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## **Utilizing Large Language Models in geographic contexts - Experiences from the FIU GIS Center**

Levente Juhasz

Boyuan Guan

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GIS CENTER

# Utilizing Large Language Models in geographic contexts

Experiences from the FIU GIS Center

Levente Juhasz & Boyuan (Keven) Guan



FLORIDA  
INTERNATIONAL  
UNIVERSITY

South Florida GIS Expo  
West Palm Beach, FL  
August 24, 2023

# Outline

- Introduction
- Case Study #1: Towards Understanding the Spatial Literacy of ChatGPT
- Case Study #2: Mapping with ChatGPT
- Case Study #3: ChatGPT as a Mapping Assistant
- Case Study #4: GeoGPT

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# FIU

GIS CENTER

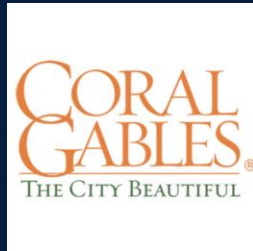


- Supports geospatial teaching and research within FIU
- Operates computer labs on 2 campuses
- Provides software, data and service licenses to the FIU community
- Conducts original research
- Works with local, state and federal partners

# FIU



- 4 faculty
- 4 full-time staff
- Part-time student and OPS
- Some of our partners:



# GeoAI Team



**Levente Juhász**  
Research Asst. Professor  
Interim Director

Geomatics/GIScience



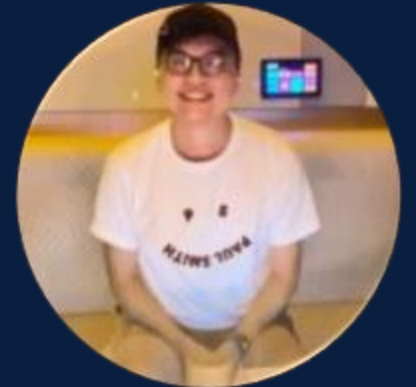
**Boyuan Keven Guan**  
Lead Digital Project Developer

Computer Science



**Jinwen Xu**  
Research Associate

Geography/GIScience




**Wencong Cui**  
Geospatial Developer II


Computer Science/Geography





# Large Language Models

## OpenAI ChatGPT 3.5



 Give me a short definition of what a large language model is in layman's terms


 A large language model is a clever computer program that has read tons of text from people talk. It can use this knowledge to chat, write, and help with all sorts of tasks.

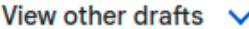

 what do prediction and probabilities have to do with large language models? keep your answer simple.

 Prediction and probabilities are how large language models guess what words come next in a sentence. They've learned from lots of text what words usually follow each other. So when you start a sentence, they use these guesses to figure out the rest of your sentence and respond sensibly.

## Google Bard

 Give me a short definition of what a large language model is in layman's terms. 

 Sure, here is a short definition of a large language model (LLM) in layman's terms:

A large language model is a computer program that has learned to understand and generate human language. It does this by analyzing a massive amount of text data, such as books, articles, and websites.  



# Large Language Models

## What are they trained on?



What are large language models trained on?



Large language models like GPT-3 are trained on a diverse and extensive dataset that contains a wide range of text from the internet. The training data typically includes:

1. **Books and Literature:** Text from various books, novels, articles, and literary works.
2. **Websites and Articles:** Text from websites, blogs, news articles, opinion pieces, and other online sources.
3. **Wikipedia:** A substantial amount of content from Wikipedia articles on a wide array of topics.
4. **Encyclopedias:** Content from other encyclopedic sources apart from Wikipedia.
5. **Forums and Discussions:** Text from online forums, discussion boards, and social media platforms.
6. **Technical Documentation:** Text from technical manuals, guides, documentation, and tutorials.
7. **Conversational Data:** Dialogues, conversations, and interactions from various sources, including chat logs.
8. **Poetry and Creative Writing:** Texts of poetry, creative writing, and artistic expressions.
9. **Scientific Papers:** Content from research papers, scientific journals, and academic publications.
10. **Translations:** Text in multiple languages, often used to improve the model's ability to understand and generate text in different languages.
11. **Question-Answer Pairs:** Pairs of questions and their corresponding answers, used to improve the model's ability to answer queries.

## How do they work?



what do prediction and probabilities have to do with large language models? keep your answer simple.



Prediction and probabilities are how large language models guess what words come next in a sentence. They've learned from lots of text what words usually follow each other. So when you start a sentence, they use these guesses to figure out the rest of your sentence and respond sensibly.

Input

Prediction

The location of the South FL GIS Expo is ...

West

cool!

the

Palm

Convention

...

...

# Large Language Models

- Learning of geographic concepts
  - What is a location? What is a place?
  - At what distance does something become "nearby"?
  - Where is my school?
- Human learning these concepts and skills is fundamentally different from ingesting large amounts of texts.

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## Towards Understanding the Spatial Literacy of ChatGPT

Taking a Geographic Information Systems (GIS) Exam

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### ABSTRACT

This paper examines the performance of ChatGPT, a large language model (LLM), in a geographic information systems (GIS) exam. As LLMs like ChatGPT become increasingly prevalent in various domains, including education, it is important to understand their capabilities and limitations in specialized subject areas such as GIS. Human learning of spatial concepts significantly differs from LLM training methodologies. Therefore, this study aims to assess ChatGPT's performance and spatial literacy by challenging it with a

the LLM, this study addresses the nuances of teaching spatial concepts to AI models and offers potential avenues for improvement in spatial literacy within future iterations of LLMs.

### CCS CONCEPTS

• Social and professional topics; • Human-centered computing → Interaction paradigms; Natural language interfaces; • Applied computing → Education;

# Towards understanding the spatial literacy of ChatGPT

## • Motivation

- AI is here and is not going anywhere
- How good are LLMs in grasping spatial concepts today?
- What does it all mean for teaching GIS skills in a higher education?

## • Goals

- Configure ChatGPT to take a real introductory GIS exam
- Quantitatively assess ChatGPT's performance

## • Outcomes

- Gain insights into the potential applications and challenges of LLMs in spatially-oriented fields
- further insights into the strengths and weaknesses of ChatGPT's GIS literacy

