UVA DATA SCIENCE

Applications Of Large Language Models

Applications of LLMs

Are you trying to learn a new language but wish you had a 24/7 tutor?

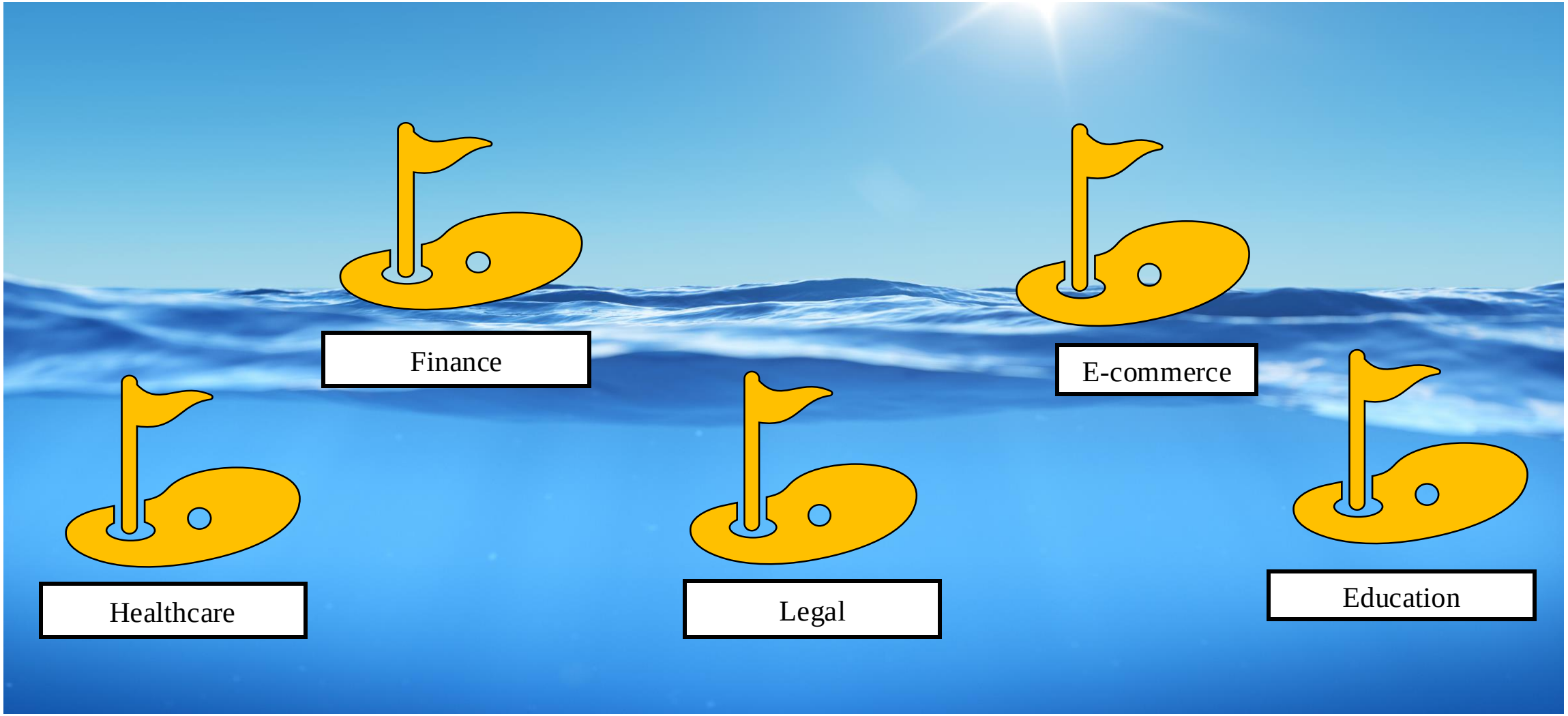
How will you feel if there is a technology that can be integrated into systems to help you perform these task?

Do you need a quick answer to a question but don’t want to sift through endless web pages?

Large Language Models (LLMs) are transforming how we work, learn, and communicate. Let's explore!!

Staring at a blank screen, struggling to describe an image or write an email?

Application of LLMs



Specific applications to cover

- Cybersecurity
- Language Translation
- Chatbots
- Gaming
- Healthcare and Biology
- Mathematics
- Computer science and engineering
- Using LLM to direct a robot digit

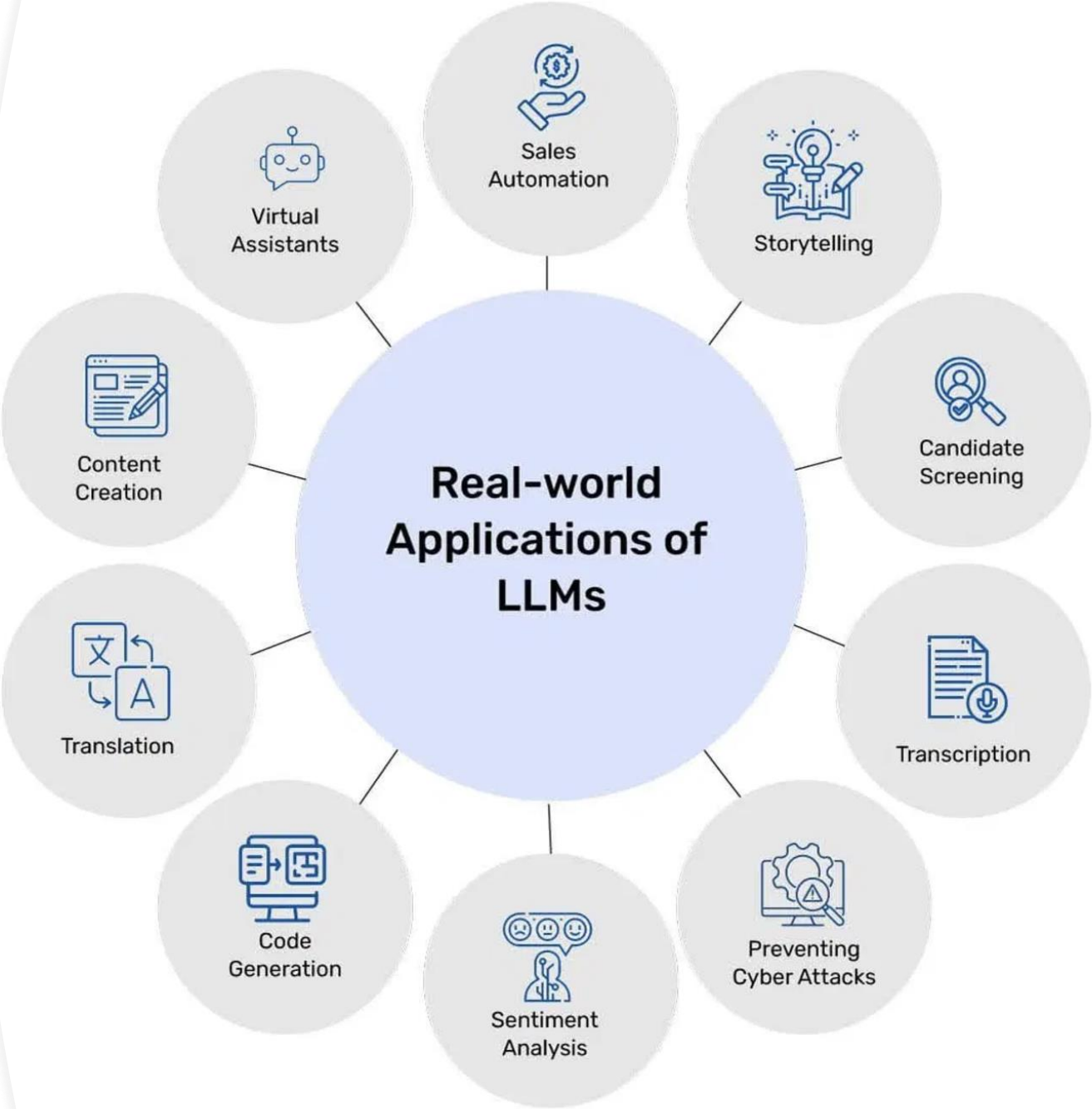
Inspiring Application: Using an LLM to direct a robot Digit

