CueCode

Team Red CS410W project

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 the model 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 take 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 made by developers, for developers - as seen in CueCode’s easy-to-use client libraries.

Table of Contents

Team Bios

John Hicks

John Hicks is a part-time Computer Science major at ODU, a 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 Front Page to WordPress. On understanding WordPress's hook and filter mechanisms, 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

Fred Boateng is 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.

Kobe Franssen

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

Diya Patel

Diya Patel is 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.

Team Bios

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 his allowance, which led to articles like "ten reasons this iphone will suceed", 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 technology 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.

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

Chase Wallace
Chase Wallace is 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
- Turning bulk unstructured data into structured data is difficult
- Humans are kept out of the loop in current AI agent based systems
- To develop human-in-the-loop natural language to API systems, it would take:
  - Specialized skills
  - Extensive backend programming changes
  - One-off development per application
  - A lot of money
- Conventional interfaces are difficult for users, which frequently results in work abandonment or lost of interest.
- Complex forms and interfaces are difficult for users to navigate, which affects the user experience.
- The vast majority of NLP tools on the market today are stand-alone programs that don't work well with current web apps.
- As applications evolve, the functionality of NLP is challenging, leading to failures in interpreting user input.

2.1 Problem Statement

To solve the above problems, we must commoditize LLM development for existing Web apps.

However, there are no frameworks/tools that leverage OpenAPI or GraphQL specifications, the two most common ways to describe API capabilities.

2.2 Problem Characteristics

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

- Hand decision-making to the LLM
  - Removes human checks
  - Removes business logic
- One-off, defined per application
- Lack a clearly defined concept of entity relationships
- Require awareness of prompt engineering and other more complex AI techniques
- => Heavy development effort

2.2 Problem Characteristics

Who is affected by the problem?

Developers:

Impact: The complex process of merging NLP systems, which requires knowledge of rapid engineering and cutting-edge AI approaches, places a significant burden on developers. They frequently don't have a well-defined framework for managing business logic or object relationships, forcing them to create custom solutions for each application.

System Architects:

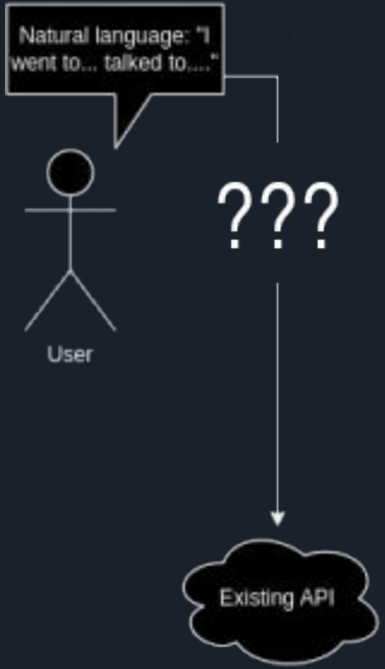
The absence of standardization in the definition and comprehension of entity connections by LLMs is a challenge for system architects. In the absence of a framework that guarantees that LLMs identify the links among data items or fields, they are forced to create unique solutions, which are prone to error and require a lot of work.

End Users (Application Users):

When end users engage with applications that rely on LLMs without human checks or structured data, they may encounter errors, inconsistent results, or actions that are not intended. These issues are caused by poor implementations of NLP-based features. The absence of human verification processes raises the risk of data entry or interaction errors, which lowers user satisfaction and trust.