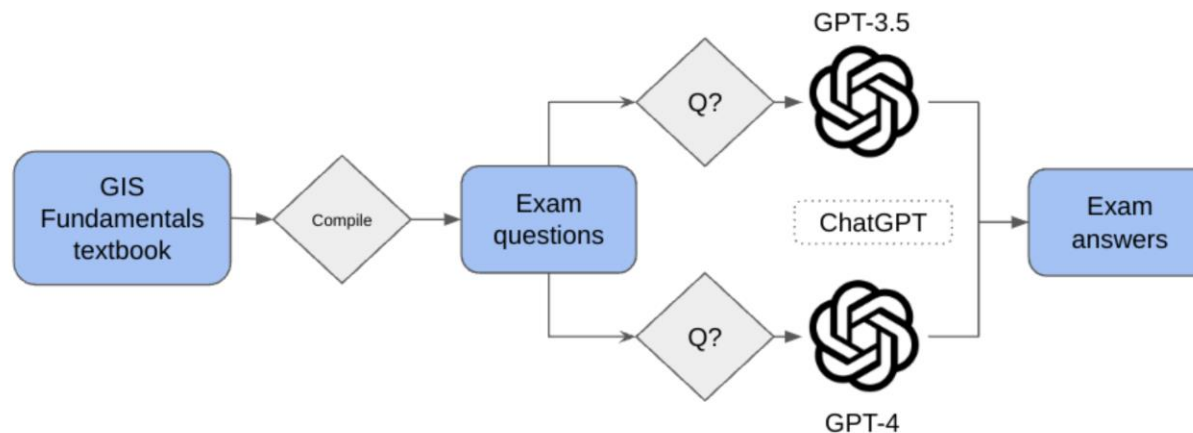
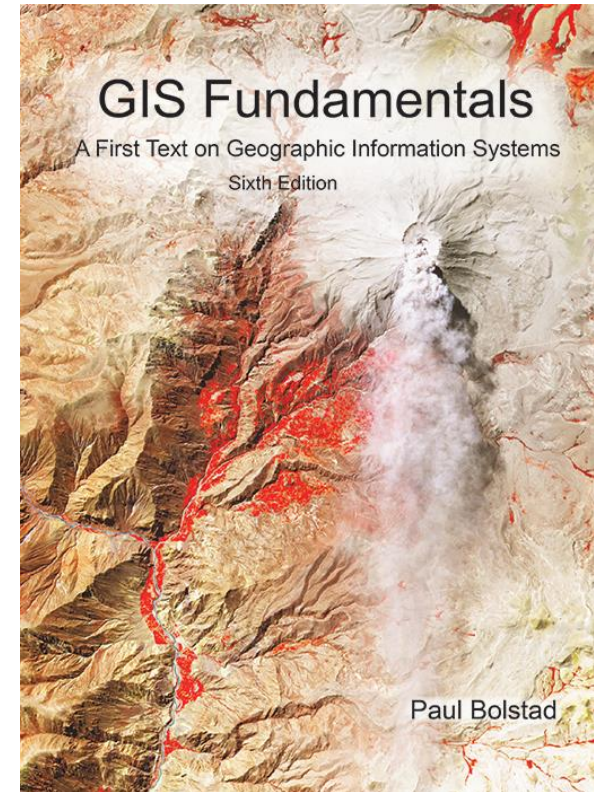




# Towards understanding the spatial literacy of ChatGPT

- 60 questions adapted from "GIS Fundamentals"

Topic	Corresponding chapters	Number of questions
Fundamental concepts of mapping and GIS	2, 3, 4, 5, 6	27
Data sources and tabular data	7, 8	5
Spatial analysis	9, 10, 11	10
Spatial statistics and interpolation	12	16
Applied GIS workflow	13	2



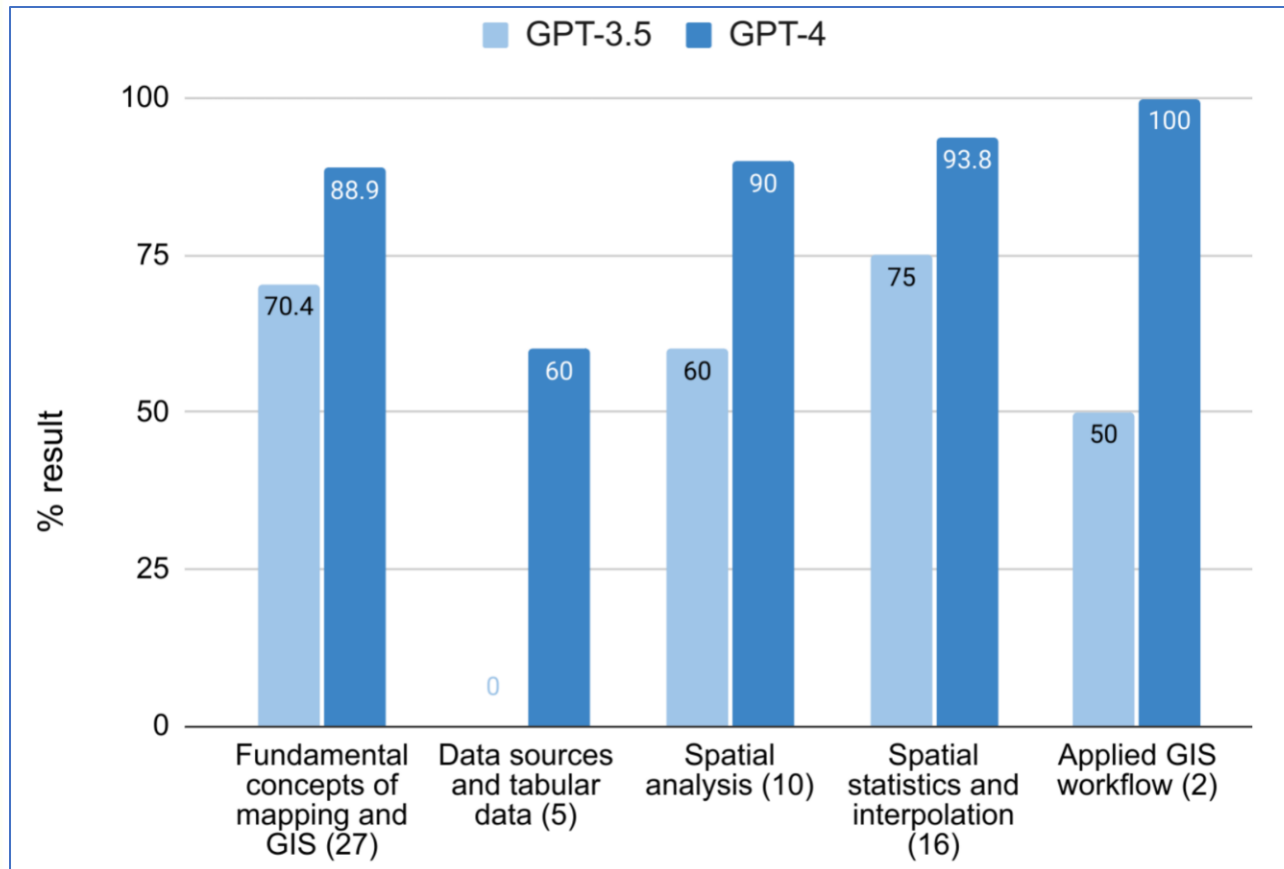
# Towards understanding the spatial literacy of ChatGPT

- **Fundamental concepts**
  - Data models, datums/projections/CS, maps, data editing, GNSS, aerial/satellite
- **Data sources and tabular data**
  - Digital data, attribute data
- **Spatial analysis**
  - Basic analysis techniques, raster analysis, terrain analysis
- **Spatial statistics and interpolation**
  - Sampling, interpolation methods, kernels estimation
- **Applied GIS workflow**
  - Select the correct steps based on an objective, e.g. "Identify flat building sites, outside of the floodplain, within 1/4 mile of a road"