video

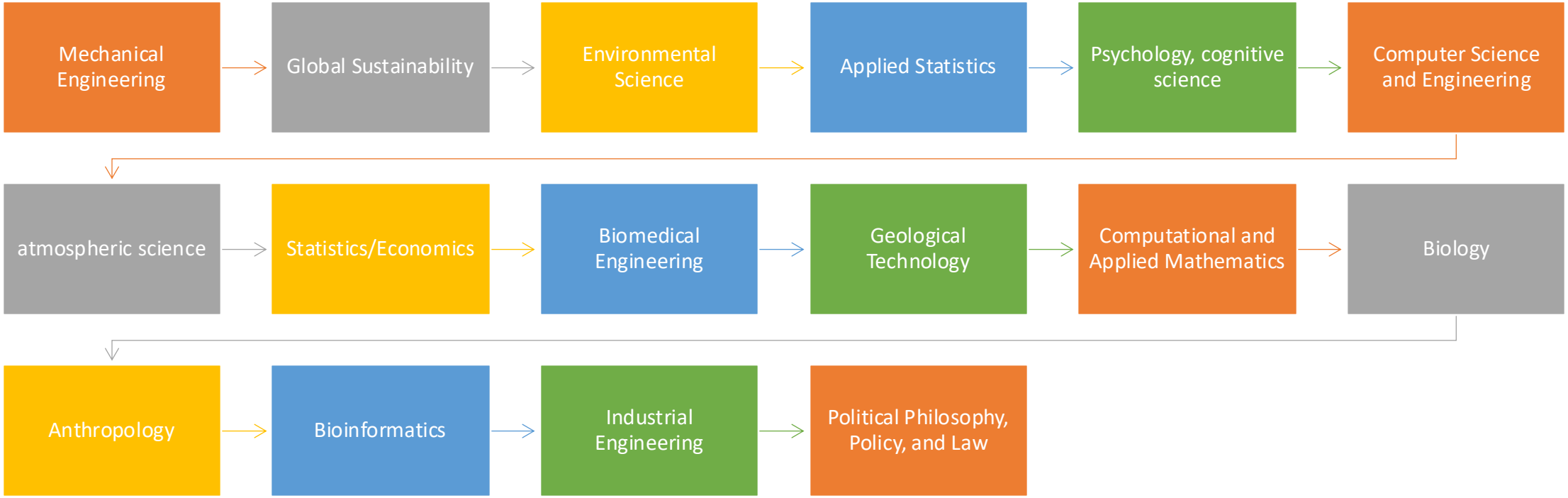
- **link: https://www.youtube.com/watch?v=CnkM0AecxYA**

What do we mean?

Application of LLMs can be defined as the practical use or implementation of LLMs in solving real-world problems or performing specific tasks.



Field of study Applications



Conversations with game characters

another video:

Link: https://www.youtube.com/watch?v=-R4PWIkgOSk

Application to cybersecurity

Cybersecurity is the practice of protecting computers, networks, programs, and data from unauthorized access, attacks, damage, or theft

LLMs in Cybersecurity?

HOW?

1. **Automated Threat Analysis:** Processing large volumes of textual data (like security logs and threat reports) to detect anomalies.
2. **Incident Response Assistance:** Generating natural language summaries and recommendations to support cybersecurity analysts.
3. **Enhanced Communication:** Bridging the gap between technical security data and human interpretation.

WHY?

1. Detect vulnerabilities weak spots we assess in networ
2. Analyze malware software that causes it not to function properly
3. Respond to attacks

Application to Cybersecurity

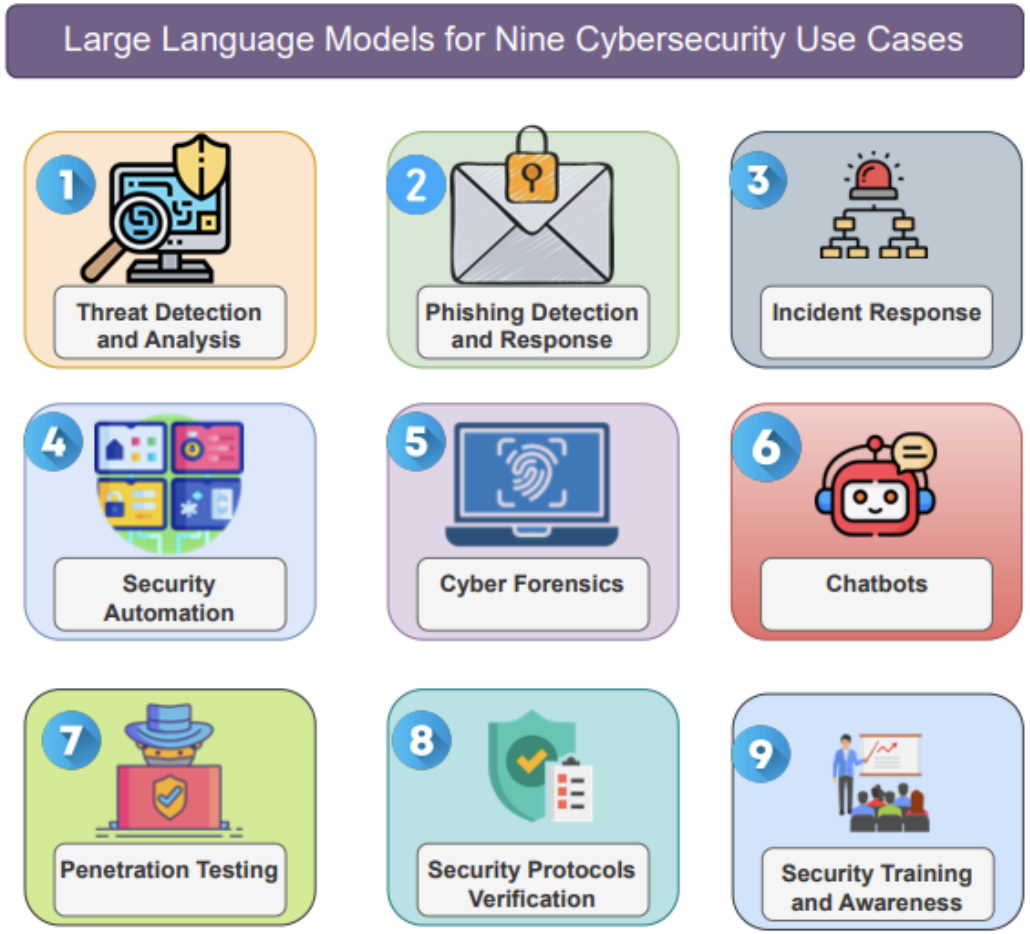


Fig. 1: LLM Use Cases And Applications for Cybersecurity.

Ensuring network security with LLMs

attackers might attack cars systems like bluetooth, etc

CAN-BERT do it? Controller Area Network Intrusion Detection System based on BERT Language Model

Natasha Alkhatib, Maria Mushtaq, Hadi Ghauch, Jean-Luc Danger
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Can id= info transmitted

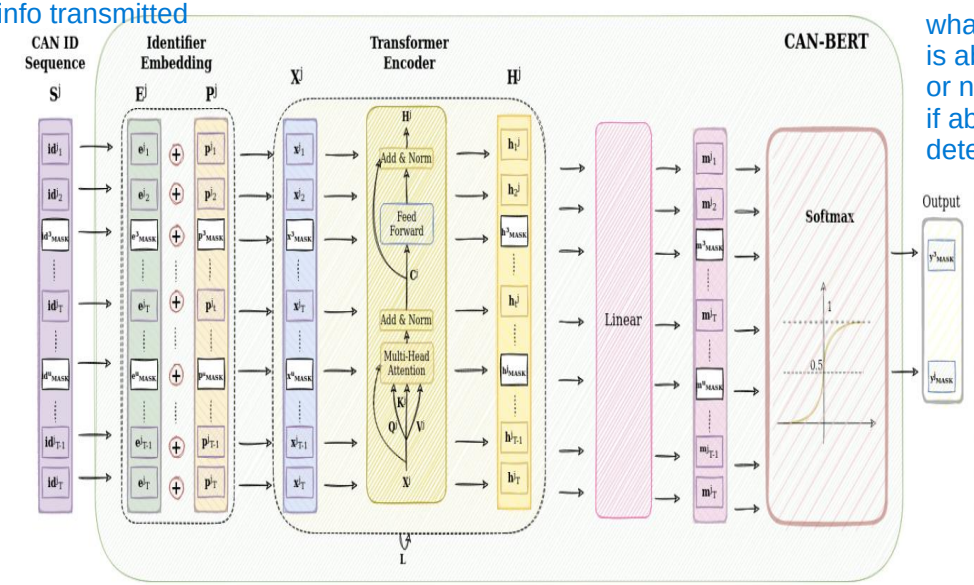
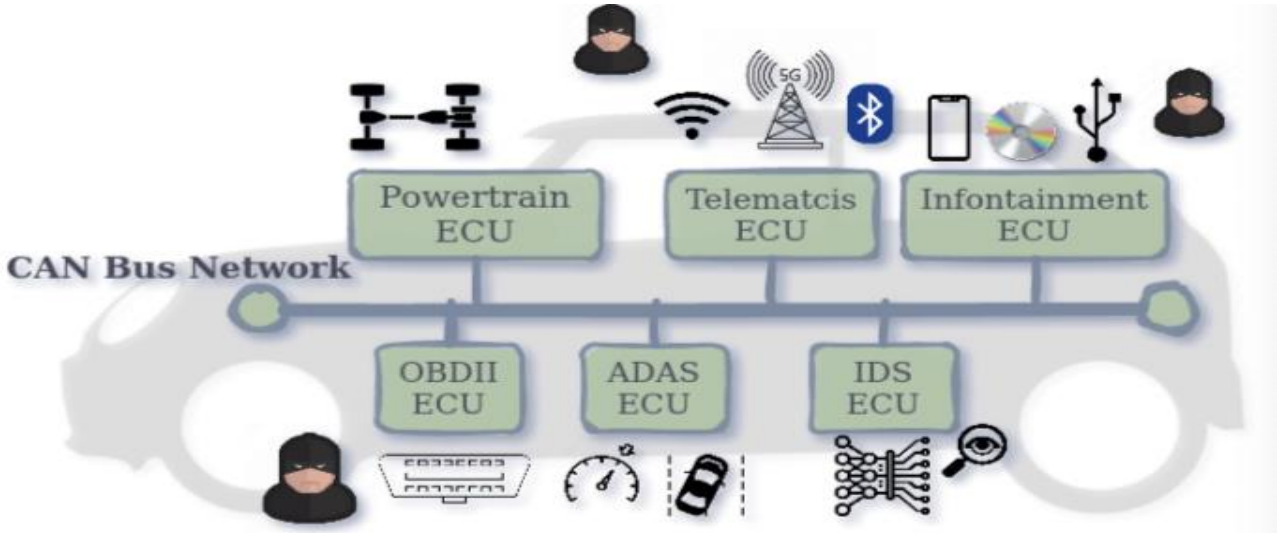


