtime - Customer Application



5.1 Major Functional Components Diagram - Runtime - CueCode



5.1 Major Functional Components Diagram - Overview



6 Risks - Customer, Operational, Regulatory

O1 - Unable to procure GPU Hardware for development.

- **Mitigation approach:** Control
- **Mitigation:**
  - Ask for GPU time from the CS department. We have a ticket in progress.
  - Personal contacts and networking

O2 - CueCode customers may overlook critical security or operational risks when generating API calls.

- **Mitigation approach:** Continue Monitoring
- **Mitigation:** Perform thorough logging, audits to provide detailed error checking tools for developers.

6 Risks - Customer, Operational, Regulatory

R1 - The use of API specifications might infringe on proprietary or closed API usage policies, leading to legal issues.

- **Mitigation approach:** Avoid
- **Mitigation:** Check downstream API usage against known limits, check with professionals about API licenses, develop and publish a platform abuse notice process for API providers to use, and stay away from violating proprietary API standards and procedures.

Probability

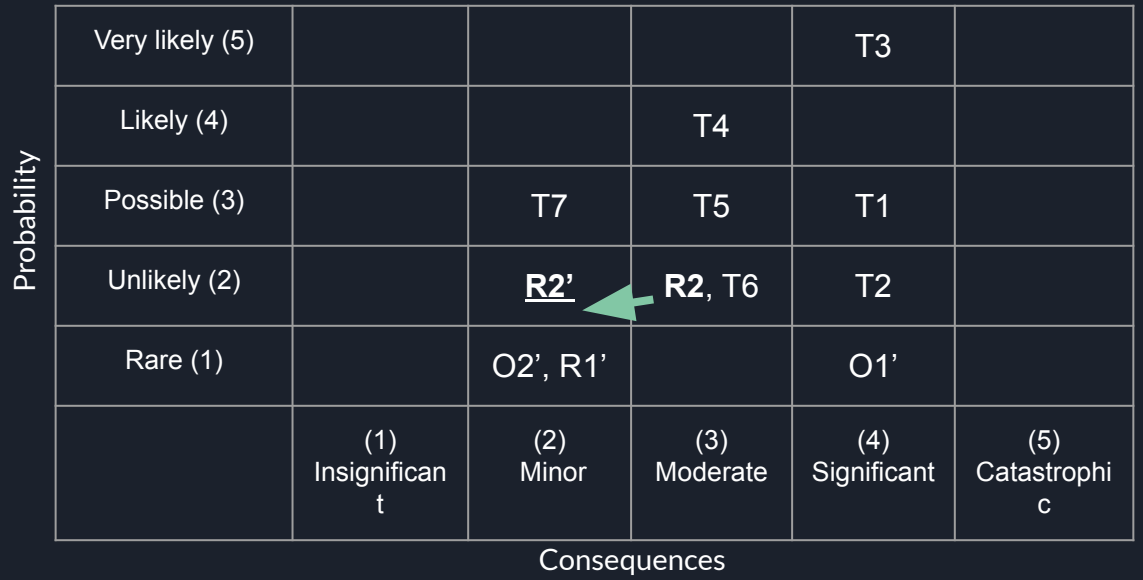
Very likely (5)				T3	
Likely (4)			T4		
Possible (3)		T7	T5	T1	
Unlikely (2)		R2’	**R1**, R2, T6	T2	
Rare (1)		O2’, **R1’**		O1’	
	(1) Insignificant	(2) Minor	(3) Moderate	(4) Significant	(5) Catastrophic

Consequences

6 Risks - Customer, Operational, Regulatory

R2 - Storage of API credentials makes CueCode an enticing target for cybersecurity attacks.

- **Mitigation approach:** Control
- **Mitigation:**
  - Legal - apply terms of use that protect CueCode in the case of data breach.
  - Technical - separate tenant credentials with care.
  - Technical - guide developers to use scoped API keys; use OAuth2 for user-specific data



6 Risks - Technical

6 Risks - Customer, Operational, Regulatory

R2 - Storage of API credentials makes CueCode an enticing target for cybersecurity attacks.