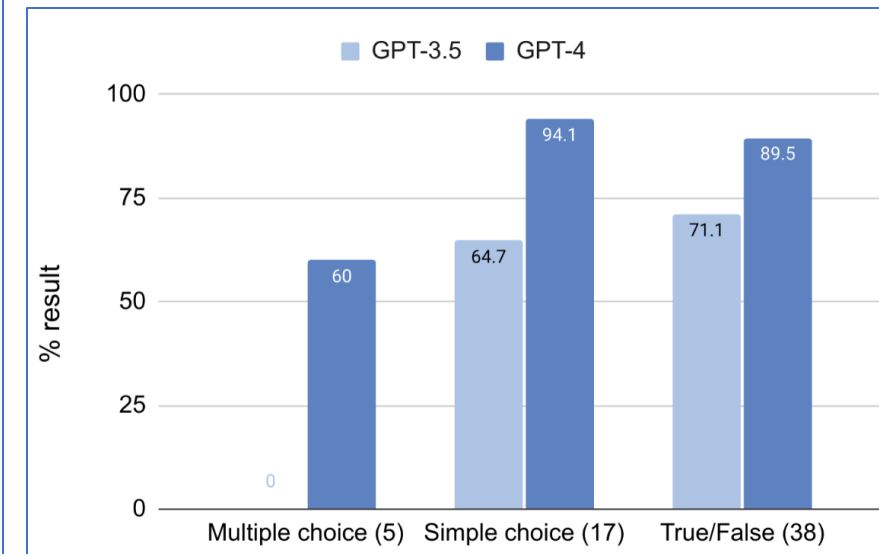
# Towards understanding the spatial literacy of ChatGPT

## • Results

- ChatGPT would pass (this) introductory GIS exam



	GPT-3.5 n (%)	GPT-4 n (%)
<b>Correct</b>	38 (63.3)	53 (88.3)
<b>Incorrect</b>	22 (36.7)	7 (11.7)
<b>Letter grade</b>	D	B+



# Towards understanding the spatial literacy of ChatGPT

- **Results**

- Particularly strong at answering simple questions about basic GIS concepts
- **Q:** *What type of attribute is human population (the number of people) in a U.S. county data layer?*
- **A:** **a)** interval/ratio (correct); **b)** nominal; **c)** ordinal
  
- **Q:** *Is the following statement true or false? Vector data models are often better for describing discrete themes such as counties, voting areas, or zip codes?*
- **A:** True (correct); False



# Towards understanding the spatial literacy of ChatGPT

- **Results**

- Latest GPT-4 appears to be good at **selecting more complex workflows**
- **Q:** You are asked to do a spatial analysis that may include some of the following data layers:
  - BOUND - Study area boundary (vector polygon);
  - FEMA - 100-year floodplain map (vector poly);
  - ...
- Select the sequence of steps that comes closest to describing how to complete your task is to **Identify flat building sites, outside of the floodplain, within 1/4 mile of a road.**

**A:** - The correct answer is a)

- a)
  - (1) Select all wetlands from WETLAND, dissolve, calculate area, and select those > 10 hectares -> 10WTL
  - (2) Select city by high population density from CENSUS, reclass, dissolve, buffer at 200m -> NEARCT
  - (3) Buffer each wetland at approx. 1.6 km (give 9sq km area), without dissolving output across separate wetlands -> WTBUFF
  - (4) Reclassify NASS to Corn/noncorn -> CRN\_RC
  - (5) Select 10WTL by location, against NEARCT -> CTWET
  - (6) Intersect CTWET with CRN\_RC, once for each individual wetland -> CRN\_WET
  - (7) Summarize area for CRN\_WET, select those that have greater than 50% area in corn nearby -> FINAL LAYER

# Towards understanding the spatial literacy of ChatGPT

- **Results**

- Not so good at questions that require calculations

**Q:** *Assume an Earth radius of 6,278 kilometers. What is the ground surface distance, expressed in meters, of an arc that spans 14.2 seconds of arc? Please enter your answer to the nearest 0.1 meter*

**A:** 864.4; **B:** 492.5; **C:** 432.2 (correct)



To calculate the ground surface distance of an arc, we need to use the formula:

$$\text{Distance} = (\text{Arc Length} / 360) * (2 * \pi * \text{Earth Radius})$$

Given that the Earth radius is 6,278 kilometers and the arc spans 14.2 seconds of arc, we can substitute these values into the formula:

$$\text{Distance} = (14.2 / 360) * (2 * \pi * 6,278,000 \text{ meters})$$

Simplifying:

$$\text{Distance} = (0.0394) * (2 * \pi * 6,278,000)$$

$$\text{Distance} \approx 493,051.5 \text{ meters}$$

Rounded to the nearest 0.1 meter, the ground surface distance is approximately 493,051.5 meters.

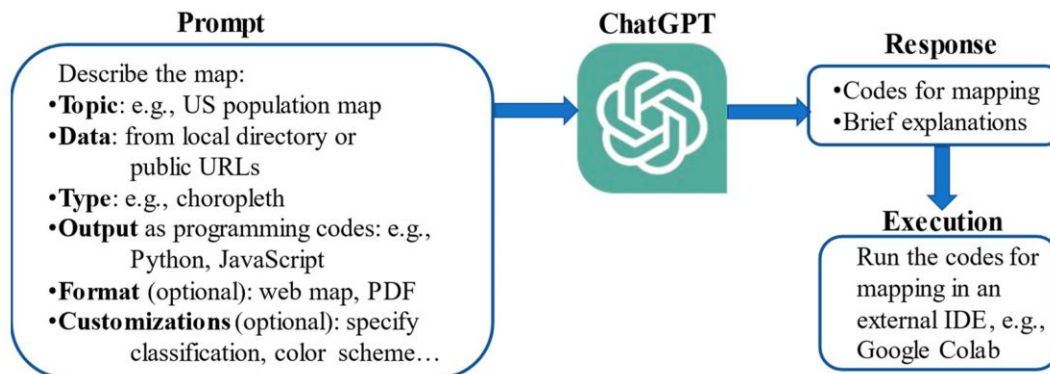
Therefore, the correct answer is B: 492.5.

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# Mapping with ChatGPT

- Use ChatGPT as a mapping specialist
- Python codes and IDE were used to interpret outputs from ChatGPT
- Thematic map production includes
  - Graduated colored map
  - Batch mapping
  - Web map