Fig. 4. CAN-BERT model architecture

what is info
is abnormal
or normal
if abnormal, can
detect



control arial network?

Fig. 1. A CAN bus network exploited by attackers through different physical and wireless interfaces.

- **Powertrain ECU** – Controls engine and transmission functions for vehicle performance.
- **Telematics ECU** – Manages wireless communications, including GPS, 5G, and Wi-Fi.
- **Infotainment ECU** – Handles media, navigation, and user interfaces like Bluetooth and USB.
- **OBDII ECU** – Provides diagnostic data and access to vehicle systems for monitoring.
- **ADAS ECU** – Supports advanced driver-assistance systems like lane-keeping and collision avoidance.
- **IDS ECU** – Monitors for cybersecurity threats and intrusion detection in the vehicle network.

It does not perform well on attacks it has not seen
The point is to make the detection of seen attacks faster- is very slow now

if info passed thru has

LLM in Cybersecurity

Towards Large Language Model (LLM) Forensics Using LLM-based Invocation Log Analysis

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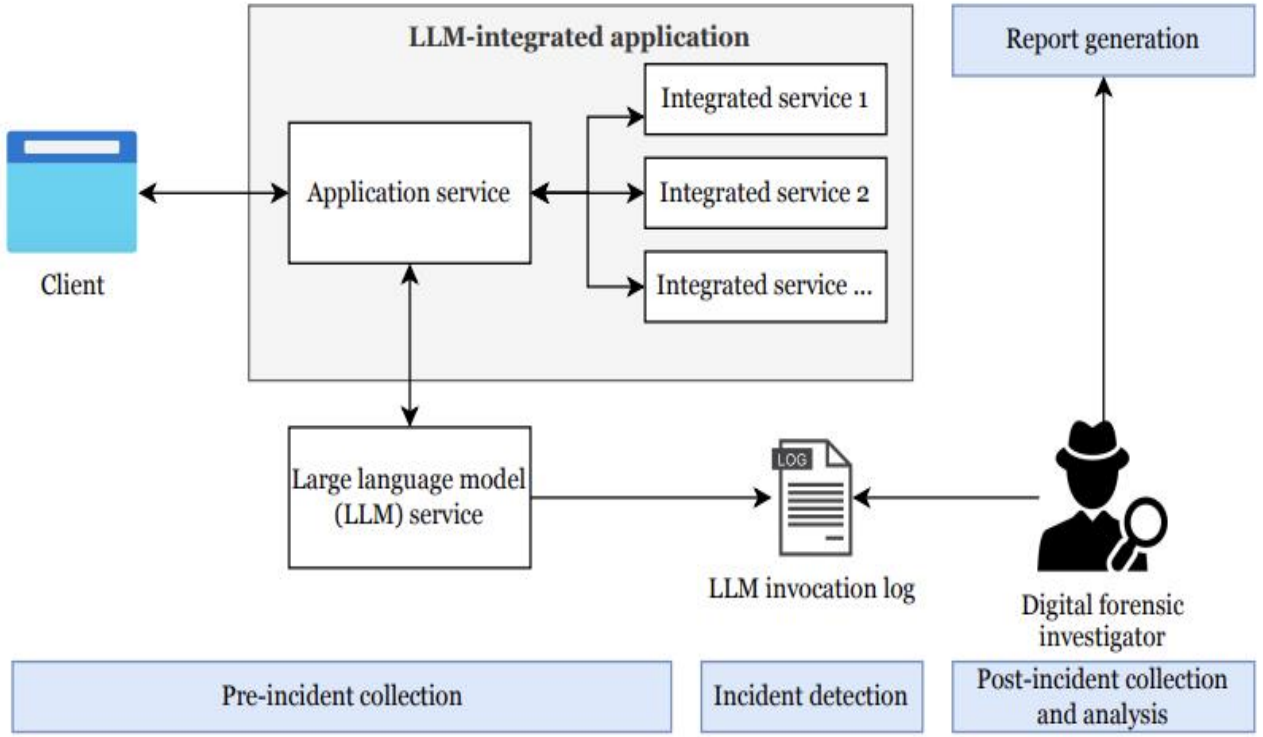

Figure 2: Large language model (LLM) invocation logging as part of digital forensic readiness and process model.

Towards Large Language Model (LLM) Forensics Using LLM-based Invocation Log Analysis

- The diagram outlines the pipeline for LLM forensic readiness, starting with attack and benign use cases processed by a scenario engine and the LLM-integrated application
- LLM invocation logs are collected and analyzed using LLM-powered forensic tools to identify security incidents
- The forensic process evaluates LLM interactions to produce actionable results, supporting incident detection and analysis

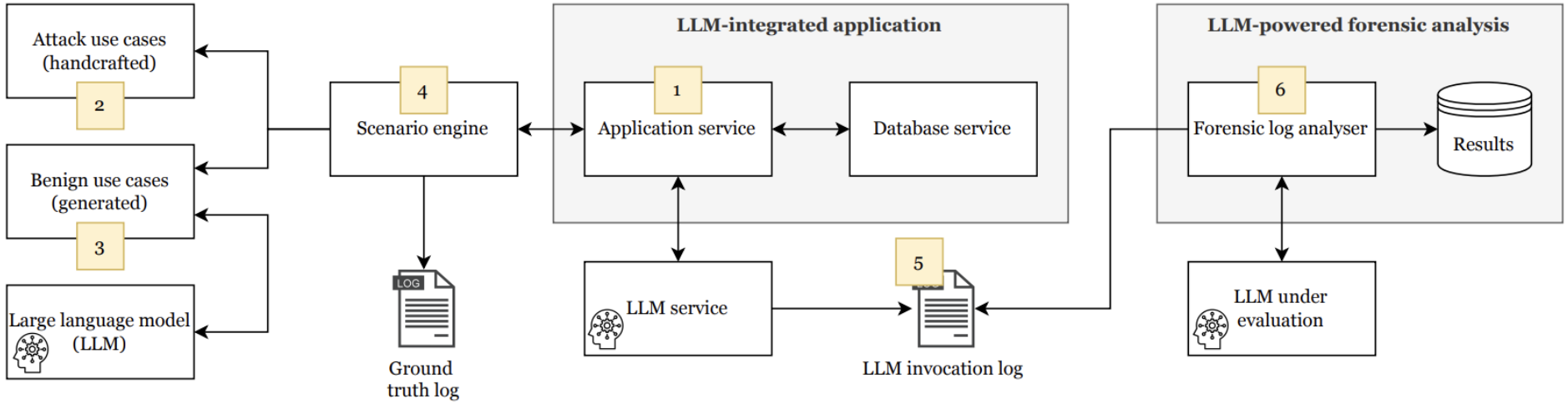

Figure 3: Large language model (LLM) invocation logging as part of digital forensic readiness and process model.

