Building an AI Copilot
for Nanofabrication Facilities

Samantha Roberts Ph.D.
Assistant Professor, Nanofabrication Facility Director, ASRC
Frederic de Vaulx
Prometheus Computing
Aakash N S
CEO, Jovian

Jovian
jovian.com

ADVANCED SCIENCE RESEARCH CENTER
THE GRADUATE CENTER
CITY UNIVERSITY OF NEW YORK

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MIT.nano

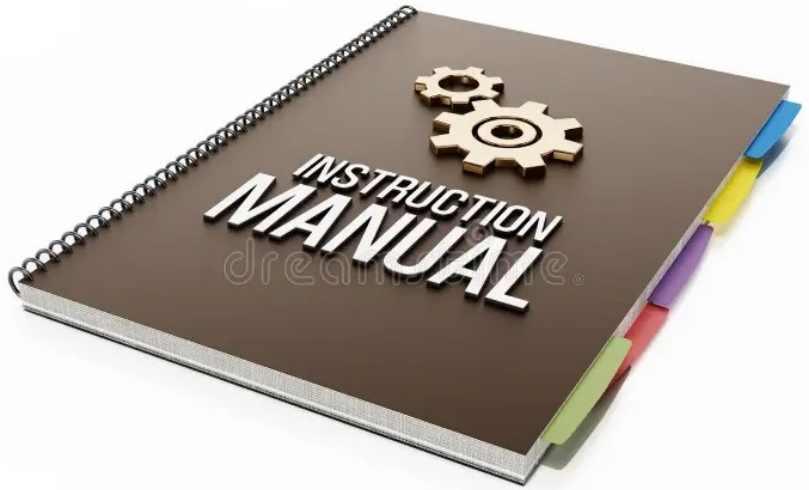
What I think about late at night…

Can AI Help us run our nanofabrication facilities?

- Large Language Models (LLM's)
- Generative Pre-Trained Transformers (GPT's)
- OpenAI (ChatGPT), Anthropic (Claude), Google (Gemini), Meta Llama ….

We already have text data

- Wiki website pages
- Labnetwork forums
- Maintenance logs
- Financial data
- Tool Maintenance Manuals
- Safety protocols/Lab Policies
- Fabrication Process recipes
- SOPs for users
- Maintenance procedures



- HTML
- PDF
- Word Files
- Text files
- PPTs
- CSV
- Excel
- Images
- Tables

Can LLM’s help us to make this data more accessible and useful?

Challenges of Generative AI for Nanofab Facilities

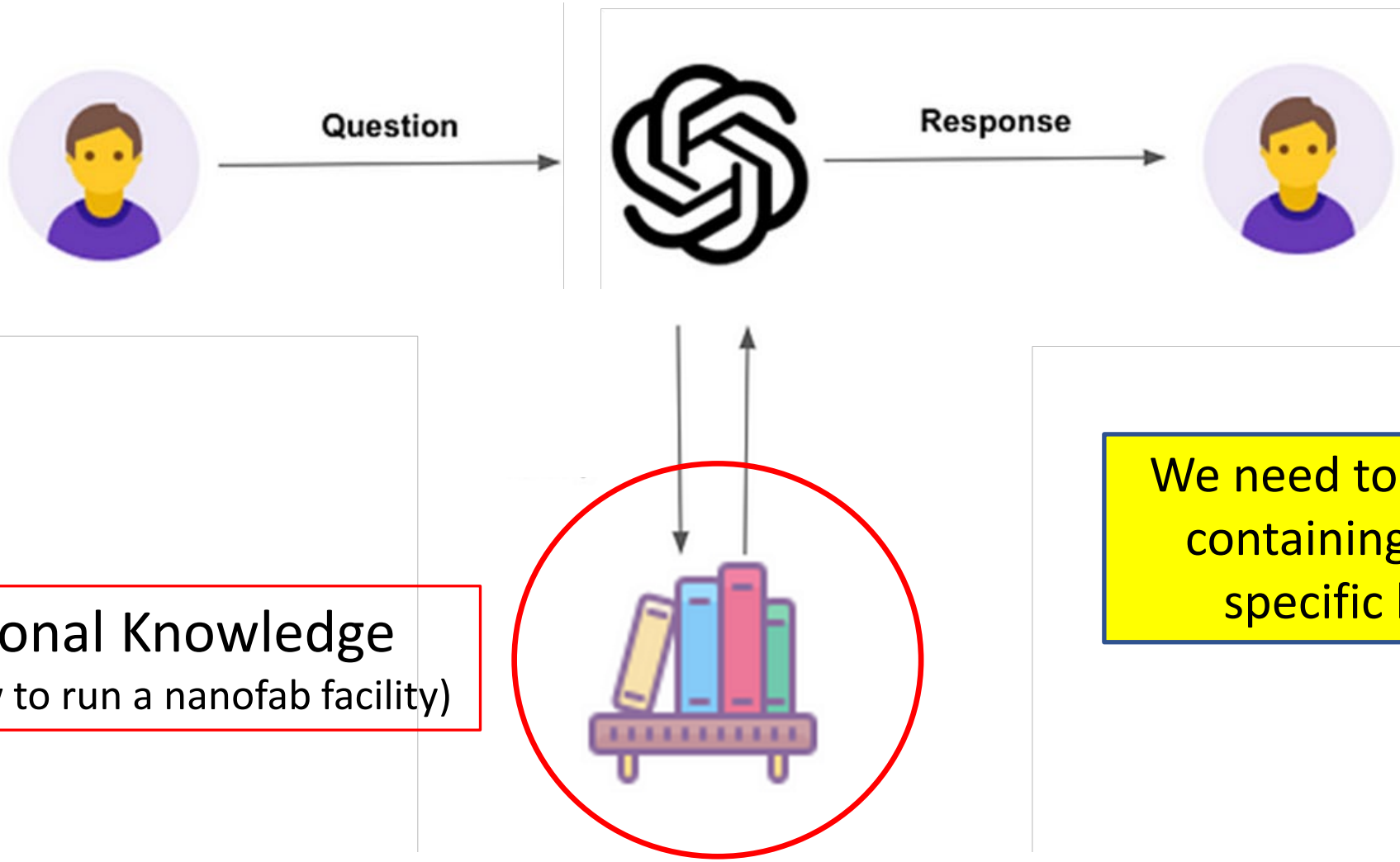
- LLM's are trained on "general" knowledge (eg: Wiki)
- Nanofabrication Facilities require domain specific knowledge