2.3 Current Process Flow

- Encode API structure
  - Build Python classes [9]
- Verify output is in JSON format
  - Tools exist for verifying a JSON format and even that LLM output matches a JSON schema. (LangChain [9], Guidance AI [6])
  - (But, this alone does not make an NLP-to-API-call engine.)
- Tell the LLM about the API structure
  - One-shot prompt is common
  - Could not find examples of encoding API information in the vector store.
- Tie it all together with backend programming
- Make your application aware of LLM API call suggestions
- Integrate the new NLP features into the existing app



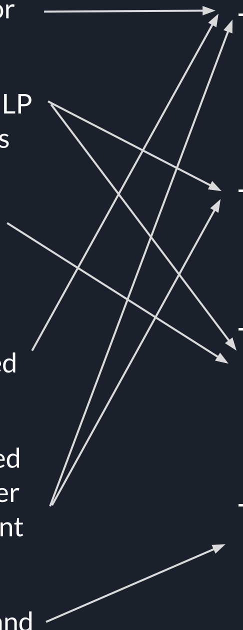
3 Solution

We aim to build client libraries for web app developers that interface with CueCode’s servers, which will deploy LLMs to convert natural language to structured API calls.

3.1 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 uses Human-in-the-Loop feedback to allow the end user to review the generated data in the existing user interface

3.2 Solution Statement

What that means:

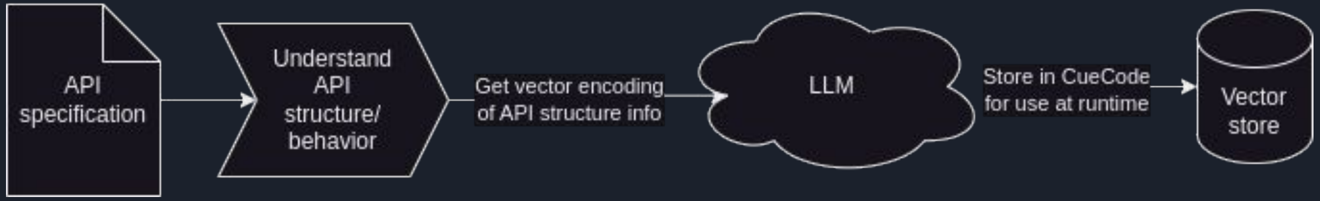
Developers will be able to use existing API specifications, which is CueCode makes understandable by LLMs, to define the structure of their API calls.

For example, if a client service representative were to provide input to an 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 JSON:

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

Which would then be converted into the appropriate API call to change the appointment date in their database, or prompt the user for additional information.

3.3 Solution Process Flow (“training” time)


API specification
Understand API structure/ behavior
Get vector encoding of API structure info
LLM
Store in CueCode for use at runtime
Vector store

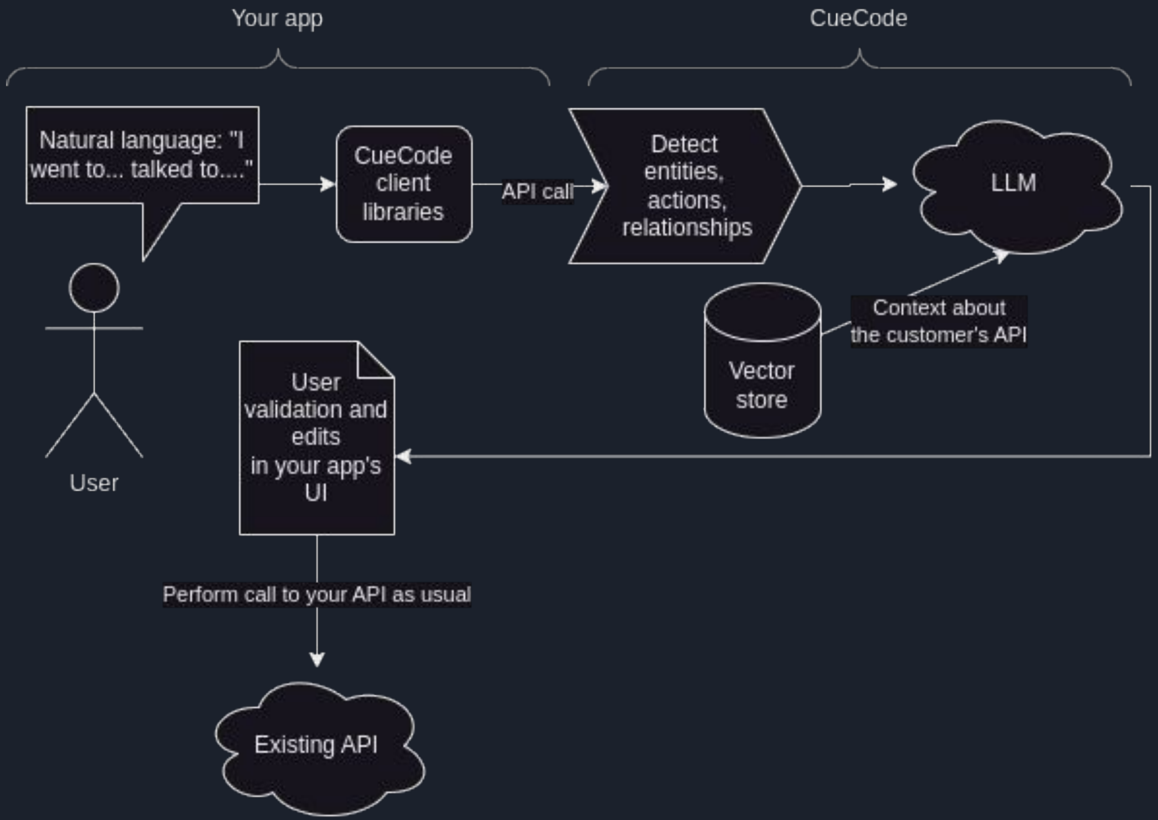
Training time:

- Upload API specification
- Answer a few questions
- CueCode stores the structure and requirements for your API in a vector store to aid the LLM in generating responses at runtime

3.3 Solution Process Flow (runtime)

Use CueCode in your app:

- Integrate text processing via CueCode libraries
- At runtime, let CueCode figure out the structured data contained in the text
- Use CueCode's extracted structured data. e.g.:
  - Show suggestions to the user
  - Perform API calls in a batch job
  - Validate through business rules
  - Whatever your use case requires


Your app
CueCode
Natural language: "I went to... talked to...."
User
CueCode client libraries
API call
Detect entities, actions, relationships
LLM
Vector store
Context about the customer's API
User validation and edits in your app's UI
Perform call to your API as usual
Existing API

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 enable quick iteration and prototyping by allowing developers to test and refine how their applications respond to the natural language inputs.
- 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 reduce the time and financial investment typically required for implementing NLP, making it affordable for smaller teams and startups
- 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 be perfect, misinterpretations could occur with certain slang, ambiguous phrasing or idioms.
- Will not be able to handle complex conversations.
- Will struggle with dialogues, conversations that require deeper understanding.
- 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.
- Will not ensure data privacy, users must manage and secure their data to the best of their abilities.

3.6 Competition Matrix

✔- Full Implementation
✓ - Partial Implementation

Feature	CueCode	OpenAI Functions	Google Natural Language API	Spacy.io	LangChain	GenKit	Phone AI Alexa, Siri,...
Entity recognition	✔		✔	✔		✓	✔
Plug and Play	✔				✓	✓	✓
LLM suggests action	✔	✓			✓		✓
Retrieval Augmented Generation	✔	✔			✔	✔	
Requires no LLM Expertise	✔	✔	✓	✓			✔
Natural language to perform action	✓						

4 Development Tools

Version Control:

- **Git with GitHub**
  Git will be our version control system, and we'll use GitHub repositories to manage branches, collaborate with team members, and monitor changes as they happen during the development process.

Integrated Development Environment (IDE):

- **VS Code**
  Our main tool for creating and managing code will be Visual Studio Code (VS Code), because of its flexibility and support for many languages and extensions.