LLMs for language translation

this lady was a previous ceo of open ai and now left and made her own startup

Link: https://www.youtube.com/watch?v=c2DFg53Zhvw

LLM for language translation

- Classic application of multimodal LLM- train an encoder on that mode (eg. audio)

this generates the output

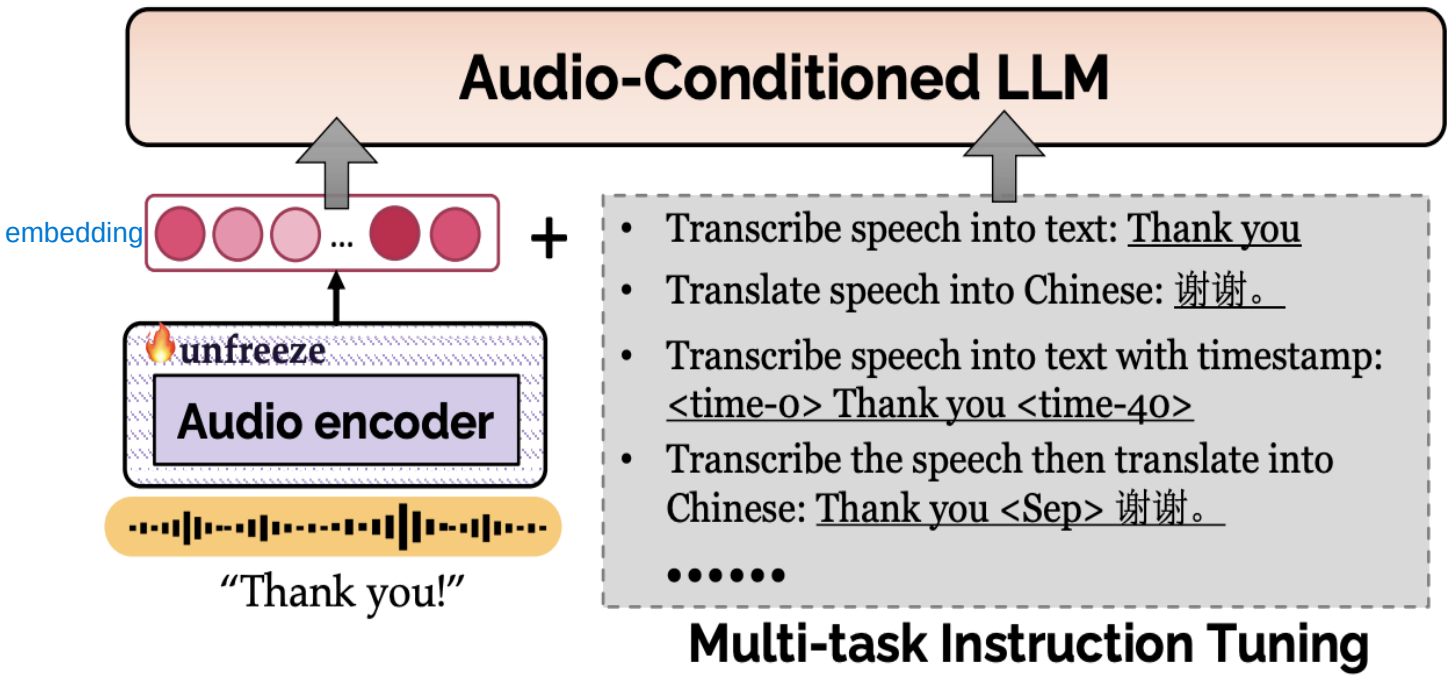

Figure 1: Framework of LLM-ST.

Speech Translation with Large Language Models: An Industrial Practice

Zhichao Huang, Rong Ye, Tom Ko, Qianqian Dong, Shanbo Cheng, Mingxuan Wang, Hang Li

ByteDance
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This encoder takes the audio bits, it does not transform to language first and then translate. It directly translates from audio bits

LLMs in chatbot systems

Building task-oriented chatbots using traditional intent-based methods is complex, labor-intensive, and often produces rigid, less natural conversations.

The authors propose a declarative approach leveraging LLMs to enable engaging, flexible interactions.

Automating the Development of Task-oriented LLM-based Chatbots

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Link: https://dl.acm.org/doi/pdf/10.1145/3640794.3665538

LLMs in chatbot systems

Air canada used LLMs in website- hallucinated rules, customer acted upon them and customer sued air canada (applications are not finished, tons of problems with them)

The diagram illustrates a modular chatbot framework where developers define chatbot behavior and configuration using structured YAML modules.

The interpreter parses these modules into structured prompts, interacting with LLMs (e.g., GPT-4, Llama2) to generate conversational responses.

The system maintains conversation memory to ensure contextual and dynamic interactions with the user.

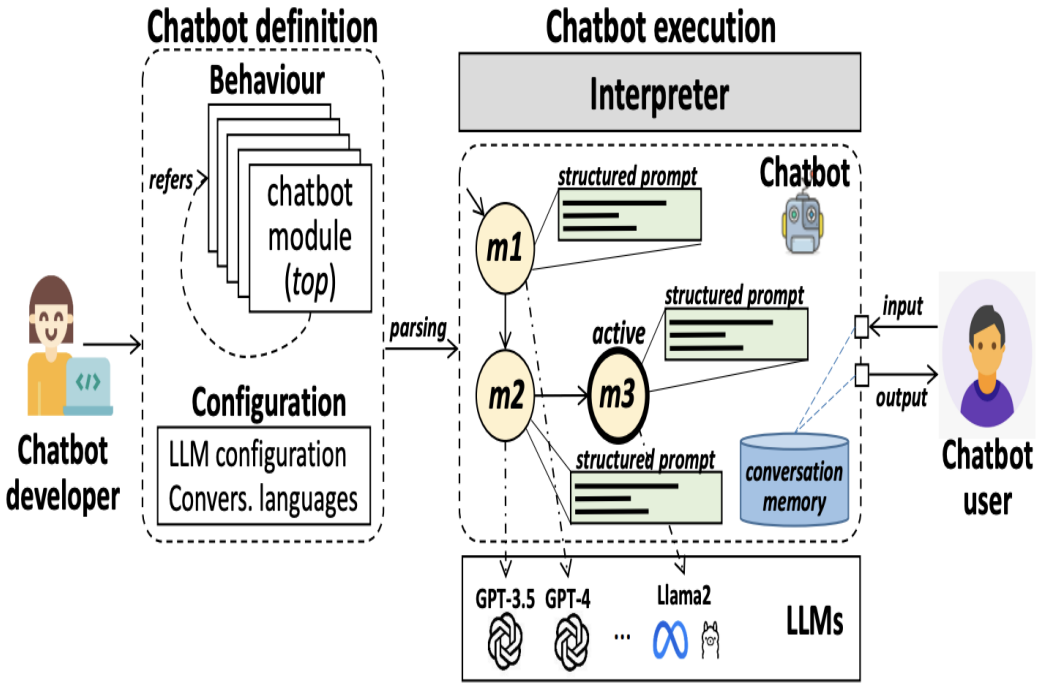


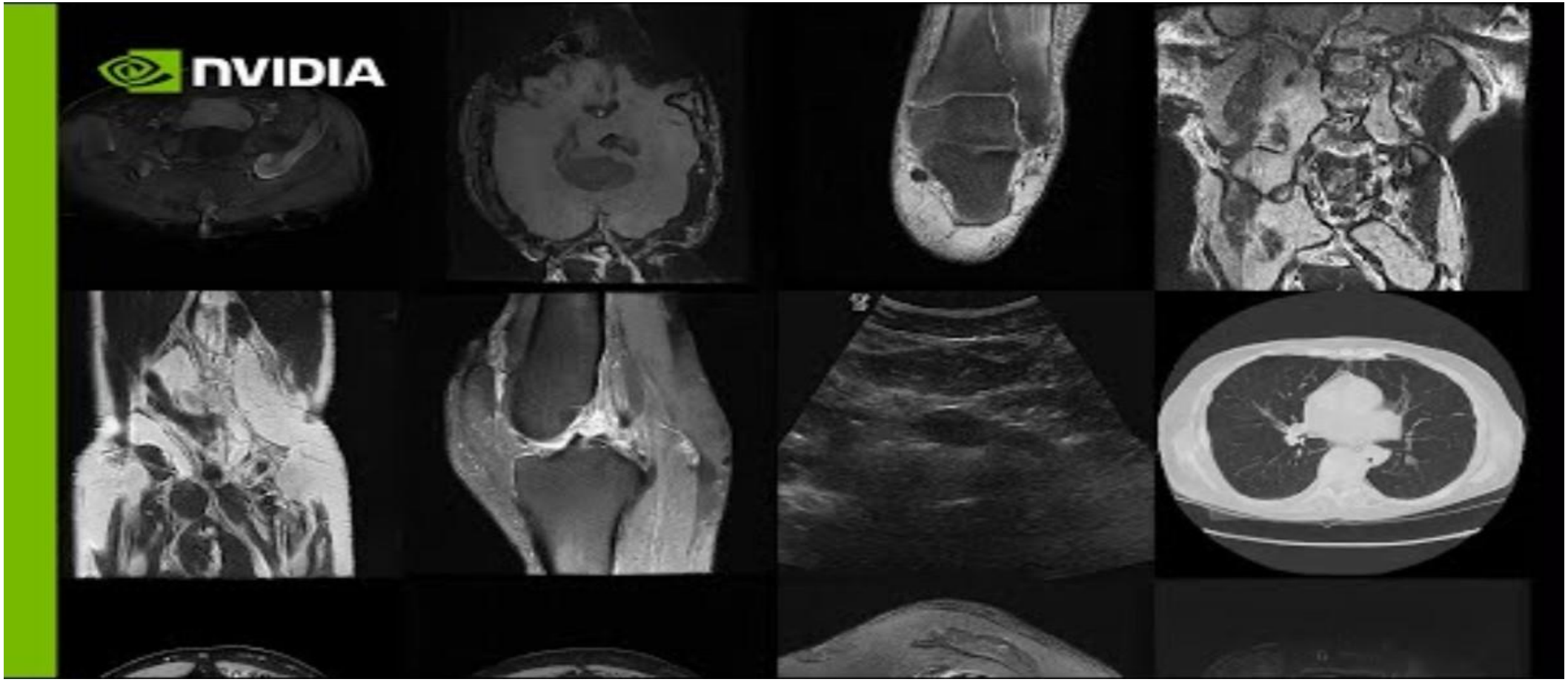
Figure 2: Overview of our approach.