Article

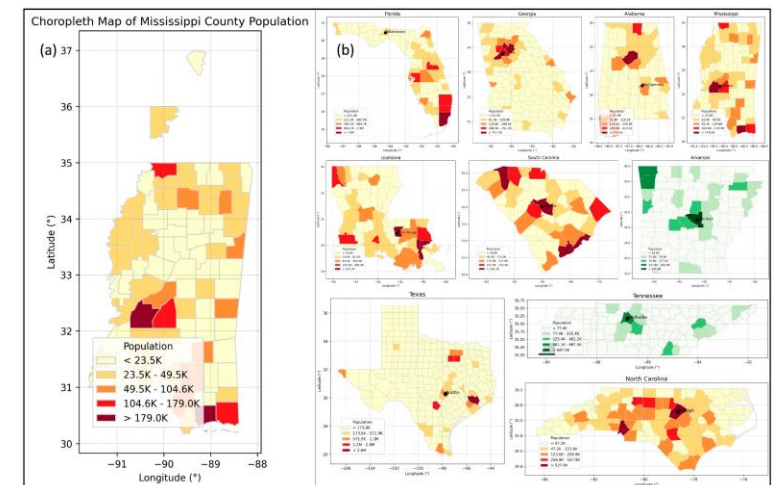
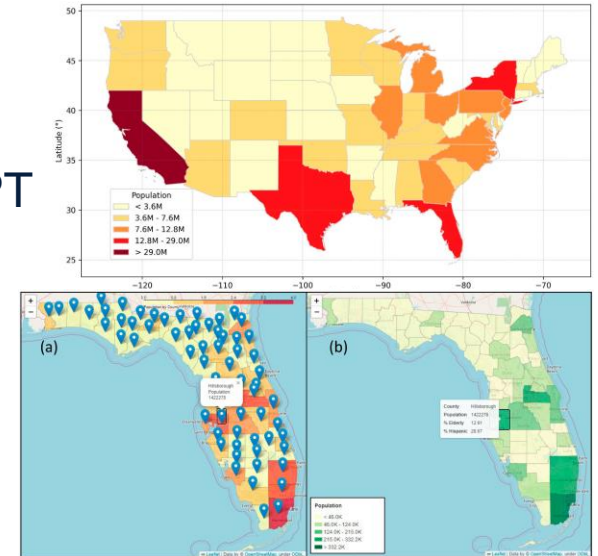
## Mapping with ChatGPT

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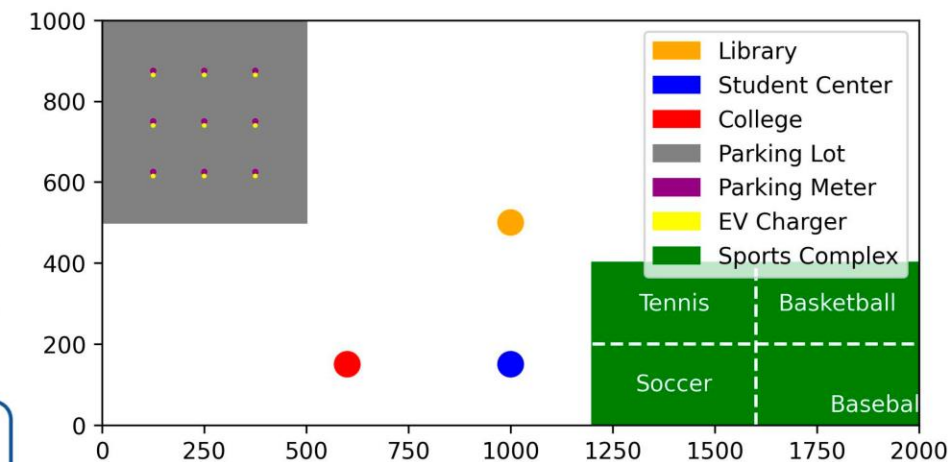
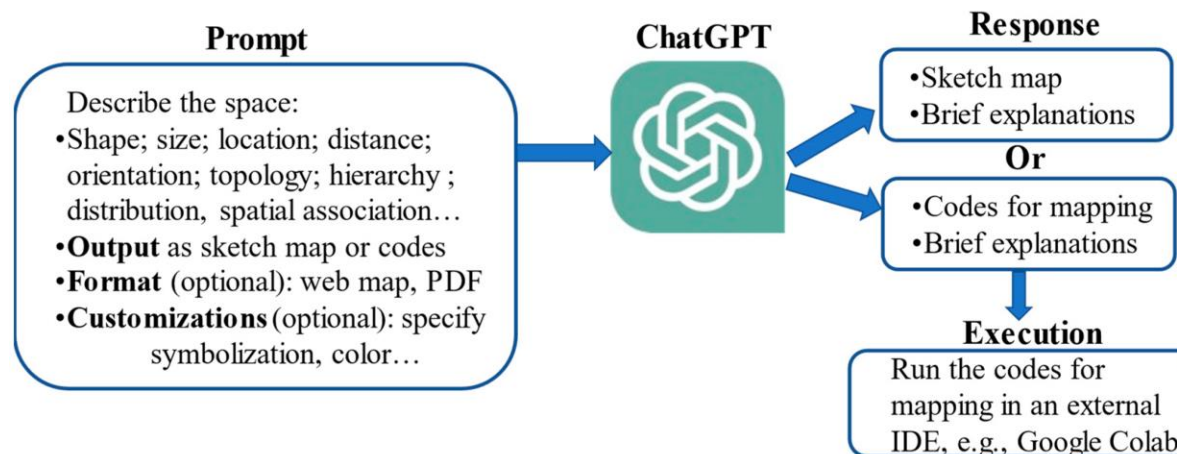
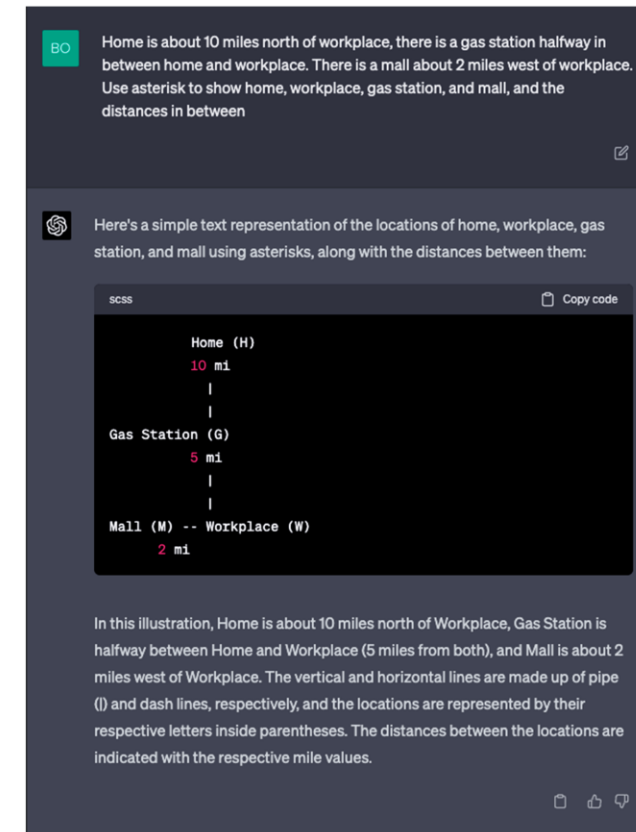
\* Correspondence: rtao@usf.edu





# Mapping with ChatGPT

- ChatGPT can also create mental maps
  - Reveal the spatial thinking of AI
- Outcomes include
  - Sketch map (right top)
  - Mental map (right bottom)



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# ChatGPT as a mapping assistant

- **Motivation**

- Is generative AI useful to enrich map databases?
- Can we design a low-cost, ready-to-use mapping workflow with off-the-shelf tools?