Possible Solutions:

- "Fine-tune" an LLM to include this "domain specific" information
  - Requires large amounts of data, expensive, and is hard to update

- Give the LLM the Ability to "look up" domain specific information

Retrieval Augmented Generation (RAG)

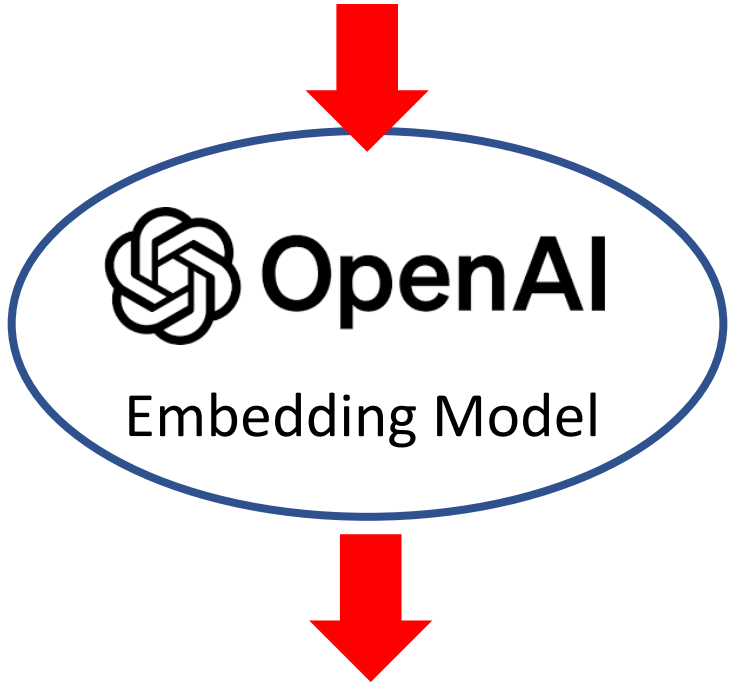


Additional Knowledge
(eg: how to run a nanofab facility)

We need to build a library containing the domain specific knowledge

Embedding Model: Text → Vector

Some chunk of text here that we want to embed. It could be a word a sentence, a paragraph a page a chapter, or more. The embedding model is also a large language model, but instead of generating text from text it generated vectors from text. The length of those vectors depends on the model, but the model that I use has 1536 components. If you have read of of this text you must be very interested in this presentation, a detail oriented scientist, and also a fast reader. good on you and thanks.



Semantic meaning is embedded in each of these coordinates

N=1536d

-0.01011659205	0.0248380769	0.007311150897	0.007304066326	-0.004849304911	0.00625202572	-0.01650