Application of LLMs in healthcare

patient notes, guiding directionally,
therapy notes, image detection, intraoperative guidance,
nurses assistant (below image)

Application of LLM in healthcare

Generating images
Latent diffusion model- helping make synthetic medical images of human anatomy
RadImage GAN- medical imaging model



Applications of LLMs in Healthcare

Recent Advances in Large Language Models for Healthcare

by Khalid Nassiri and Moulay A. Akhloufi *

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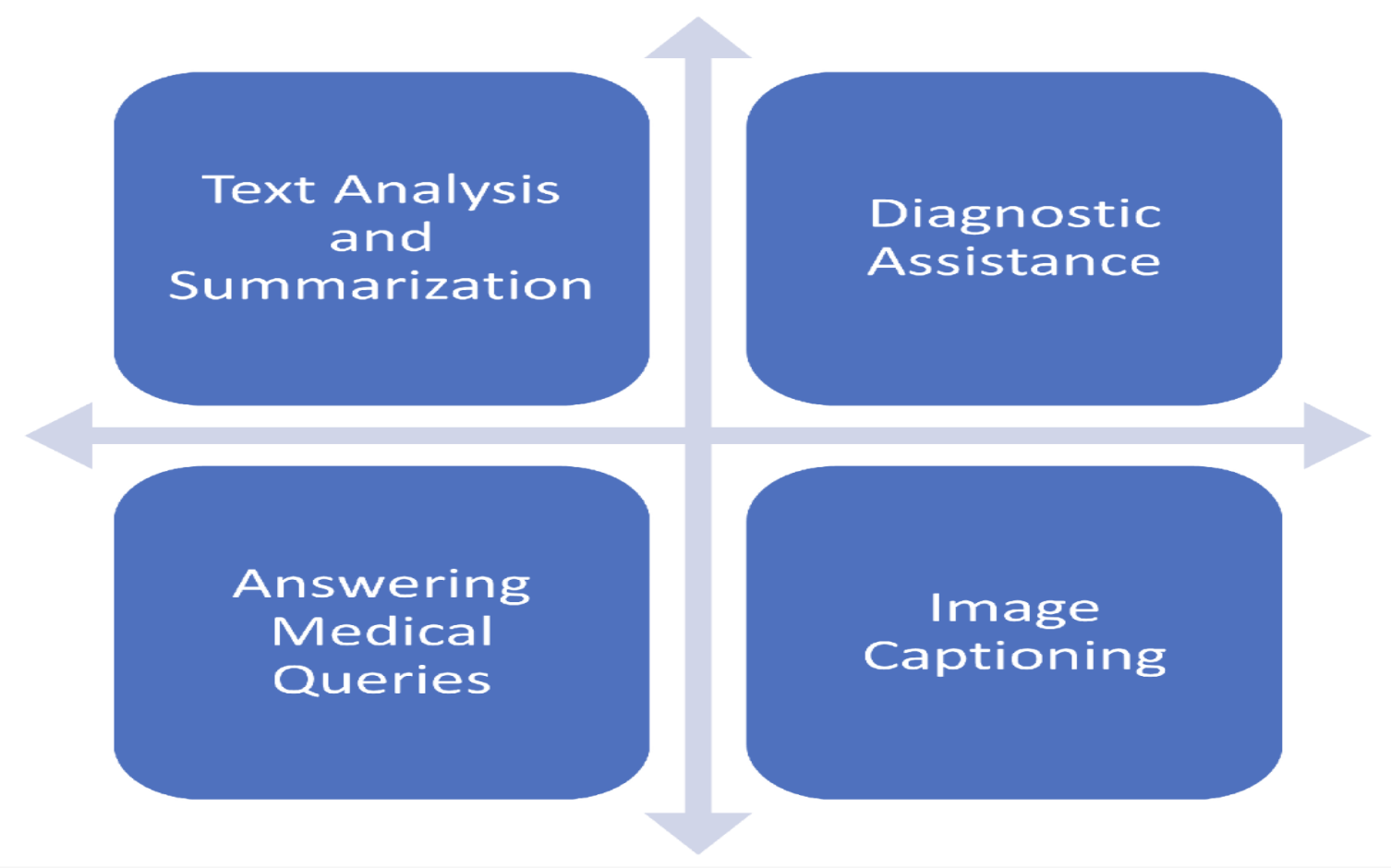
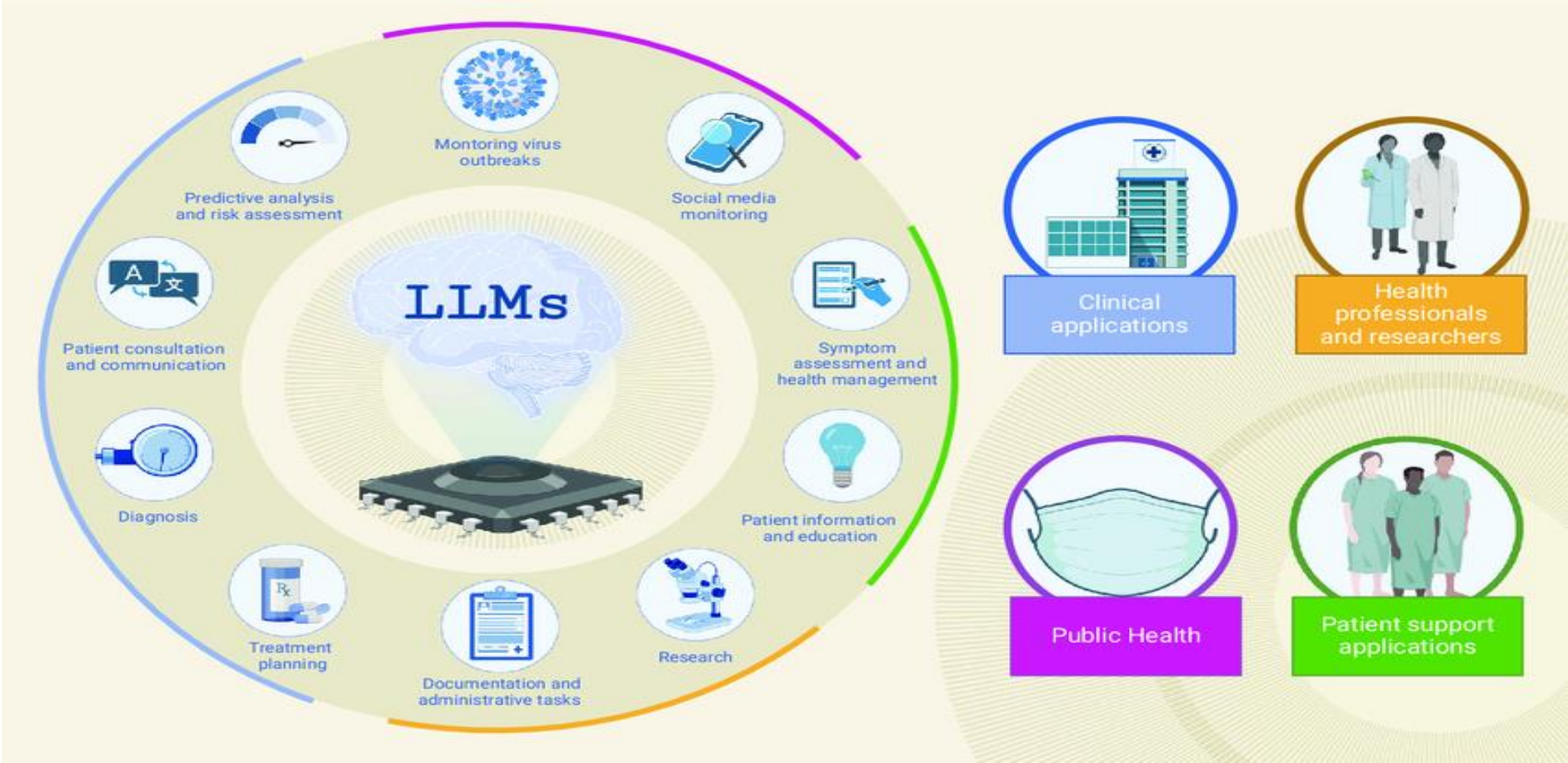
* Author to whom correspondence should be addressed.