ChatGPT as a mapping assistant: A novel method to enrich maps with generative AI and content derived from street-level photographs

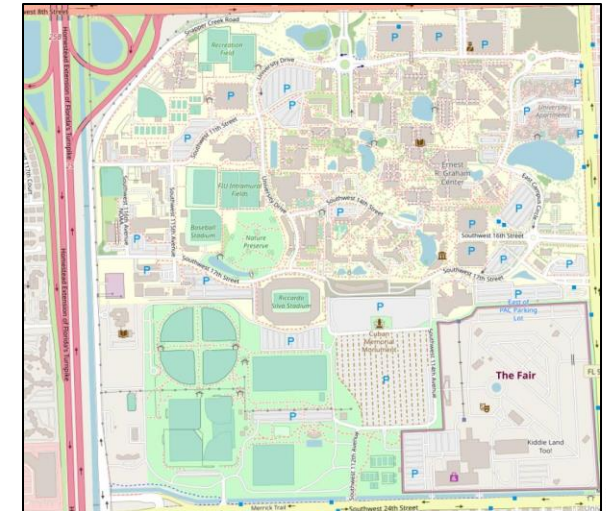
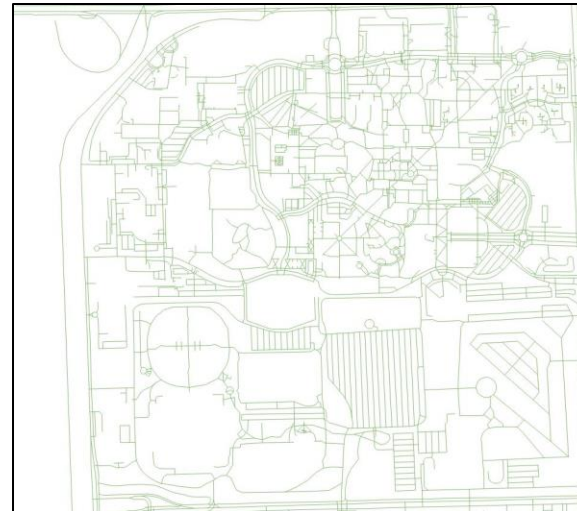
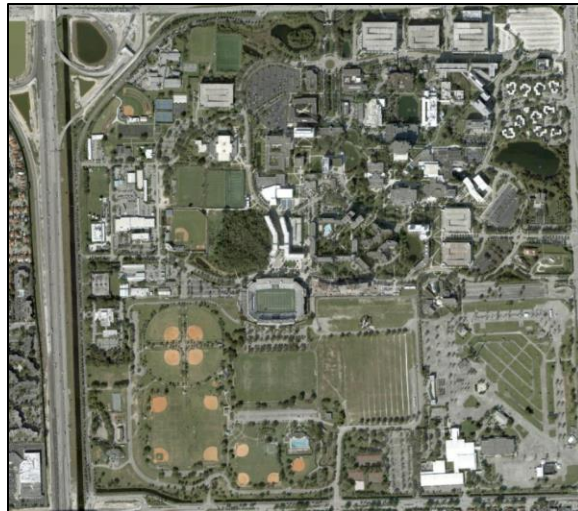
Levente Juhász<sup>1</sup>[0000-0003-3393-4021], Peter Mooney<sup>2</sup>, Hartwig H. Hochmair<sup>3</sup>, and Boyuan Guan<sup>1</sup>

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**Abstract.** This paper explores the concept of leveraging generative AI as a mapping assistant for enhancing the efficiency of collaborative mapping. We present results of an experiment that combines multiple sources of volunteered geographic information (VGI) and large language models



OpenStreetMap  
The Free Wiki World Map



# ChatGPT as a mapping assistant

- 3 analysts (2 undergraduate students and an AI analyst)



<https://mapillary.com>

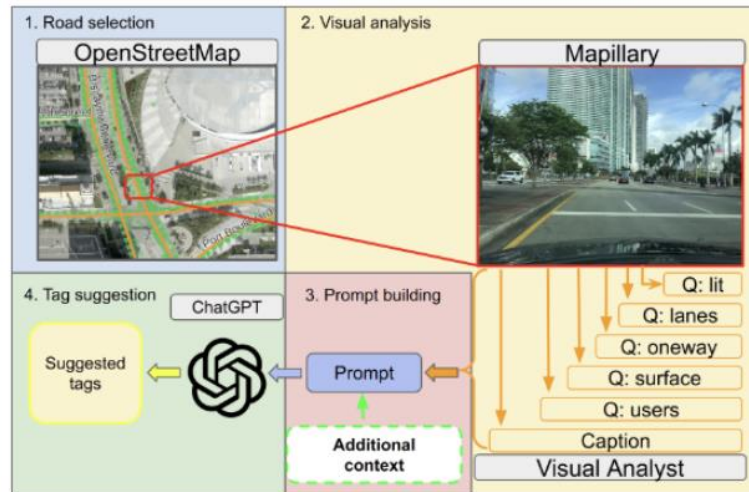


Table 2. Questions and tasks performed by analysts.

Variable	Question/task	Example response
"caption"	Describe what you see in the photo in your own words.	<i>A city road in an urban area along an elevated railway. There is a wide sidewalk on both sides and trees on the left.</i>
"users"	Who are the primary users of the road that is located in the middle of the photograph? Cars, pedestrians or bicyclists?	<i>Cars</i>
"lanes"	How many traffic lanes are there on the road that is in the middle of the photograph?	<i>3</i>
"surface"	What is the material of the surface of the road that is in the center of the photograph?	<i>Asphalt</i>
"oneway"	Is the road that is in the center of the photograph one-way?	<i>No</i>
"lit"	Are there any street lights in the photograph?	<i>Yes</i>



# ChatGPT as a mapping assistant

- **Prompt building** (Baseline scenario)
  - Based on the following context that was derived from a street-level photograph showing the street, recommend the most suitable tagging for an OpenStreetMap highway feature. Omit the 'oneway' and 'lit' tags if the answer to the corresponding questions is no or N/A. Format your suggested key-value pairs as a JSON. Your response should only contain this JSON
  - The content of the photograph was described as follows: ***A city road in an urban area along an elevated railway. There is a wide sidewalk on both sides and trees on the left.*** The road is ***mainly used by: cars.*** The ***surface of the road is: asphalt.*** When asked how many **traffic lanes** there are on the road, one would answer: **3**. When asked if this street is a **one-way road**, one would answer: **No**. When asked if there are any **street lights** in the photograph, one would answer: **Yes**.