- **Mitigation approach**: Control
- **Mitigation**:
  - **Legal** - Apply terms of use that protect CueCode in the case of data breach.
  - **Technical** - Separate tenant credentials with care.
  - **Technical** - Guide developers to use scoped API keys; use OAuth2 for user-specific data.

6 Risks - Technical

T1 - LLM won't generate API calls without few-shot prompt examples.

- **Mitigation approach:** Control
- **Mitigation:** Require that developers include a few examples in their OpenAPI specs.

T2 - LLM won't generate API calls without hundreds or thousands of examples.

- **Mitigation approach:** Continue Monitoring.
- **Mitigation:** Pivot to change value propositions and require backend development from the customer to publish API request bodies to CueCode for its consumption and storage.

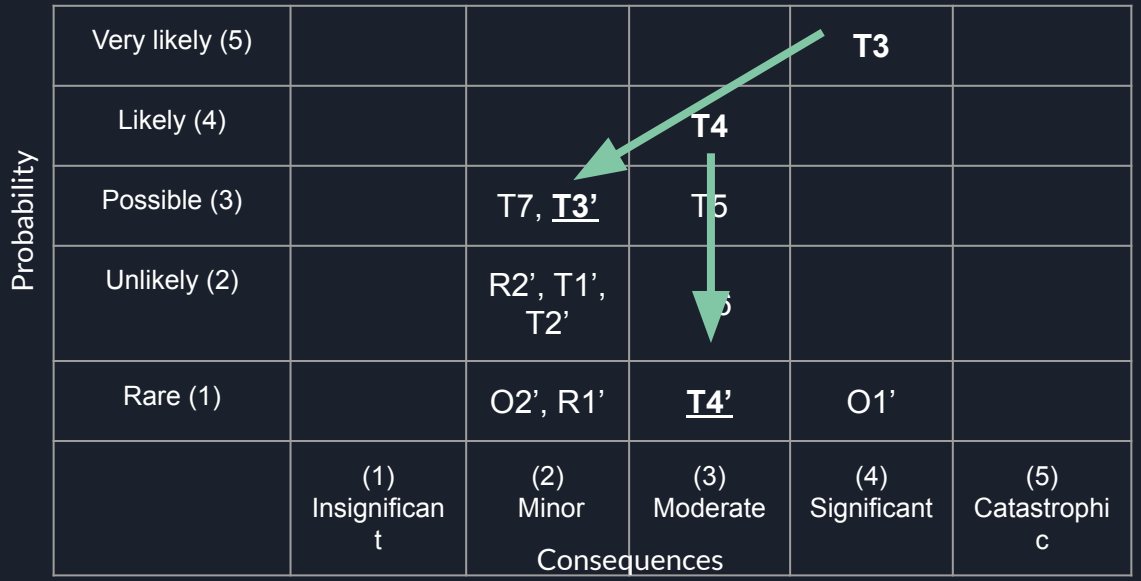
6 Risks - Technical

T3 - Vastness of frontend API client ecosystem precludes building CueCode client libraries for all popular languages and frameworks.

- **Mitigation approach:** Transfer
- **Mitigation:**
  - Use Swagger CodeGen for our own CueCode backend API.
  - Open-source our client library code.

T4 - Potential exposure of sensitive API information through generated API calls.