Figure 5. Applications of transformer-based LLMs in healthcare.



LLMs in medicine and healthcare



LLM for Protein-Protein Interaction prediction

graph models built these

- cells, organs, etc could be nodes
- graph neural networks were used

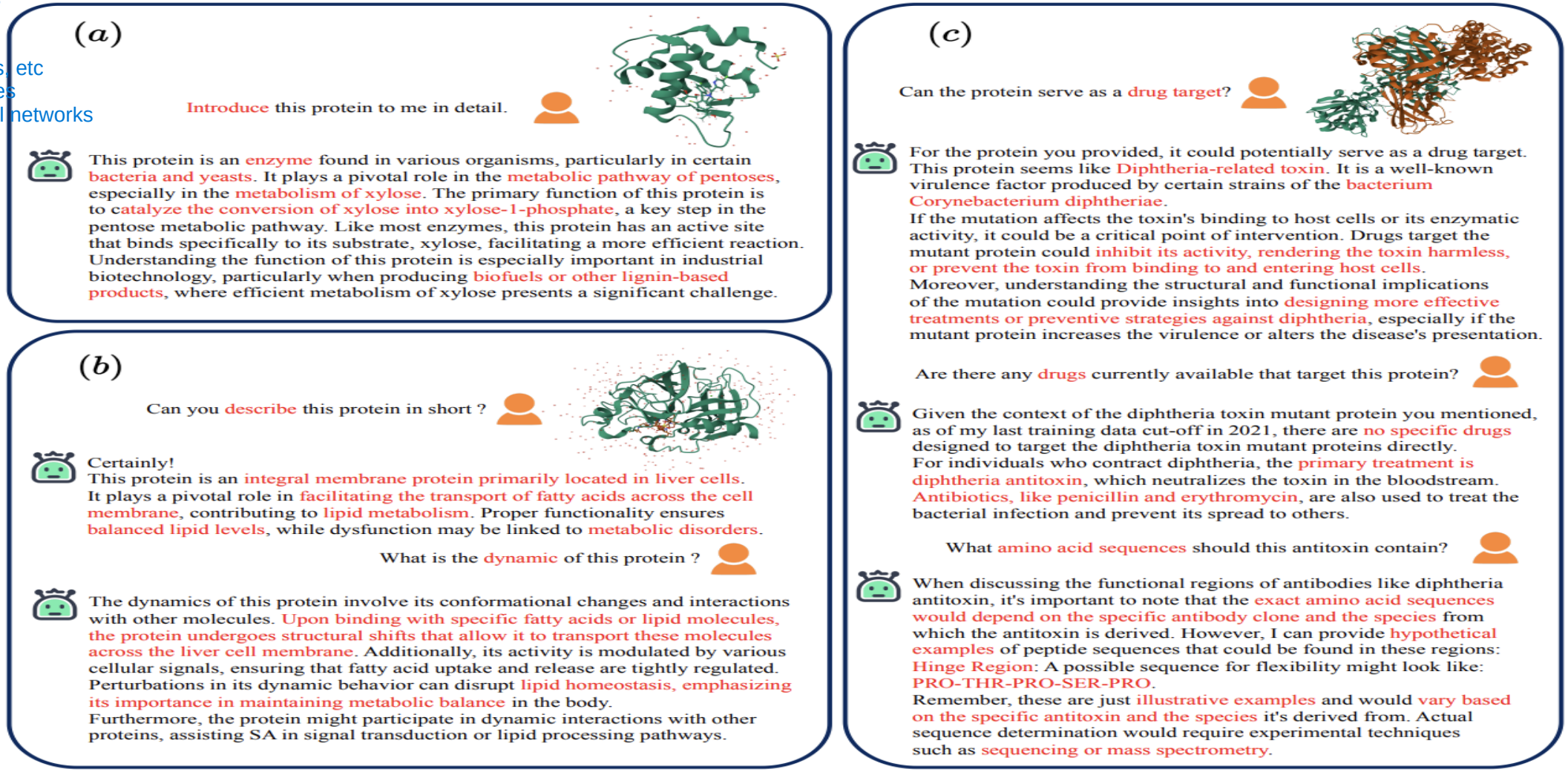


Figure 3. Dialogue examples of ProtChatGPT for protein understanding and analysis (a, b) as well as customized protein design (c) tasks.

deep mind alpha fold
- able to predict protein structure designs

won nobel prize in chemistry

khanmigo

Application of LLM in Mathematics

Application of LLM in Mathematics

- The study explores the potential of Large Language Models (LLMs) like GPT-3 in supporting elementary math
- Various prompting methods are tested to provide multi-step conceptual explanations for math topics aligned with the Khan Academy curriculum.
- A conversational virtual assistant, MathyAI, is developed to benchmark prompting methods and improve elementary math learning.
- Preliminary user studies evaluate the system's effectiveness, focusing on its educational application rather than merely solving math problems.

MathyAI: An LLM-based Educational Virtual Assistant Application for Elementary Math Education

CS 224V: Conversational Virtual Assistants with Deep Learning

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December 23, 2022

Abstract

In this work, we explore the potential of Large Language Models (LLMs) in supporting elementary math education. First, we experiment with various ways of prompting an LLM, in this case GPT-3, to provide a multi-step conceptual explanation to various math topics in the elementary math curriculum from Khan Academy. We benchmark the various prompting methods explored. Second, with those findings we build an original system: an elementary math conversational virtual assistant we call MathyAI. Finally, we conduct preliminary user studies of the system to analyze how it could be improved. While our project touches on related research of using LLMs to solve math problems, our focus was primarily on the potential educational application of it.

All **code** can be found here for the data processing repository and here for the user-facing system repository. A **demo** of the system can be watched here.

Link here: https://priscillazhao9.github.io/224V.pdf

Application of LLM in Mathematics

Q: "Write an expression to represent: Eight more than the product of two and a number x."

A: $8 + 2x$

(a) Standard (baseline) which consists of zero-shot prompting. This serves as our baseline when experimenting with various prompting methods.

Here is a math question: "Write an expression to represent: Eight more than the product of two and a number x."

What concepts can we use to solve this?

We can use the concepts of addition and multiplication to solve this.

How can we approach this problem?

We can start by looking at what we know. We know that the expression represents the result of adding eight to the product of two and some number x. This gives us a good starting point. We can see that the expression involves adding eight to the product of two and some number x.

How would you solve this?

The expression would be: $8 + 2x$

(b) ConceptChain is our prompting method to prompt for various conceptual steps in a math problem and the answer all the way at the end. Visualized is the complete chain conversation.

Here is a math question: "Write an expression to represent: One more than the quotient of a number x and 4."

What concepts would you use to solve this? Think step by step.

Step 1: What is the problem asking for? In this problem, you are being asked to write an expression that represents "two more than the quotient of a number x and 3."
Step 2: What is the quotient of a number x and 3? The quotient of a number x and 3 is the number of times that 3 goes into x, or x divided by 3.
Step 3: How do you represent "two more than" in an expression? In an expression, you can represent "two more than" by adding 2 to a number.
Step 4: Putting it all together, the expression that represents "two more than the quotient of a number x and 3" is $2 + \frac{x}{3}$.

(c) ConceptChain + "Think Step by Step" method. A variation to our ConceptChain prompting method, which prompts for concepts to solve the problem but also has the appended phrase "think step by step".

Q: "Write an expression to represent: Three minus the product of two and a number x."

A: If we subtract $2x$ from 3, we have $3-2x$. So the answer is $3-2x$.

Q: "Write an expression to represent: Nine more than the quotient of two and a number x."

A: If we add 9 to $\frac{2}{x}$, we have $\frac{2}{x}+9$. So the answer is $\frac{2}{x}+9$.

(d) This is Chain of Thought (CoT) prompting, where the pink highlight indicates the manually added thought chain.

Figure 1: All the four prompting methods described in Section 3.3 using questions from the Writing Expressions module of the Khan Academy Dataset. Green highlight indicates GPT-3's output. Pink highlight indicates the manually added CoT – only present in (d).