Vector Database Retrieval – Semantic meaning

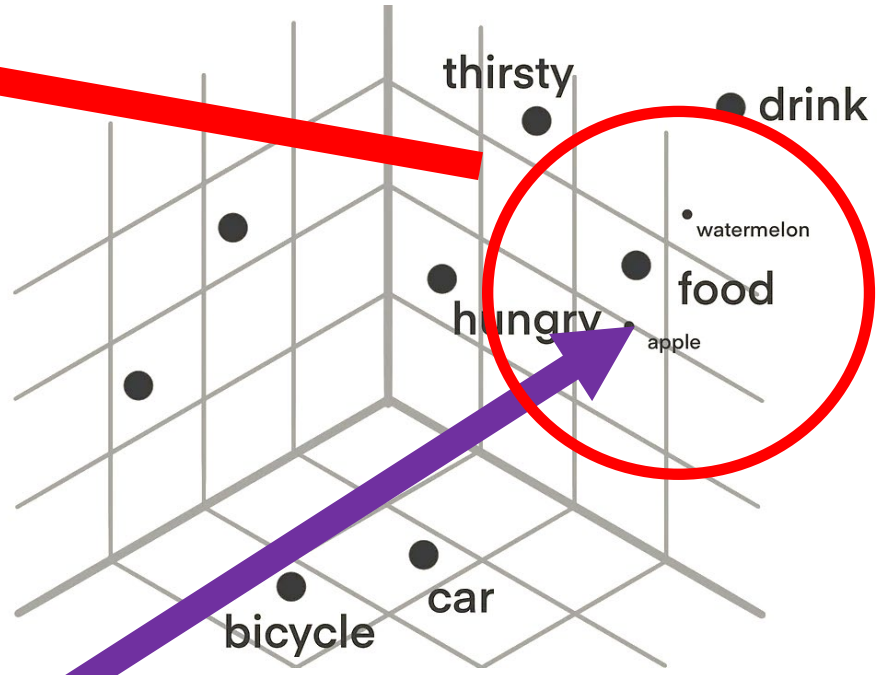
kNN – Nearest Neighbors

Additional Information Sent with the prompt to the Generative AI Model

User Prompt: "Tell me some things I can eat"

Embedding Model

-0.01011659205	0.0248380769	0.007311150897



Eg: Cosine similarity, dot product etc…

NOTE: Difference between "Keyword" and "Semantic" Searches

MIT Labnetwork – Email Forum with Domain Knowledge

Labnetwork @mtl.mit.edu

The labnetwork Archives

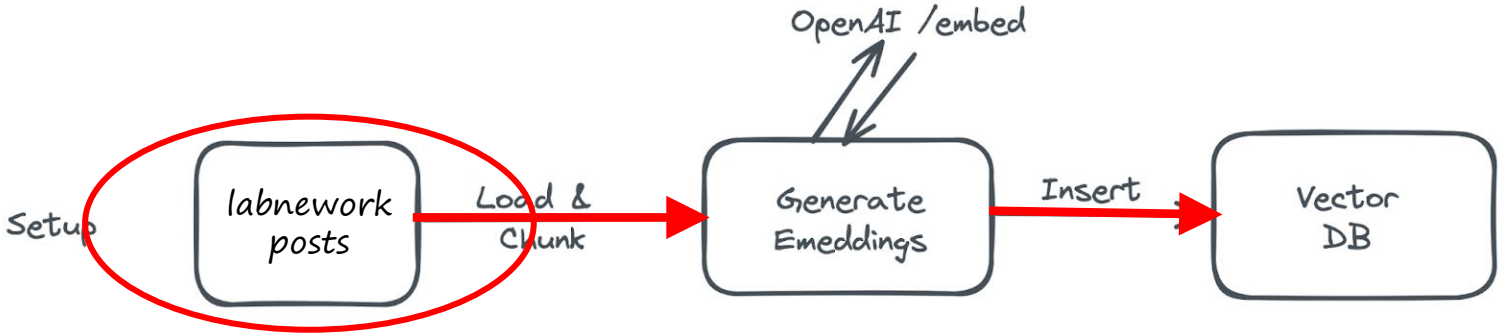
You can get more information about this list.

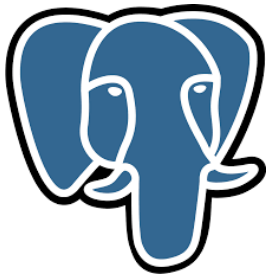
Archive	View by:	Downloadable version
June 2024:	[Thread] [Subject] [Author] [Date]	[Text 79 KB]
May 2024:	[Thread] [Subject] [Author] [Date]	[Text 166 KB]
April 2024:	[Thread] [Subject] [Author] [Date]	[Text 85 KB]
March 2024:	[Thread] [Subject] [Author] [Date]	[Text 96 KB]
February 2024:	[Thread] [Subject] [Author] [Date]	[Text 89 KB]
January 2024:	[Thread] [Subject] [Author] [Date]	[Text 106 KB]
December 2023:	[Thread] [Subject] [Author] [Date]	[Text 114 KB]
November 2023:	[Thread] [Subject] [Author] [Date]	[Text 81 KB]
October 2023:	[Thread] [Subject] [Author] [Date]	[Text 107 KB]
September 2023:	[Thread] [Subject] [Author] [Date]	[Text 207 KB]
August 2023:	[Thread] [Subject] [Author] [Date]	[Text 136 KB]
July 2023:	[Thread] [Subject] [Author] [Date]	[Text 83 KB]
June 2023:	[Thread] [Subject] [Author] [Date]	[Text 104 KB]
May 2023:	[Thread] [Subject] [Author] [Date]	[Text 66 KB]
April 2023:	[Thread] [Subject] [Author] [Date]	[Text 102 KB]
March 2023:	[Thread] [Subject] [Author] [Date]	[Text 180 KB]