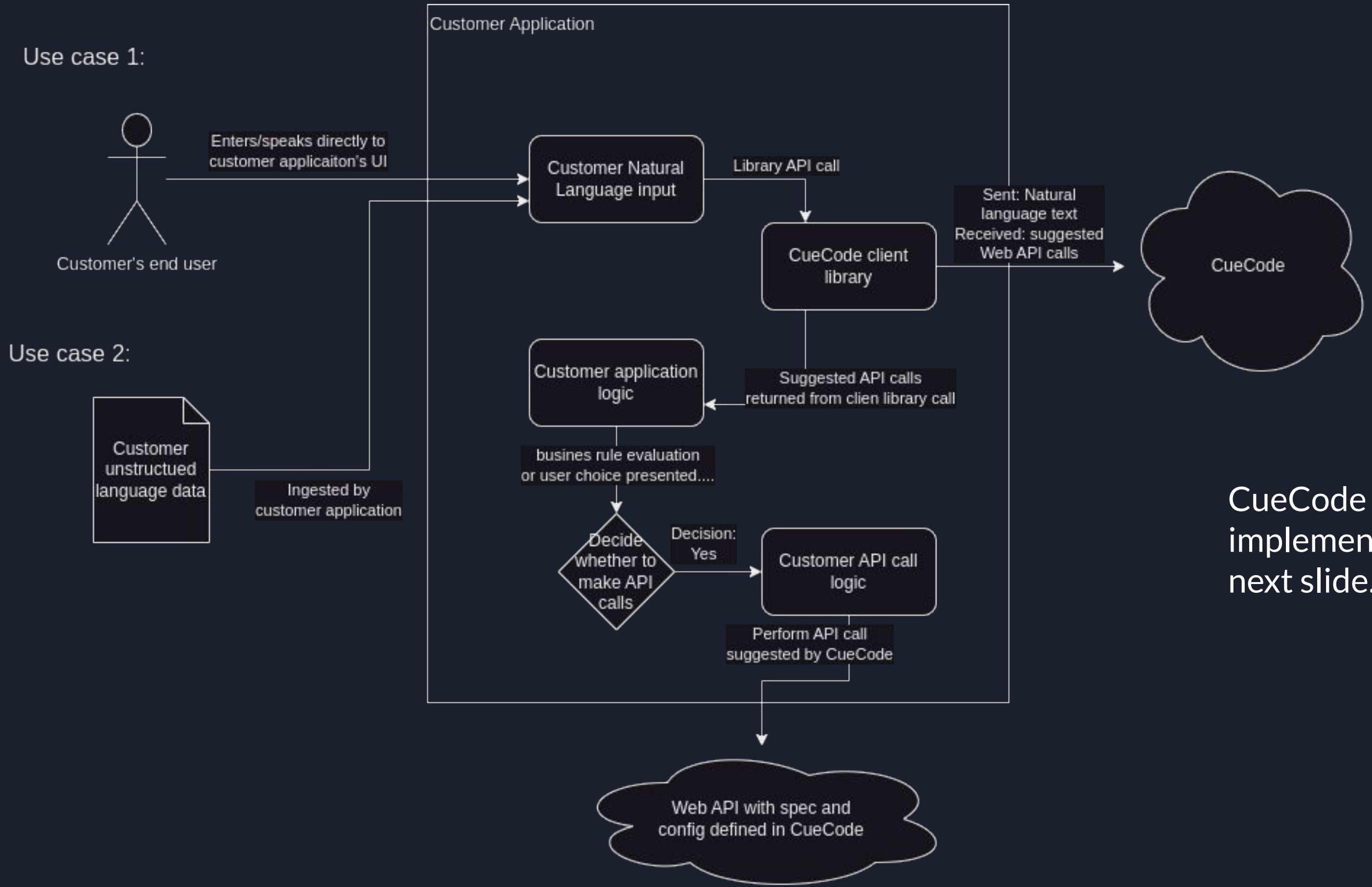
Continuous Integration (CI) & Continuous Deployment (CD):

- **GitHub Actions and Workflows**
  We will use GitHub Actions and Workflows for automated testing and deployment, ensuring code is continuously combined, tested, and deployed in an efficient manner.