# ChatGPT as a mapping assistant

- Prompt building

- Locational context (LC)

- Baseline + *The photograph was taken near Downtown Miami, Florida.*

- Object-Detection context (OD)

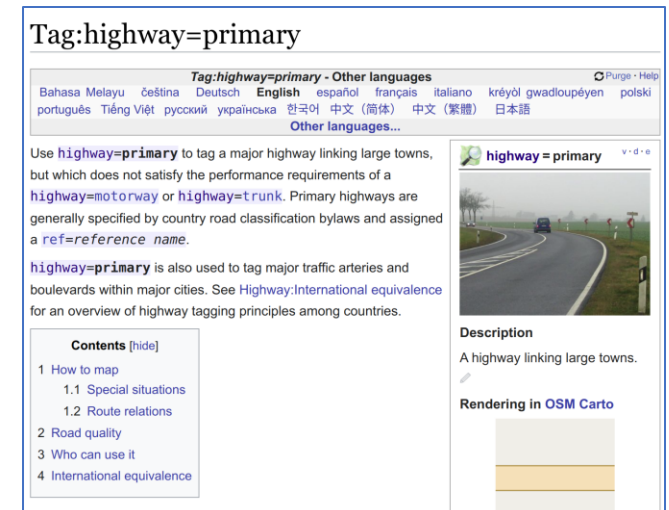
- Baseline + *When guessing the correct category, consider that the following list of objects (separated by semicolon) are present in the photograph: Temporary barrier; Traffic light - horizontal; Traffic light - pedestrian; Signage*

- Object-Detection + Locational Context (OD + LC)

- Baseline + OD + LC

- ChatGPT's answer

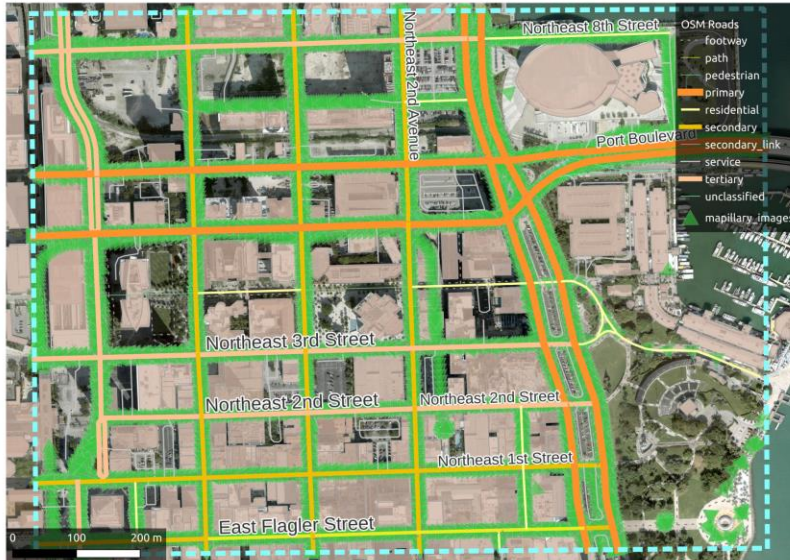
- {"highway": "primary", "lanes": 3}



The screenshot shows the OpenStreetMap wiki page for the tag `highway=primary`. The page title is "Tag:highway=primary". It features a navigation bar with various languages, including English, Spanish, French, Italian, and others. The main content area explains the use of the `highway=primary` tag, stating it is for major highways linking large towns. It also includes a description, a rendering in OSM Carto, and a table of contents with sections like "How to map", "Road quality", and "International equivalence".



# ChatGPT as a mapping assistant



Scenario	Based on semantic road categories					
	BLIP-2	Analyst #1	Analyst #2	Avg. correct [%]	% change	
Baseline	25.5	54.3	41.5	40.4	-	
LC	35.1	64.9	45.7	48.6	+8.2	
OD	29.8	63.8	60.6	51.4	+11.0	
OD + LC	43.6	66.0	70.2	59.9	+19.5	
Avg. correct [%]	33.5	62.3	54.5			

- Accuracy increases with the level of detail
  - Human analysts are better at describing images
- Accuracy increases with additional context provided
- Tag suggestions based on Analyst #2 achieved up to 70% accuracy

Table 1. Grouping distinct "highway" tag values into semantically similar categories.

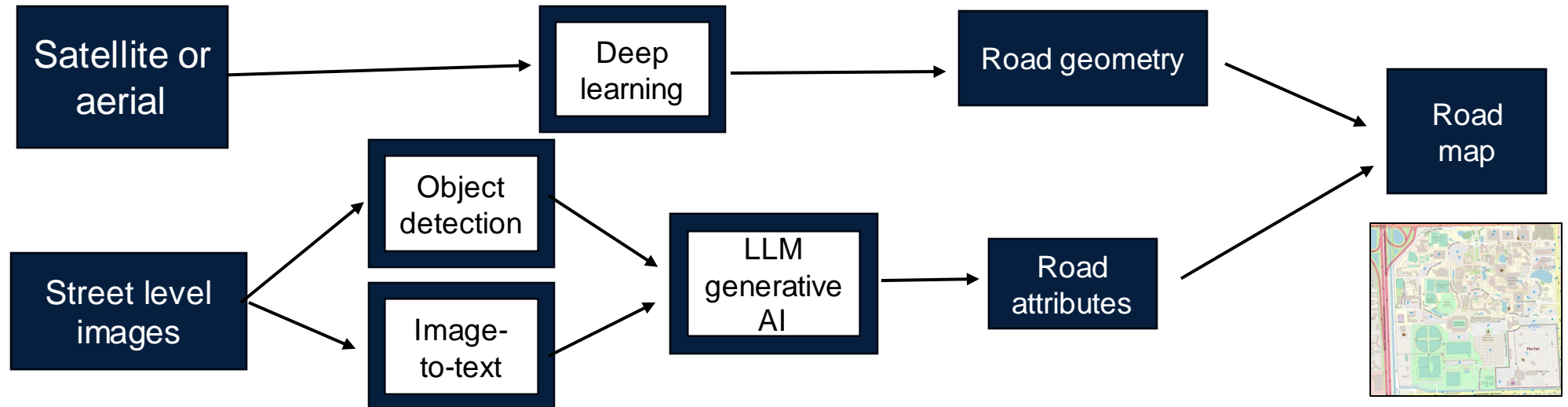
Category name	OSM "highway"	# of roads
Major, access controlled road	motorway trunk	0
Main road	primary secondary tertiary	81
Regular road	residential unclassified service	4
Not for motorized traffic	pedestrian footway cycleway	9

# ChatGPT as a mapping assistant

Table 4. ChatGPT suggestions of the "lit" tag.

	BLIP-2	Analyst #1	Analyst #2
Correctly tagged	15 (63%)	20 (83%)	22 (92%)
Additional	58	61	44

- **Additional tag suggestion**
  - "lit"="yes" 24 road segments in the dataset
  - One question for analyst explicitly asks if street lights are visible on the photo
- First step towards generating road maps with mainly AI technologies using freely available data?