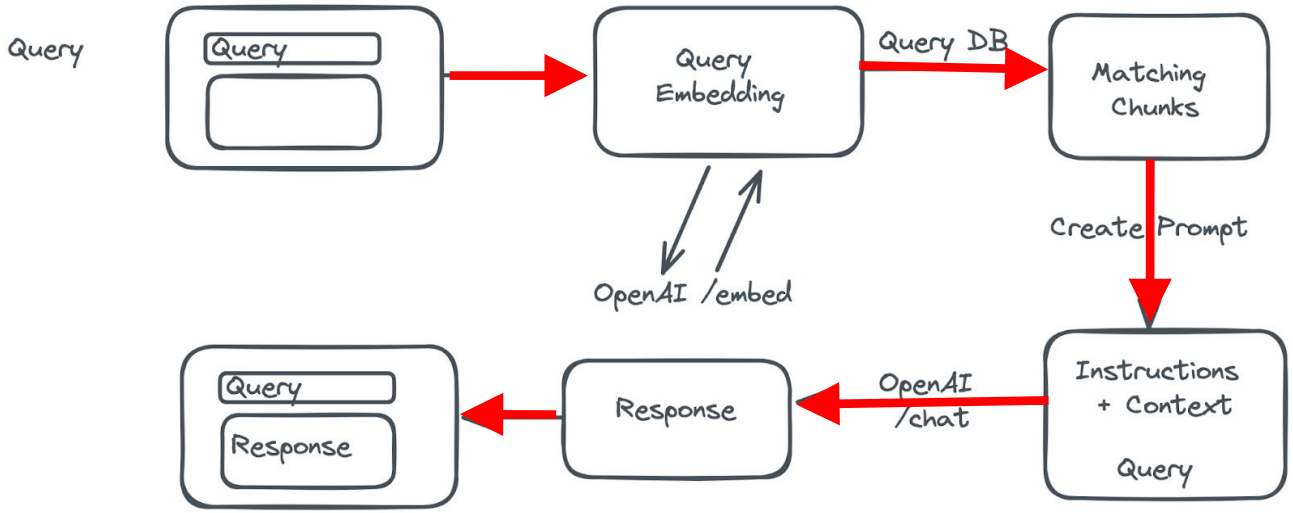
- Scrape all text files (2007 to 2024)
- From each message extract (python):
  - Date
  - Sender
  - Email
  - Institution
  - Thread ID
  - Subject
  - Email Body

MTL microsystems technology laboratories

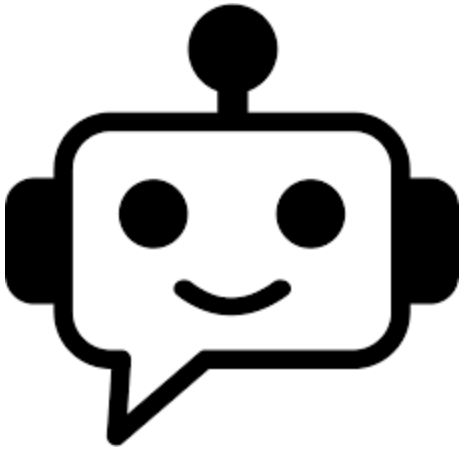
Building our nanobot







Meet nanobot !



www.nanobot.chat

Labnetwork beginnings

```
Subject: labnetwork e-mail
To: labnetwork@mtl.mit.edu
From: reif@mtl.mit.edu (Rafael Reif)
Date: Fri, 21 Jul 1995 16:36:09 -0400 (EDT)
Cc: reif@mtl.mit.edu (Rafael Reif), boning@mtl.mit.edu (Duane Boning)

Dear colleagues:

I think it is a good idea to set up a "labnetwork" e-mail to enable
all of us (i.e., faculty and staff dealing with microfabrication facilities)
to reach each other, and we decided to do so.  At this point, and until
we all figure out how to organize things, it may be better to limit
this e-mail "labnetwork" to academic facilities only.  The purpose
of this labnetwork is, among other things, to be able to reach very
quickly colleagues dealing with the same kinds of issues, and to
request and/or offer help with microfabrication technologies,
equipment, facilities, etc.

There are about 98 academic people receiving this e-mail.  Mail to
this address (labnetwork@mtl.mit.edu) will be redistributed to these
98 faculty and staff.  You may want to request to be removed from
the list (or added to the list) by sending an e-mail to
"labnetwork-request@mtl.mit.edu".  Mail sent to
labnetwork-request@mtl.mit.edu will NOT be redistributed.

I hope you find this useful...

/Rafael Reif
reif@mtl.mit.edu
(617)253-7317
```