Applications of LLMs in Finance

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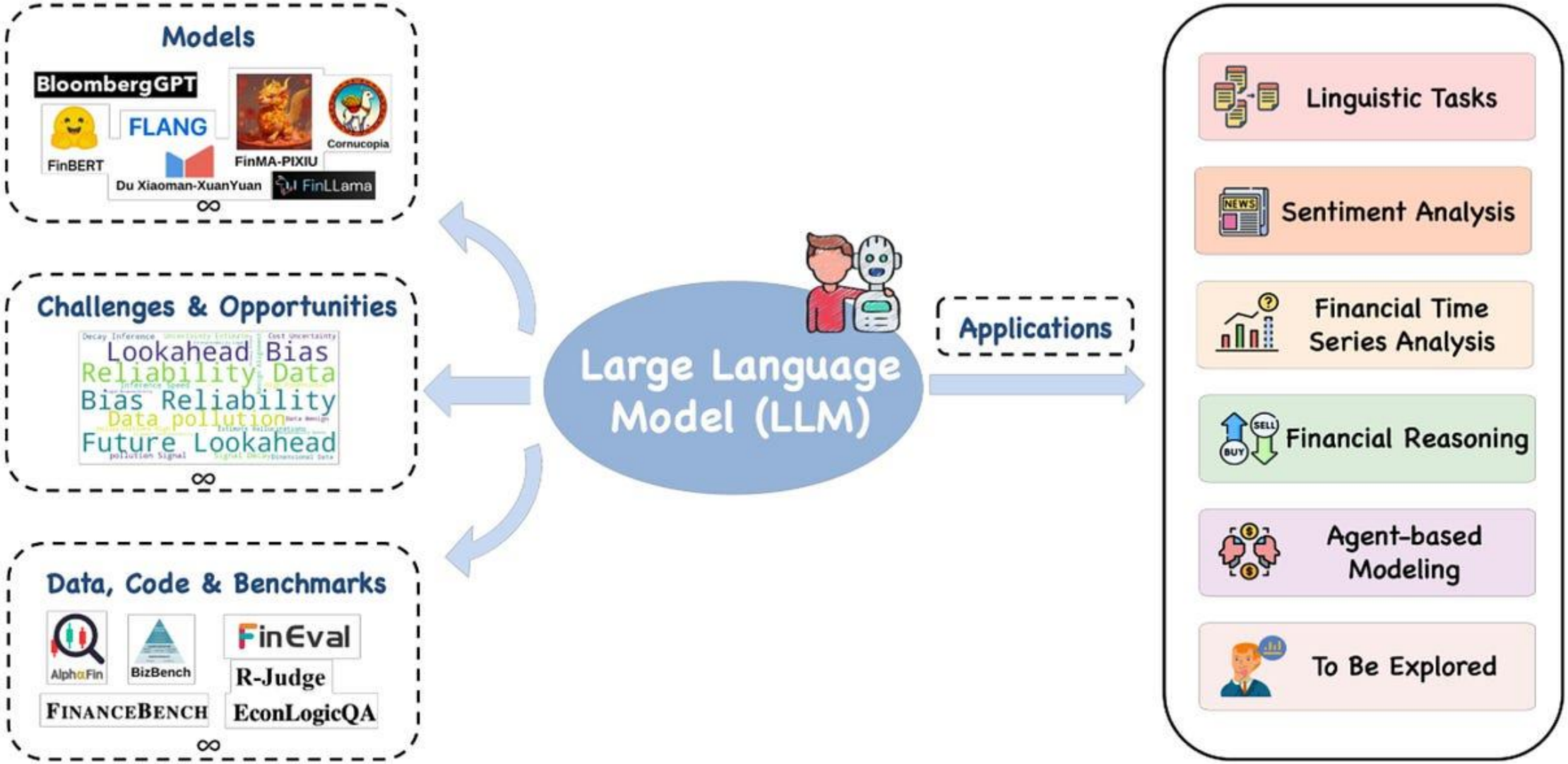

LLM in Finance

Enhancing Financial Sentiment Analysis via Retrieval Augmented Large Language Model

RAG

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Pulls from these sources

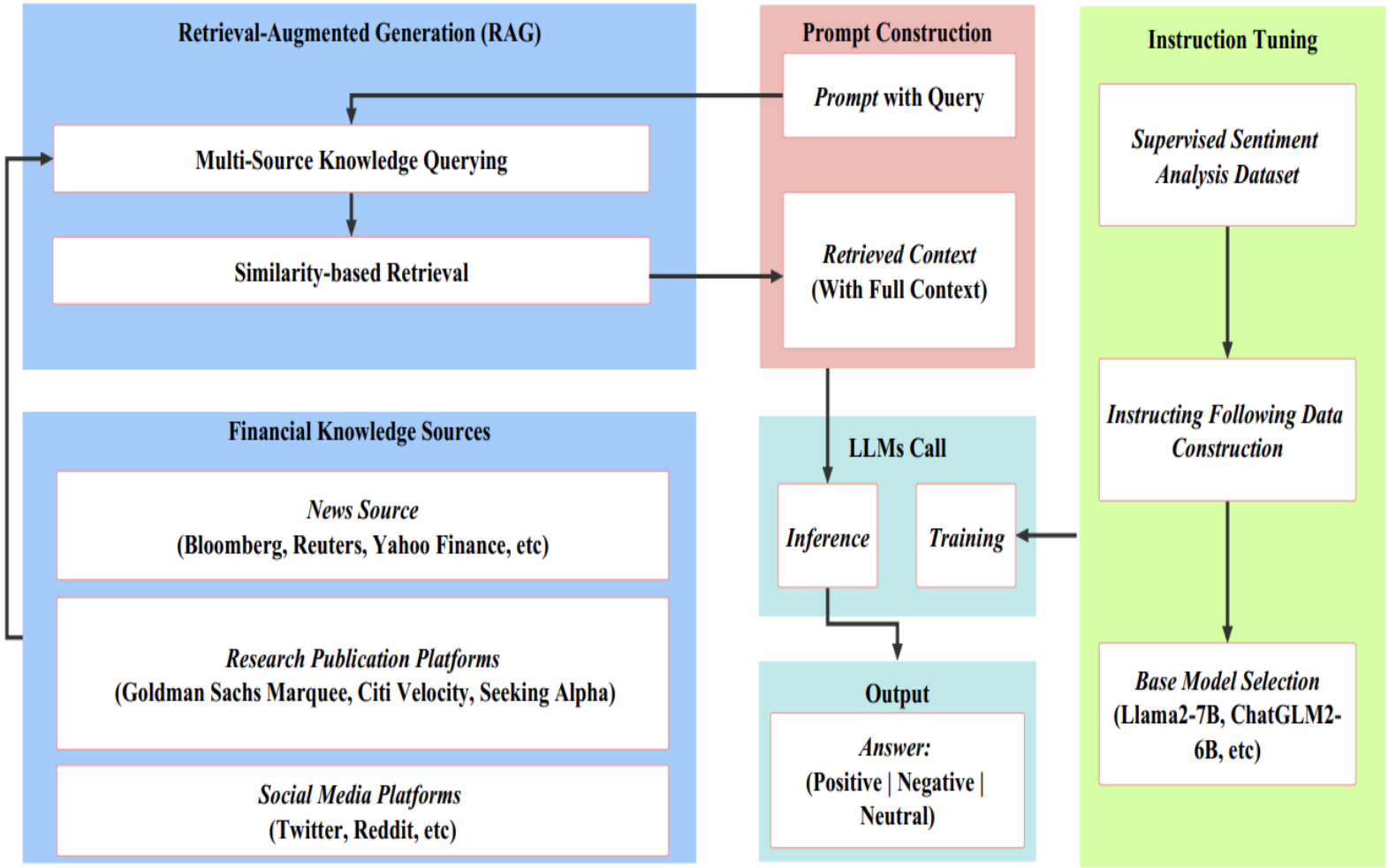

Figure 1: Framework of retrieval-augmented large language model for financial sentiment analysis.

LLM in Finance

TIME SERIES ANALYSIS

Temporal Data Meets LLM - Explainable Financial Time Series Forecasting

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Prompt: Generate a short description for stock AAPL' s company. Also list general positive and negative factors that might impact the stock price; be brief and use keywords. Consider diverse general factors, such as macro economic situation (e.g. inflation, CPI growth), business factors (e.g. sales, investment, products), technology factors (e.g. innovation), and others. Use format Description: ..., Positive Factors: ..., Negative factors: ...

GPT-4 Response:

Description:

AAPL (Apple Inc.) is a world-renowned technology company based in Cupertino, California. Known for its sleek designs and innovative technologies, the company produces a wide range of products including the iPhone, iPad, Mac, Apple Watch, and services like iCloud, App Store, and more.