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# GeoGPT

- Motivation
  - Limited by **model** and **context**
  - Contains **bias, errors, and misunderstandings**



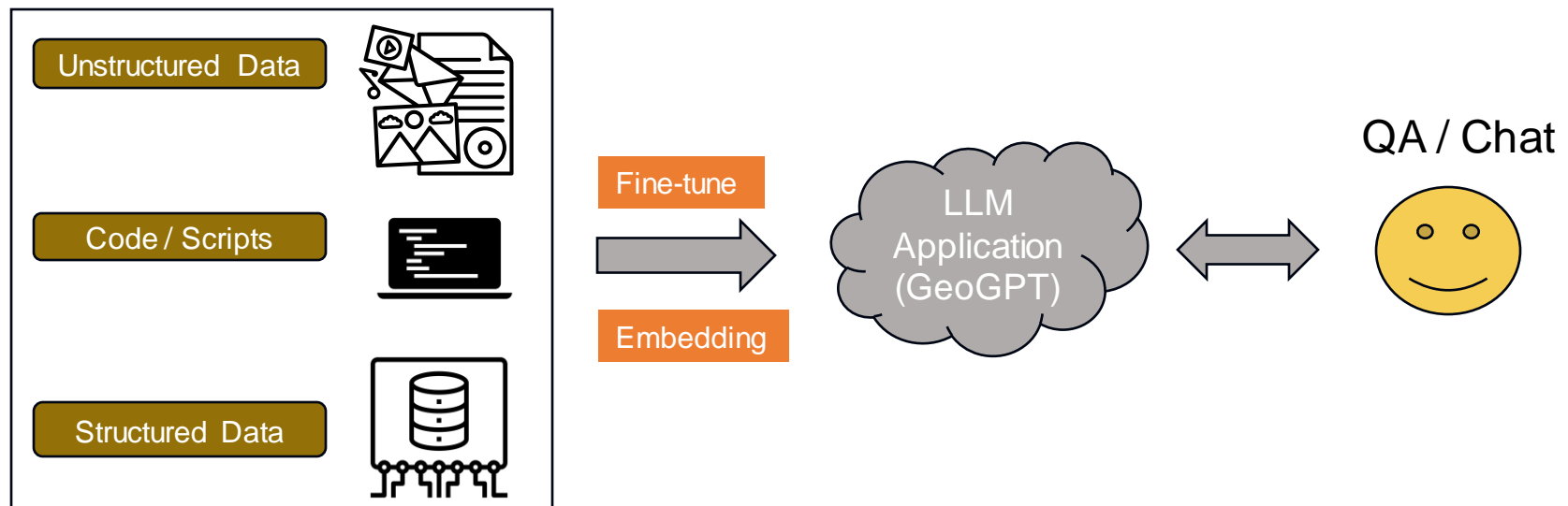
- Married **domain expertise** with **LLMs**
- Enhance the **relevance**



Domain-specific GPT  
tailored for GIS

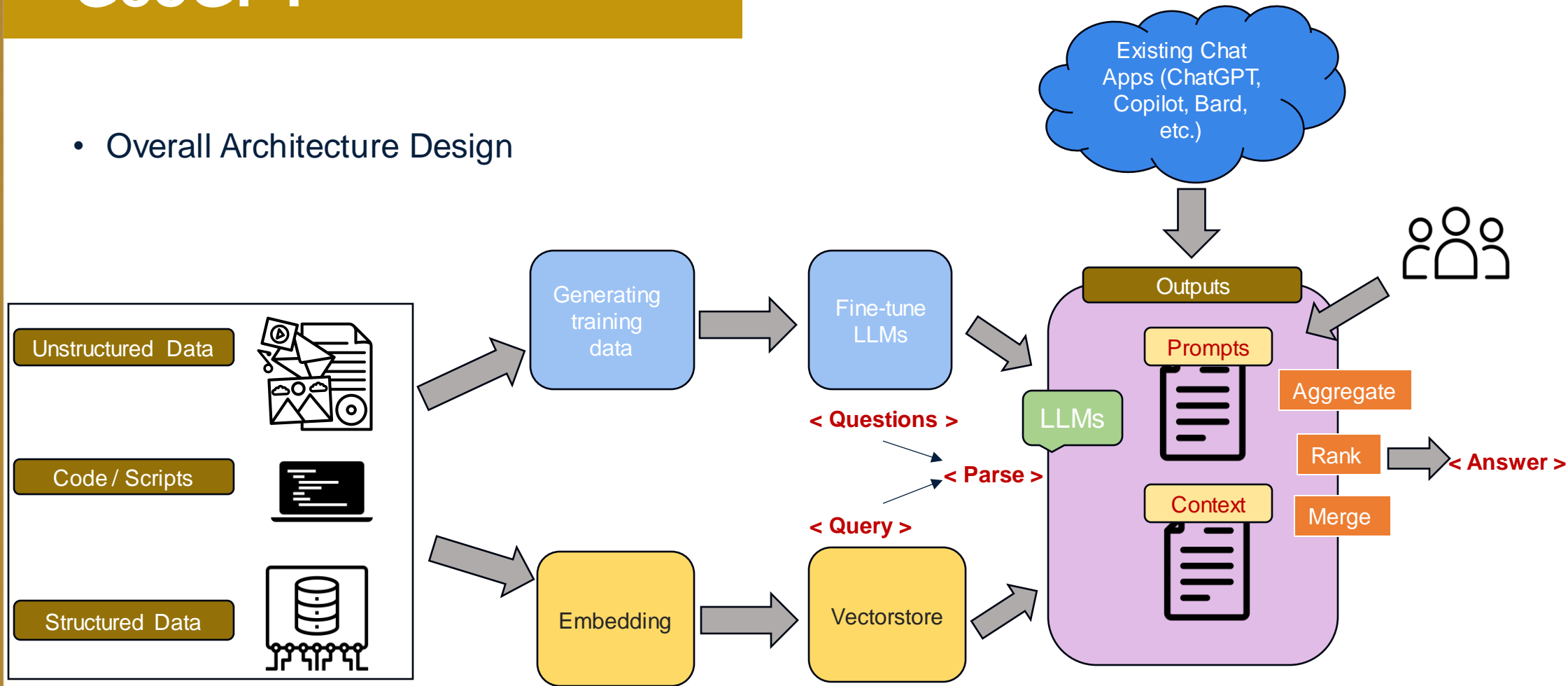
# GeoGPT

- Integrate **domain-specific** local data with LLMs Application
  - Fine-tune existing LLMs
  - Generate vector index of the local data
  - Create front-end interface so that client can "chat" with the local data



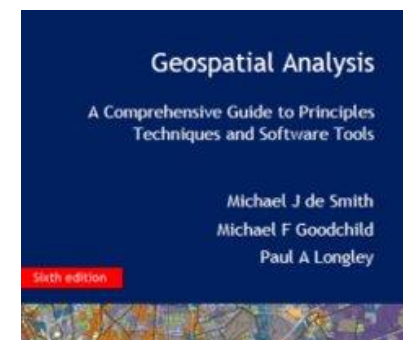
# GeoGPT

- Overall Architecture Design





# GeoGPT



<https://spatialanalysisonline.com>



<https://www.ucgis.org/gis-t-body-of-knowledge>

- Chatbot with domain knowledge (embedding gis book + gpt 3.5)

**FIU GIS Center Chatbot Beta 0.1**  
Ask a question

**You:** Great. Do they provide consultant service?

**Chatbot:** No, the FIU GIS Center does not provide consultant services.

**You:** How can I attend their workshop?

**Chatbot:** I don't know.

**You:** In GIS, Is the following statement true or false? An inverse-distance interpolator can use varying numbers of points for interpolation at a point, within any given interpolation, e.g., an interpolated point in a layer may depend on only one sample value, while an adjacent point in the same layer may depend on several sample values.