July 21, 1995

98 People

Our humble moderator

Prof. Duane Boning, MIT

Electrical Engineering and Computer Science

Associate Director MTL

MTL microsystems technology laboratories

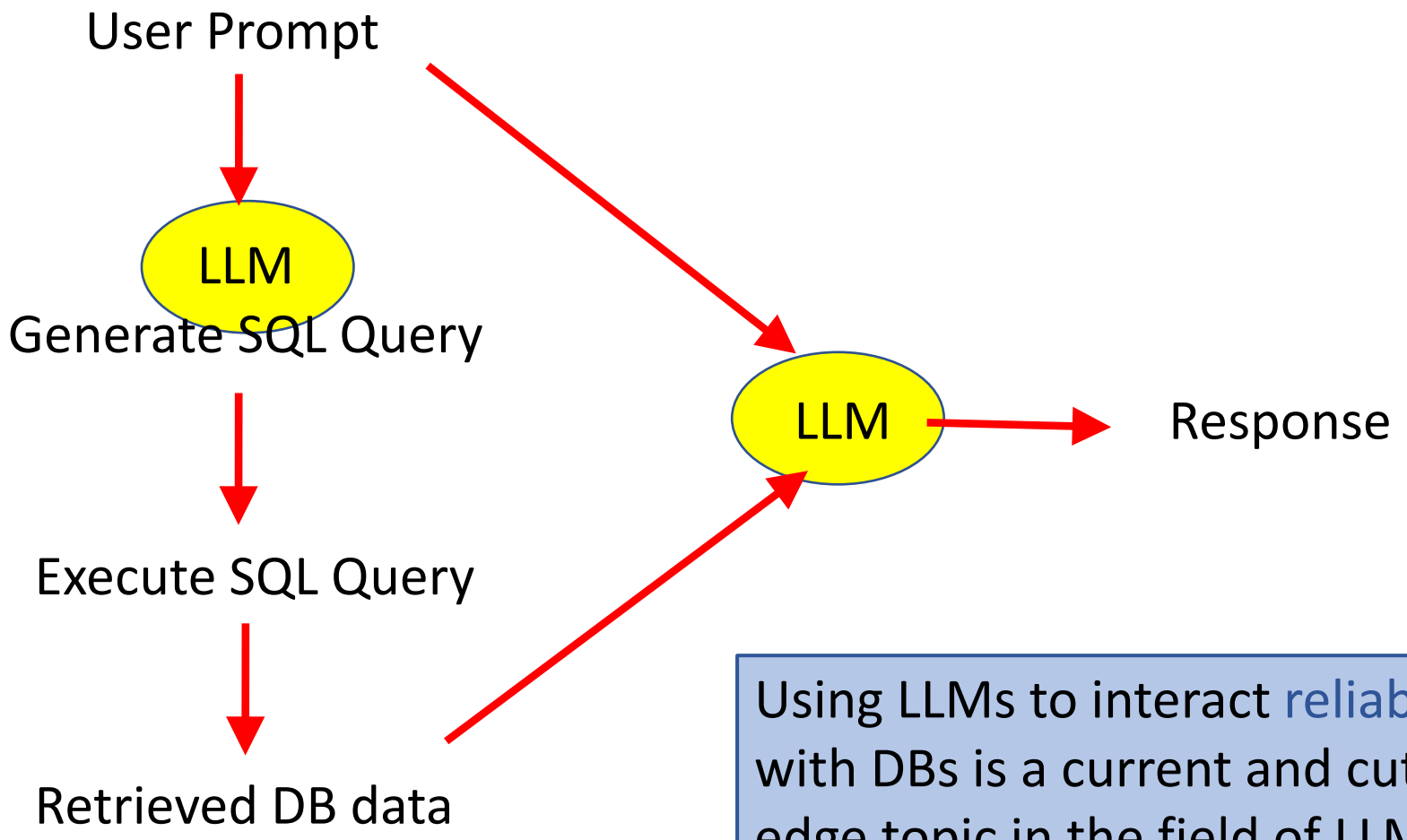
Thank you Bill Flounders for Images (2014 UGIM)

Another Type of Retrieval – SQL Queries

We do not need to know SQL! (use: function Calling)

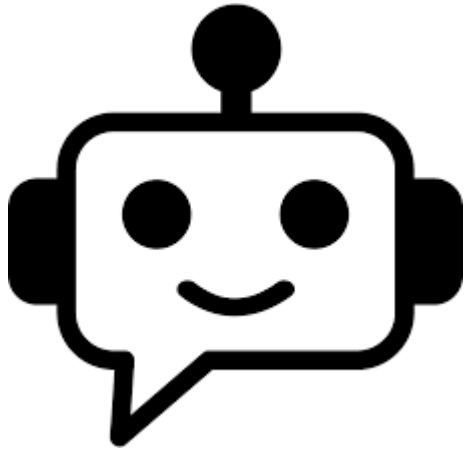
DB Schema:

- Date
- Sender
- Email
- Institution
- Thread ID
- Subject
- Email Body
- 1536d Vector



Using LLMs to interact reliably with DBs is a current and cutting edge topic in the field of LLMs

You can do SQL Queries with nanobot too!