Positive Factors:

Macroeconomic: Economic growth, increased consumer spending
Business: Strong sales, expansion into new markets, positive earnings reports, strategic acquisitions
Technology: Innovation, new product launches, advancements in artificial intelligence and augmented reality
Brand: Strong global brand, loyal customer base
Legal/Regulatory: Favorable policy changes, successful patent applications

Negative Factors:

Macroeconomic: Inflation, economic downturn, trade restrictions
Business: Decreased sales, poor earnings reports, lack of new investments
Technology: Slow pace of innovation, delays in product launches
Brand: Damage to brand reputation, loss of customer loyalty
Legal/Regulatory: Antitrust investigations, unfavorable policy changes, patent disputes
Environmental: Failure to meet sustainability goals, negative environmental impact

Figure 1: An example of a stock's company profile consisting of the company description, the general positive/negative factors impacting the company's stock prices.

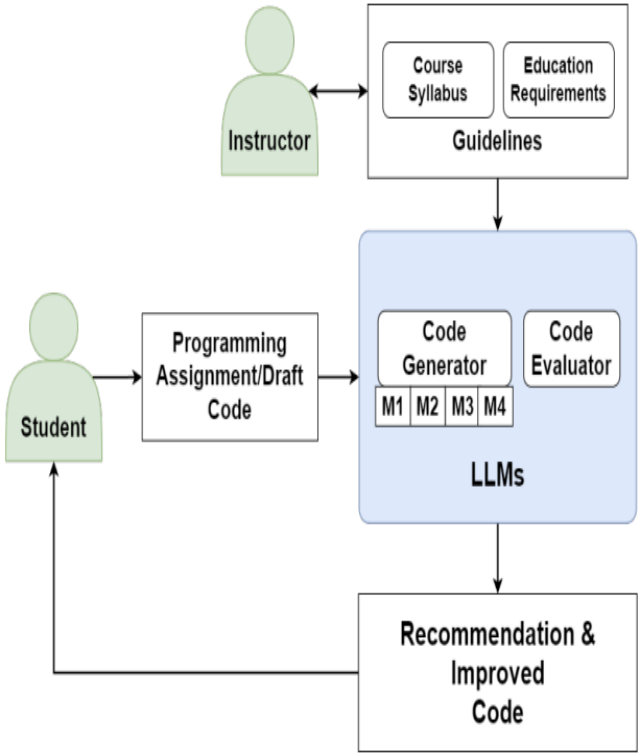
Application of LLM in computer science and engineering

The instructor provides course requirements and educational standards that guide the code generation process

The student supplies an initial programming assignment or draft code to be improved.

LLM acting as both code generators and evaluators, apply instructor guidelines to refine, correct, and enhance the student's draft code.

The system returns improved code recommendations for the student to review, learn from, and incorporate into their final solution



Application of LLM to Psychology and cognitive science

They can assist in analyzing mental health data and identifying factors influencing behavior.

LLMs can help find patterns in qualitative research data and suggest new hypotheses about human cognition.

Diff kinds of behaviors from patients=>

By simulating conversational scenarios, LLMs can support counseling exercises and training.

Some LLMs for conducting research- pulls articles related to your kind of research

LLMs can streamline literature reviews and synthesize findings for cognitive science research.

Inspiring Application: LLM application for robot digit control

- link:https://www.youtube.com/watch?v=Vq_DcZ_xc_E

Application of LLM to computer vision

- The paper explores the use of Large Language Models (LLMs) for zero-shot anomaly detection to enhance safe visual navigation.
- A framework combining the Yolo-World object detection model and LLMs identifies anomalies in camera-captured frames and generates concise descriptions for better situational awareness.
- The system leverages LLMs and open-vocabulary models for dynamic scenario transitions, addressing limitations in traditional visual navigation methods.
- Performance evaluations highlight improvements in visual accessibility and navigation, paving the way for advancements in video anomaly detection and vision-language understanding.

Link here: https://arxiv.org/pdf/2403.12415

VisionGPT: LLM-Assisted Real-Time Anomaly Detection for Safe Visual Navigation

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Abstract

This paper explores the potential of Large Language Models(LLMs) in zero-shot anomaly detection for safe visual navigation. With the assistance of the state-of-the-art real-time open-world object detection model Yolo-World and specialized prompts, the proposed framework can identify anomalies within camera-captured frames that include any possible obstacles, then generate concise, audio-delivered descriptions emphasizing abnormalities, assist in safe visual navigation in complex circumstances. Moreover, our proposed framework leverages the advantages of LLMs and the open-vocabulary object detection model to achieve the dynamic scenario switch, which allows users to transition smoothly from scene to scene, which addresses the limitation of traditional visual navigation. Furthermore, this paper explored the performance contribution of different prompt components, provided the vision for future improvement in visual accessibility, and paved the way for LLMs in video anomaly detection and vision-language understanding.

Application of LLM to computer vision

- The framework integrates edge devices with an open-object detector to extract raw object information, processed further for anomaly detection.
- A detection class manager refines object information and collaborates with a prompt generator for real-time responses in voice or text formats.
- Anomaly handling triggers emergency responses, supported by a master program to ensure safety and navigation efficiency.
- The system utilizes GPT models for advanced semantic information, scene reading, visual identification, and emergency checking, enabling seamless decision-making.

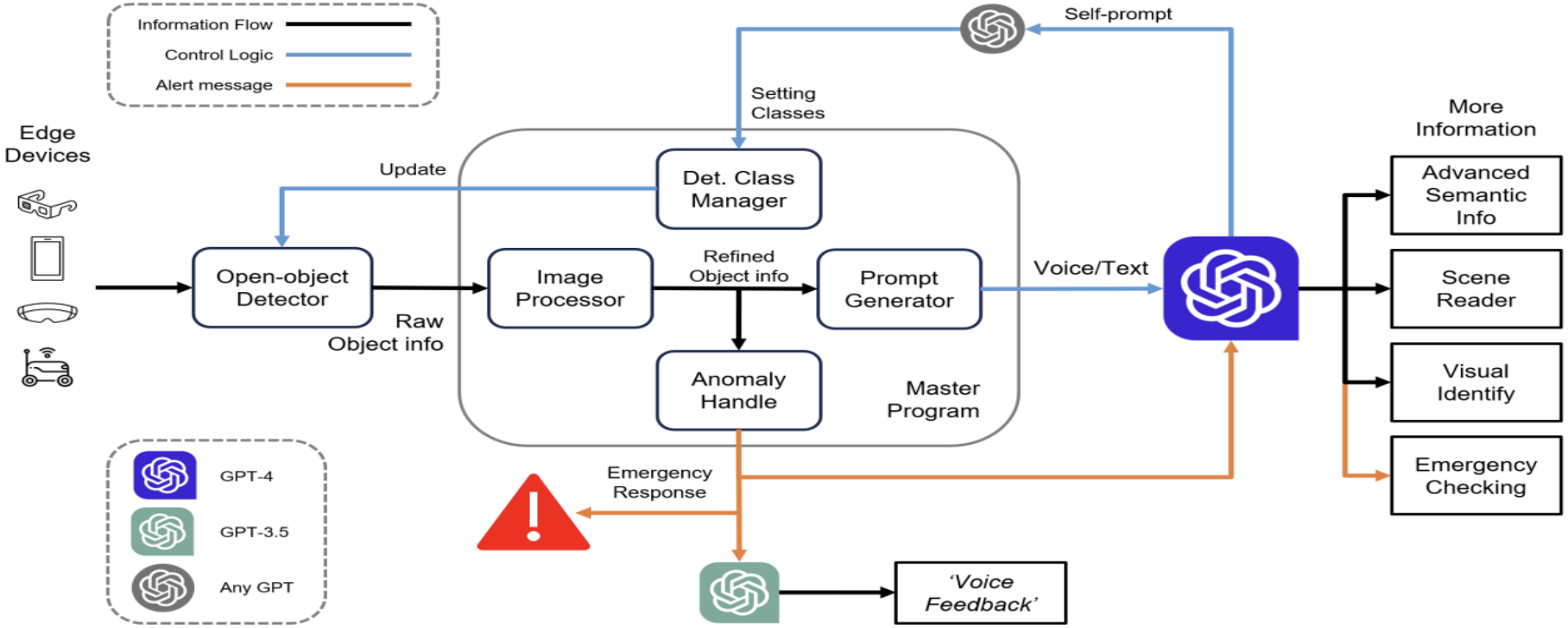

Figure 1: Framework for vision-language processing and prompting.

Application of LLM to computer vision

- The Type H image splitter divides the scene into four regions: left (1), right (2), ground area (3), and front area (4).
- Objects like cars, trash cans, and street signs are identified with confidence scores within their respective areas.
- The segmentation enables localized anomaly detection and dynamic navigation decision-making.
- The structured split improves focus on specific regions for detailed object identification and emergency response.

Figure 2: Type H image splitter. (1) and (2) represent the left and right area, (3) represent the ground area, and (4) represent the front area.

LLMs for building Games

it built flappy bird