5 Major Functional Components

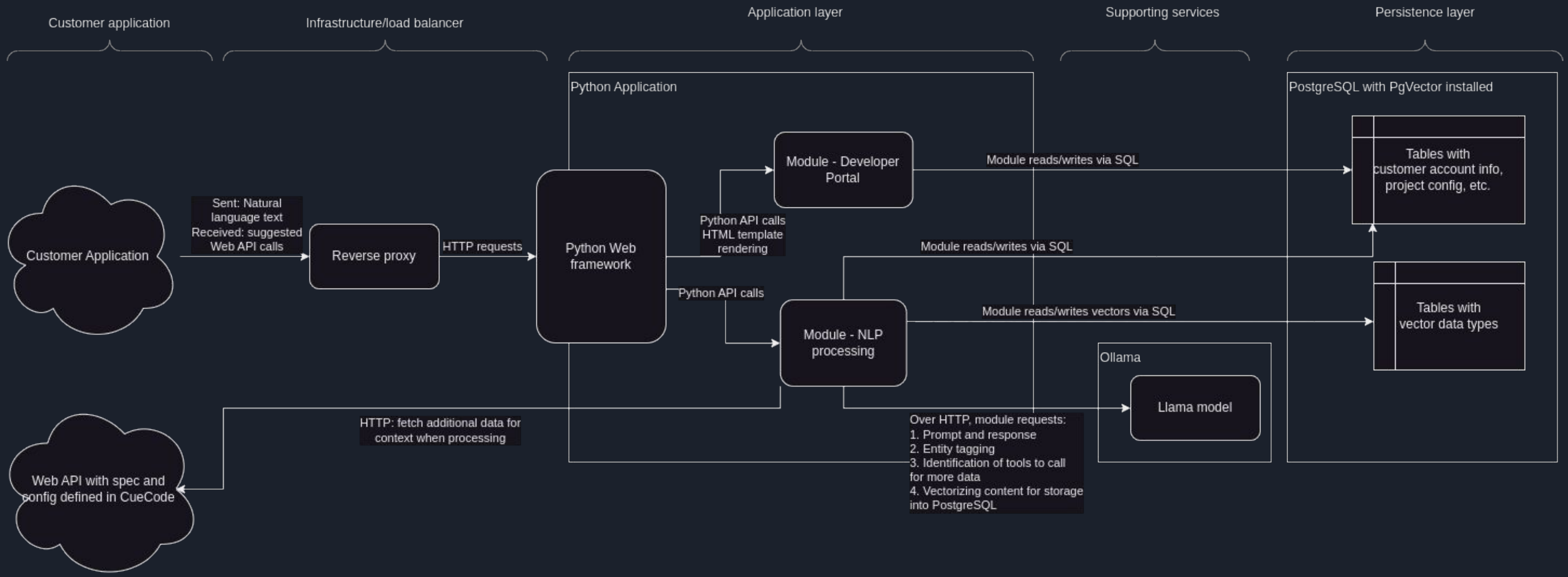
- Client libraries for customers to use for integrating with CueCode’s service
- Python modular monolith:
  - All modules exposed via Flask, a Python Web framework
  - Module: Python NLP API - receives natural language input and generates Web API calls from it.
  - Module: Developer Portal - account registration/management, API spec upload, configuration, generation audit and monitoring
  - Horizontally scalable via 12-factor app methodology
- PostgreSQL persistence:
  - PgVector extension for storing vectors generated by the LLM
  - Normal PostgreSQL tables for customer accounts, configuration, generation monitoring and audit information
- Ollama:
  - A Web service and set of standardized LLM-call APIs that standardizes running various LLMs in one service

5.1 Major Functional Components Diagram


Customer Application
Use case 1:
Enters/speaks directly to customer applicaiton's UI
Customer's end user
Customer Natural Language input
Library API call
CueCode client library
Sent: Natural language text Received: suggested Web API calls
CueCode
Use case 2:
Customer unstructued language data
Ingested by customer application
Customer application logic
Suggested API calls returned from clien library call
busines rule evaluation or user choice presented....
Decide whether to make API calls
Decision: Yes
Customer API call logic
Perform API call suggested by CueCode
Web API with spec and config defined in CueCode

CueCode implementation on next slide....