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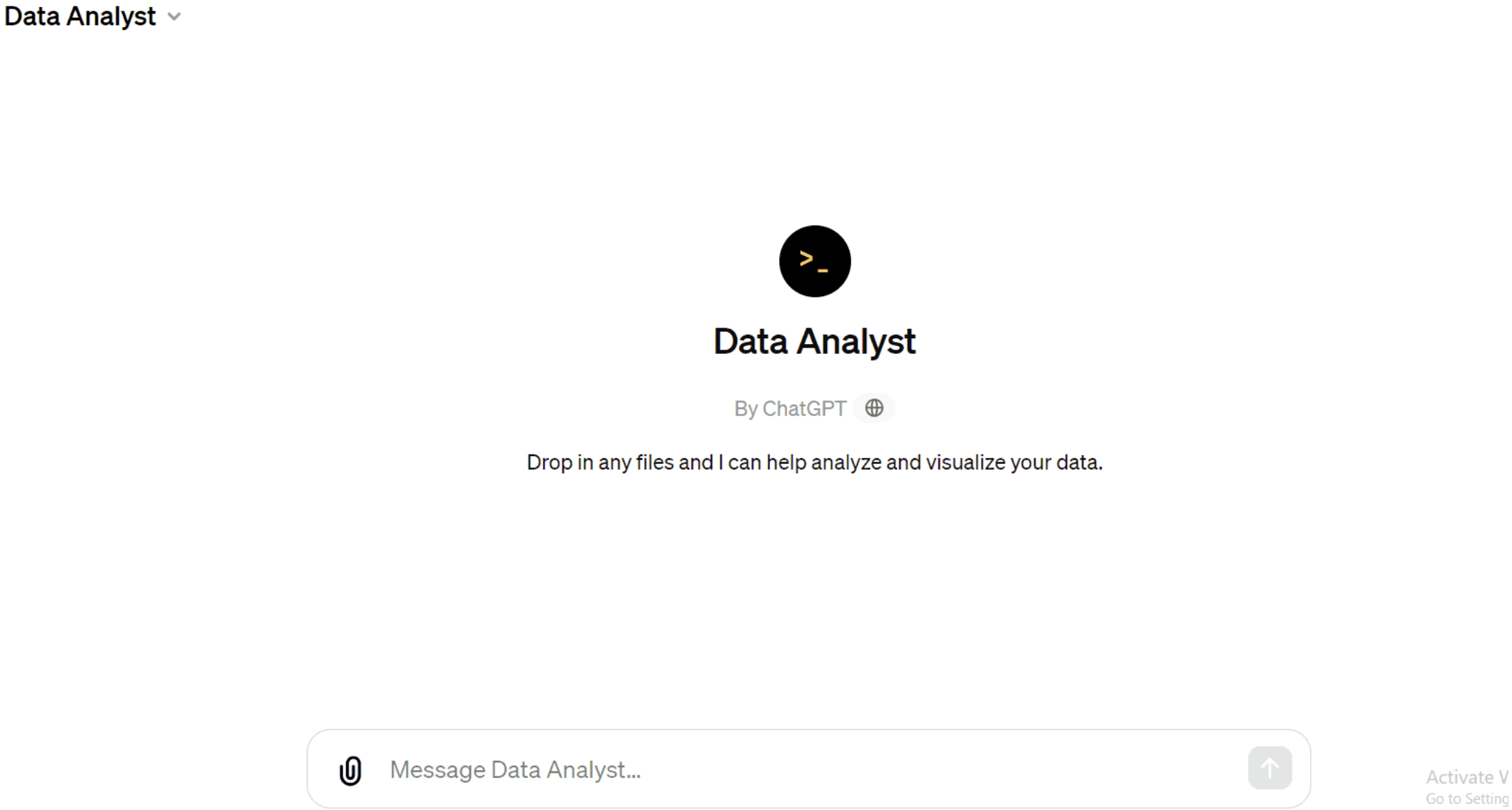
Assistants API (Beta)

- LLMs are very good at writing code
- Code is very good with numbers and tabular data analysis
- Especially useful for people who do not code

How it works:

1. Give the LLM Assistant a file with some data
2. Instruct LLM in some natural language
3. LLM translates English into code (Python)
4. The code is executed (analysis results)
5. LLM explains results in natural language

OpenAI “Assistants” Code Interpreter – (Beta)



Code Interpreter for Lab Data Dashboard

Choose Your Filters Below:

Choose the Facility

Choose an option

Choose the University

Choose an option

Choose the Principal Investigator

Choose an option

Choose the Member

Choose an option

Choose the Tool

Choose an option

Nanoscience Core Facility Analysis

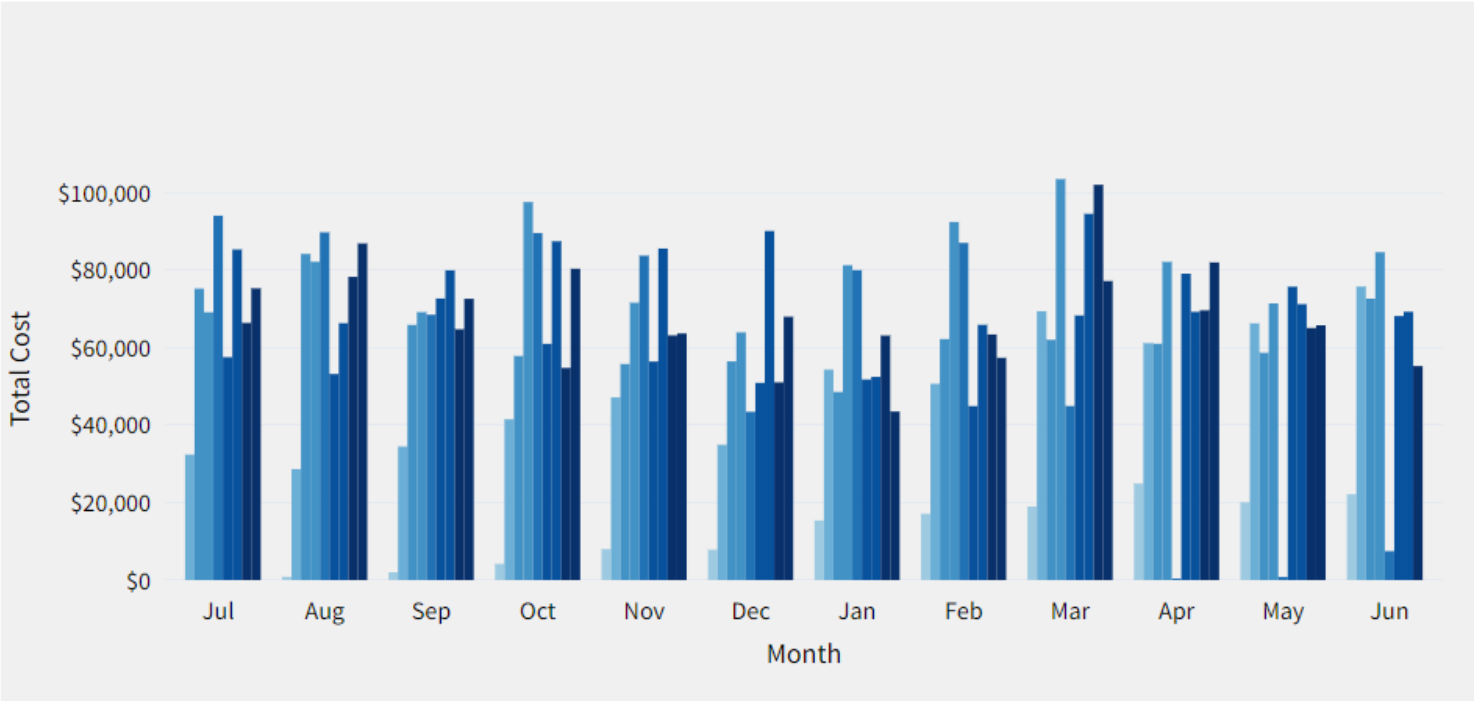
Click Below to Set the Start Date

2015/08/06

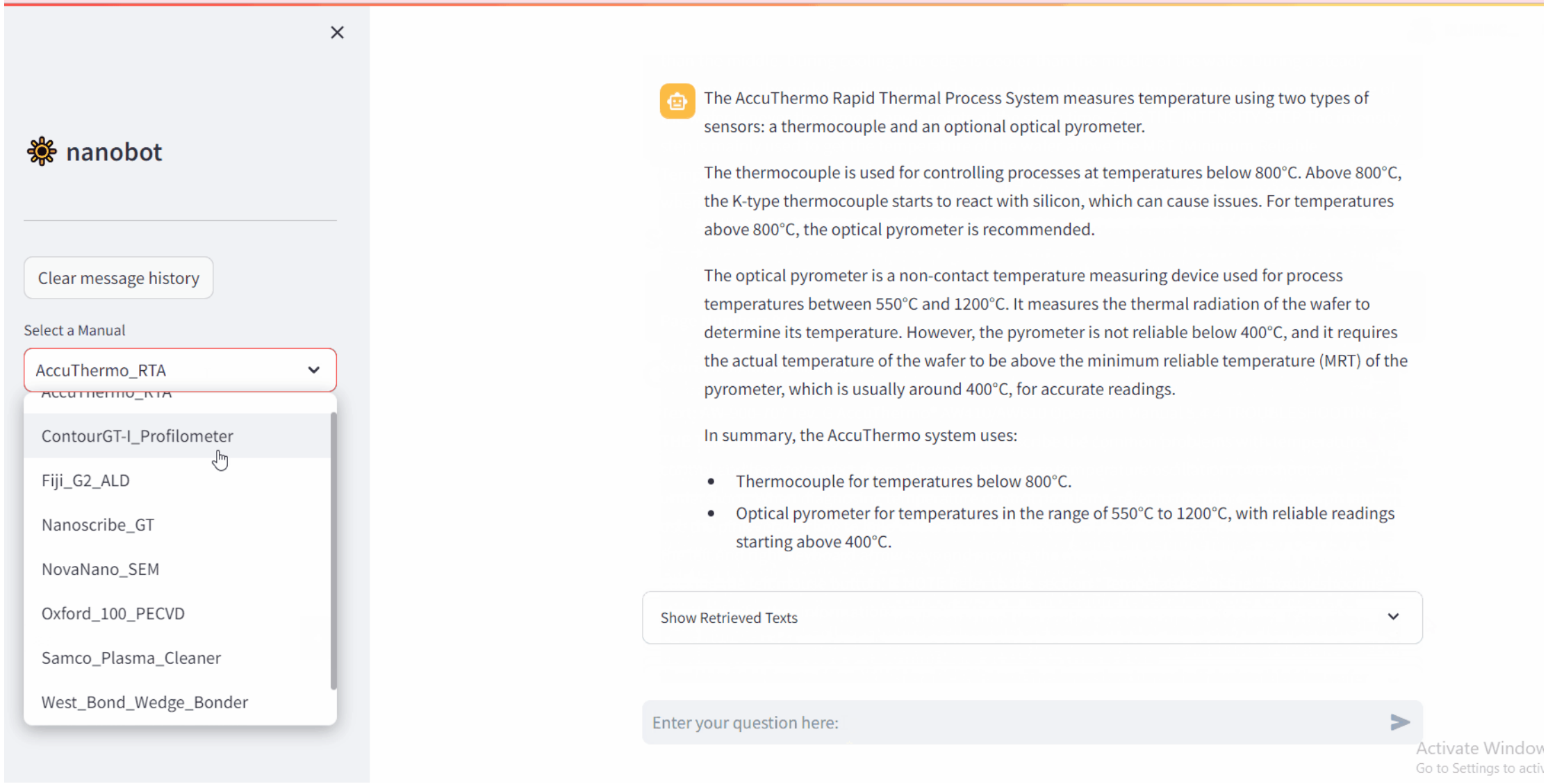
Click Below to Set the End Date

2024/05/31

Total Costs by Fiscal Year



PDF Data – Lab manuals (including tables)



We can interact with data in ways never available before...

Retrieval Methods

- Vector Retrieval (semantic meaning)
- SQL query generation and retrieval
- Code Interpreter (python analysis)

Text Formats

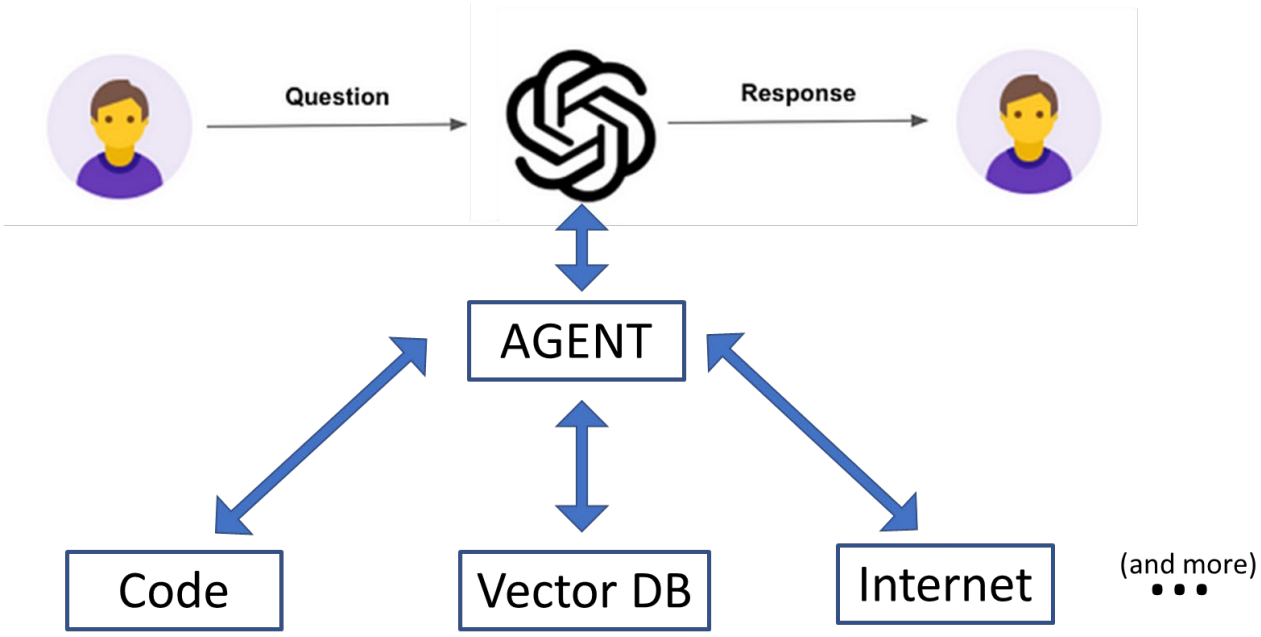
- HTML / website (labnetwork)
- PDFs (most difficult text format)
  - Tables and image captions
- CSVs (tabular text and numbers)

Next: Multimodal Inputs

- Text
- Images
- Audio
- Video

Agents

Multiple AI making decisions sequentially / together



How do we implement this technology in our nanofabs?

Vision: Open-source platform

NEMO

Calendar


Tool control


Status dashboard


Safety


Send feedback


Contact the NanoFab staff

View your usage


Supplies/Consumables


Knowledge base

News and events


Sensor data

NIST
National Institute of Standards and Technology

29 Years since the first Labnetwork message….

WWW

LLM

(Thank you for this one Bill F. ☺)

Thank You!

- Aakash N S, Jovian
- Frederic de Vaulx, Prometheus

- Duane Boning, MIT
- Bill Flounders, Berkeley
- Mary Tang, Stanford

- Shawn Kilpatrick and staff, CUNY ASRC

- Jorg Scholvin and UGIM organizing folks, MIT

Nanobot for you! :)

Beta Version

labnetwork@

www.nanobot.chat

Questions, Comments, Collaboration: sam@nanobot.chat