**Chatbot:** No, an inverse-distance interpolator requires a fixed number of points for interpolation at a point within any given interpolation.

Write your question Send

Model: Default (GPT-3.5)

In GIS, Is the following statement true or false? An inverse-distance interpolator can use varying numbers of points for interpolation at a point, within any given interpolation, e.g., an interpolated point in a layer may depend on only one sample value, while an adjacent point in the same layer may depend on several sample values.

The statement is true. In GIS (Geographic Information Systems), an inverse-distance interpolator can indeed use varying numbers of points for interpolation at a point within any given interpolation.

Inverse distance interpolation is a technique used to estimate values at unknown locations based on the values observed at known locations. The basic principle of inverse distance interpolation is that the values at unknown locations are estimated based on the weighted average of the known values, with closer known points having a higher weight.

In this method, the user can define a radius or a number of neighboring points to consider when estimating a value at a particular location. This means that an interpolated point in a layer may depend on only one sample value if the interpolation is configured to use only the closest point, while an adjacent point in the same layer may depend on several sample values if the interpolation is configured to consider a larger number of neighboring points.

The flexibility to vary the number of points used for interpolation allows for adaptability in capturing local variations in the data and can be helpful in situations where the data density is not uniform across the study area.

Model: GPT-4

In GIS, Is the following statement true or false? An inverse-distance interpolator can use varying numbers of points for interpolation at a point, within any given interpolation, e.g., an interpolated point in a layer may depend on only one sample value, while an adjacent point in the same layer may depend on several sample values.

True. Inverse Distance Weighting (IDW) is a type of deterministic method for multivariate interpolation with a known scattered set of points. The assigned values to unknown points are calculated with a weighted average of the values available at the known points.

The number of points (or neighbors) used in the interpolation can indeed vary based on the specific IDW method used or based on the configuration parameters set by the user. It's not necessary to always use the same number of points for interpolation. So, one point might be interpolated based on a single nearby point while another point might be interpolated based on several points. This can vary depending on the specific data, the distances involved, and the settings chosen for the interpolation.

However, it's important to note that if only one sample value is used in IDW, it becomes simply assignment of that value, not interpolation. IDW generally involves at least two points to actually interpolate.

# GeoGPT

- Chain different agent (searching)
- Prioritize on local data
- Controllable output

FIU

FIU GIS Center Chatbot Beta 0.1  
Ask a question

**You:** do you know there is a gis center in FIU?

**Chatbot:** Yes, there is a Geographic Information Systems Center (GIS Center) at Florida International University.


**You:** tell me something about that

**Chatbot:** The GIS Center at Florida International University supports and facilitates the teaching and research activities of the FIU community in the areas of geographic information systems, remote sensing, geospatial web visualization and geospatial data management. It offers a wealth of geo-datasets, including high resolution imagery data and historical coastal maps and data, and a robust 80 TB cloud server cluster. It also provides specialized software programs such as ArcGIS, ENVI, and SAGA for classroom teaching. The Center collaborates on grants and contracts with a wide variety of University departments, offering expertise in geospatial web, geospatial data/metadata creation, data management and dissemination,

Write your question Send


⚡ Model: Default (GPT-3.5)

I do you know there is a gis center in FIU?

 Yes, I am aware that Florida International University (FIU) has a GIS (Geographic Information Systems) Center. The GIS Center at FIU is dedicated to promoting research, education, and application of geospatial technologies. It serves as a resource for students, faculty, and the community in utilizing GIS tools and geospatial data for various projects and studies. The center offers training, workshops, and access to GIS software and data resources. It collaborates with other academic departments, government agencies, and private organizations to enhance the understanding and use of GIS technology in various fields.

⚡ Model: GPT-4

I do you know there is a gis center in FIU?

 As of my knowledge cutoff in September 2021, I don't have the specific information on whether there is a GIS (Geographic Information System) center at Florida International University (FIU). My training data only includes knowledge up until September 2021, and this type of information can change or evolve after that date.

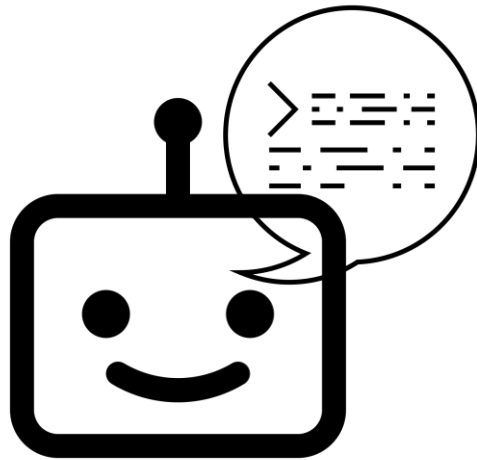
As of that time, many universities around the world had GIS centers or programs due to the importance of GIS in many fields such as environmental science, urban planning, transportation, and public health. FIU, being a large and comprehensive public university, offers various programs and resources for its students. So it's quite possible that they would have resources related to GIS.

I would recommend checking FIU's official website or contacting them directly for the most accurate and up-to-date information.

# GeoGPT

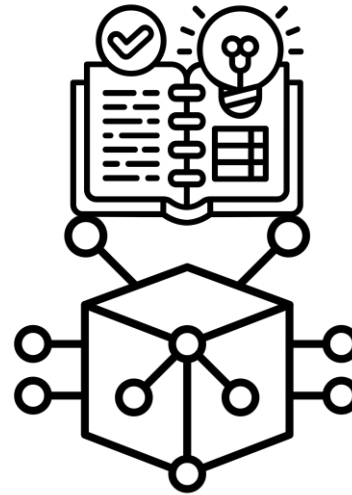
- Future works

Virtual Assistant / Tutor



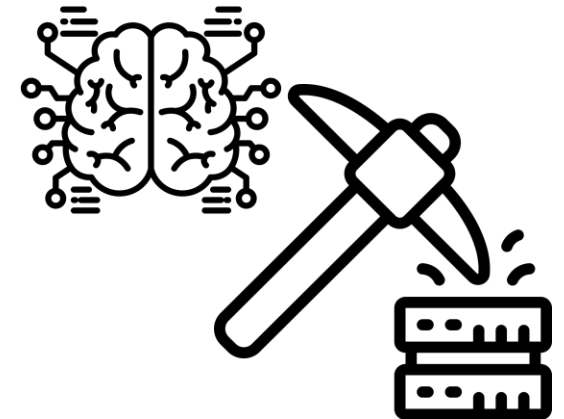
 Education & Services


Domain Specific Model



 Domain Knowledge Extension & Enrich

AI Data Miner



 Existing Data Discovery & Exploration

# Outline

- Introduction
- Case Study #1: Towards Understanding the Spatial Literacy of ChatGPT
- Case Study #2: Mapping with ChatGPT
- Case Study #3: ChatGPT as a Mapping Assistant
- Case Study #4: GeoGPT
- Summary

# Summary

- Generative AI and LLMs are here
- A lot of potential to help GIS workflows
  - Coding, designing workflows, generating maps, assisting analysts, etc.

More research is needed to harness full potential, understand limitations, biases, etc.



# Thank you!! Questions??

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