5.1 Major Functional Components Diagram


Customer application
Infrastructure/load balancer
Application layer
Supporting services
Persistence layer
Python Application
PostgreSQL with PgVector installed
Customer Application
Sent: Natural language text Received: suggested Web API calls
Reverse proxy
HTTP requests
Python Web framework
Python API calls HTML template rendering
Python API calls
Module - Developer Portal
Module reads/writes via SQL
Module reads/writes via SQL
Module - NLP processing
Module reads/writes vectors via SQL
Tables with customer account info, project config, etc.
Tables with vector data types
Ollama
Llama model
Over HTTP, module requests:
1. Prompt and response
2. Entity tagging
3. Identification of tools to call for more data
4. Vectorizing content for storage into PostgreSQL
HTTP: fetch additional data for context when processing
Web API with spec and config defined in CueCode

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
  - 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.

Probability

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

Consequences

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

Probability

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

Consequences

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.

Probability

Very likely (5)				T3	
Likely (4)			T4		
Possible (3)		T7	T5	**T1**	
Unlikely (2)		R2', **T1', T2'**	T6	**T2**	
Rare (1)		O2', R1'		O1'	
	(1) Insignifican t	(2) Minor	(3) Moderate	(4) Significant	(5) Catastrophi c

Consequences

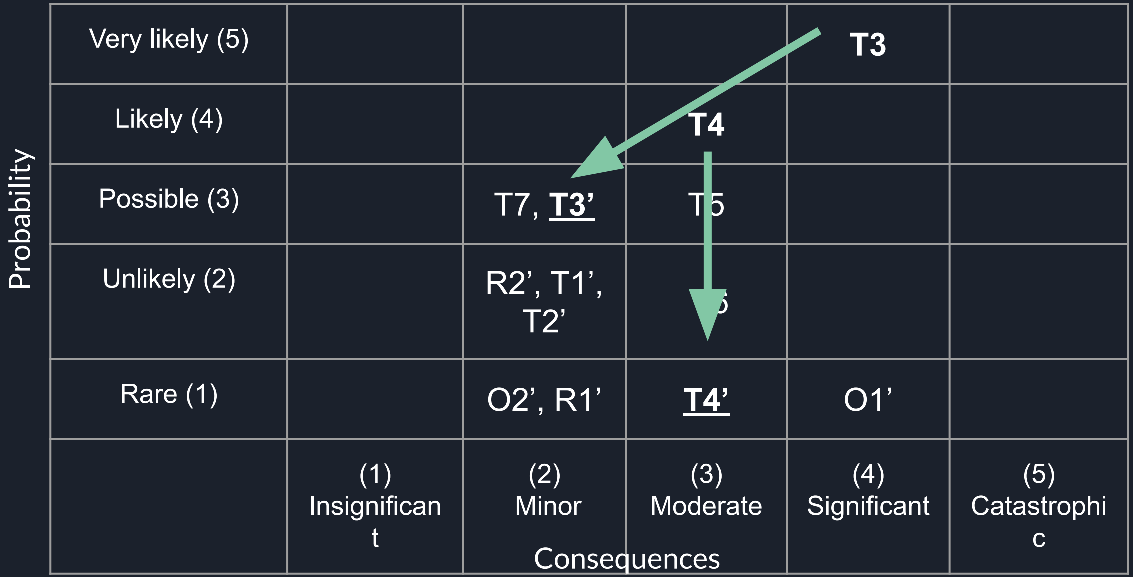
6 Risks - Technical

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.



Probability

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

Consequences

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.

Probability

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

Consequences

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.

Probability

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

Consequences

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’, <u>**T7’**</u>	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

7 References

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7 References

8 Appendix

8.1 Real World Product vs Prototype Table

Not in scope for Feasibility iteration 1.

That said, we will likely implement CueCode for OpenAPI specs but not GraphQL specs.