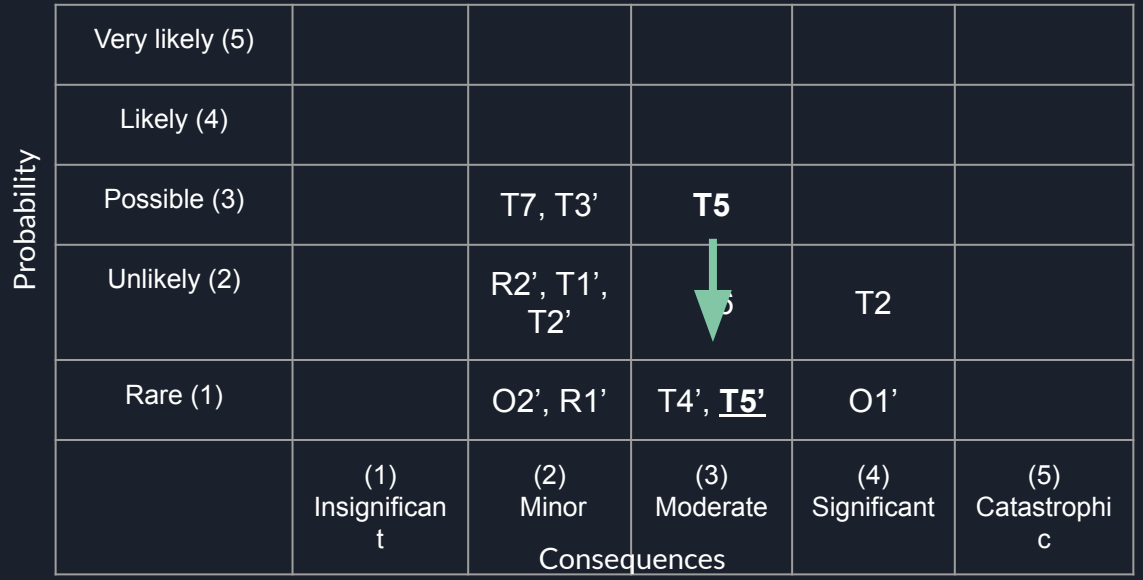
- **Mitigation approach:** Control
- **Mitigation:** Partition customer data; Give customers the ability to partition their customers' data in CueCode's data storage; use strong encryption when transferring data; and enforce stringent access limits.



6 Risks - Technical

T5 - Obsolescence of vendor libraries and services in the greenfield AI market.

- **Mitigation approach:** Avoid
- **Mitigation:**
  - Use OLLama backend communication with the LLM, allowing swappable LLM models according to CueCode's needs.
  - Use PgVector, an extension to the FOSS PostgreSQL RDBMS, for vector storage.
  - Develop a simple Python backend without undue reliance popular AI libraries, most of which are pre-v1 and, incidentally, overfit for CueCode's purpose.



6 Risks - Technical

T6 - The performance of an API model declines with complexity.

- **Mitigation approach:** Continue Monitoring
- **Mitigation:** Defer development of frontend libraries until we know whether backend processing takes so long as to require asynchronous processing, instead of request-response.

6 Risks - Technical

T7 - Elevated demand may surpass the capacity of the system, resulting in disruptions or delays.

- **Mitigation approach:** Continue Monitoring
- **Mitigation:** As traffic increases, scalability and efficiency are ensured through:
  - Starting development with architecture that allows scaling (containerized 12-factor app)
  - Regular performance testing
  - Load balancing.

Probability

Very likely (5)					
Likely (4)					
Possible (3)		**T7**, T3’			
Unlikely (2)		R2’, T1’, T2’	T6’	T2	
Rare (1)		O2’, R1’, **T7’**	T4’, T5’	O1’	
	(1) Insignificant	(2) Minor	(3) Moderate	(4) Significant	(5) Catastrophic

Consequences

6 Risks - Mitigation landscape

Before

Probability						
(5)				T3		
(4)			T4			
(3)		T7	T5	T1	O1	
(2)			R1, R2, T5, T6	T2		
(1)			O2			
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	

Consequences

After

Probability						
(5)						
(4)						
(3)		T3’				
(2)		R2’, T1’, T2’	T6’			
(1)		O2’, R1’, T7’	T4’, T5’	O1’		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	

Consequences

Conclusion

CueCode:

- Leverages existing tools and techniques
- Develops a framework for developers
- Delights users
- Reduces risk for important actions/data entry

=> Humanize Web APIs, without the headache.

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