Some helpful tools I’m using in my research

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Guest Lecture – ARE 202A, Introduction to Applied Research Methods
November 19th, 2024

Layout

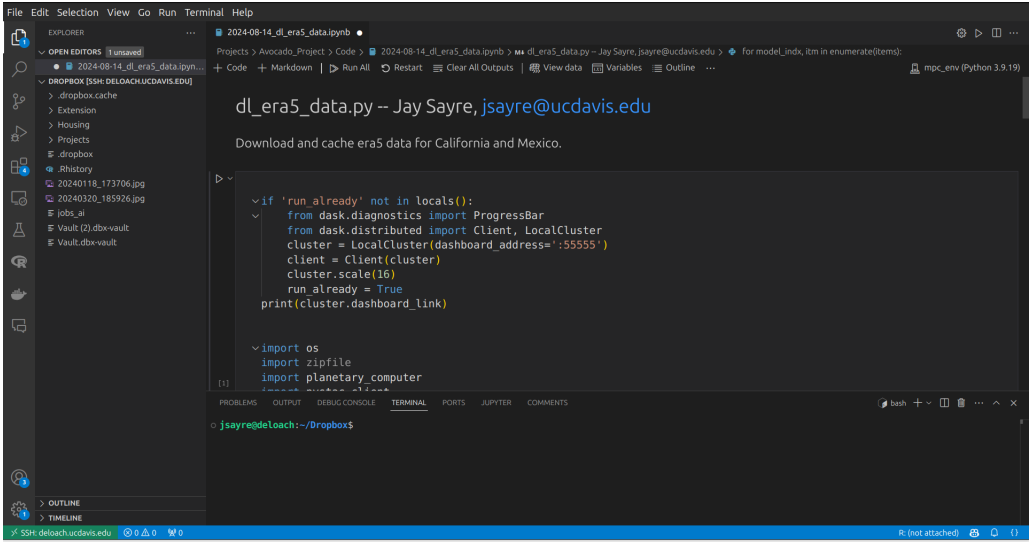
1. VS Code and the ARE Servers
2. GitHub Copilot
3. Makefiles
4. APIs for LLMs: Converting image, text, and audio inputs into quantitative data

Visual Studio Code (VS Code)

What is VS Code?

- A lightweight, open-source code editor
- Similar to Jupyter notebooks or RStudio, but supports multiple programming languages
- Most importantly, has vast ecosystem of plugin tools
  - Integrates with git and Github, as well as Github Copilot (more on this later)
  - Has extensions for running Python, R, and Julia code in neat blocks
- My favorite feature: lets you use the ARE departmental servers via SSH without needing to have a virtual window (RDP) to the server, which can have latency issues on slow connections
  - Arnon Erba can help you get set up with this

VS Code running resources on Deloach



GitHub Copilot

What is GitHub Copilot?

- AI-powered code completion tool that suggests code snippets as you type
- Supports multiple programming languages (Julia, Python, R, Stata,...) and integrates in popular IDEs like VS Code and RStudio

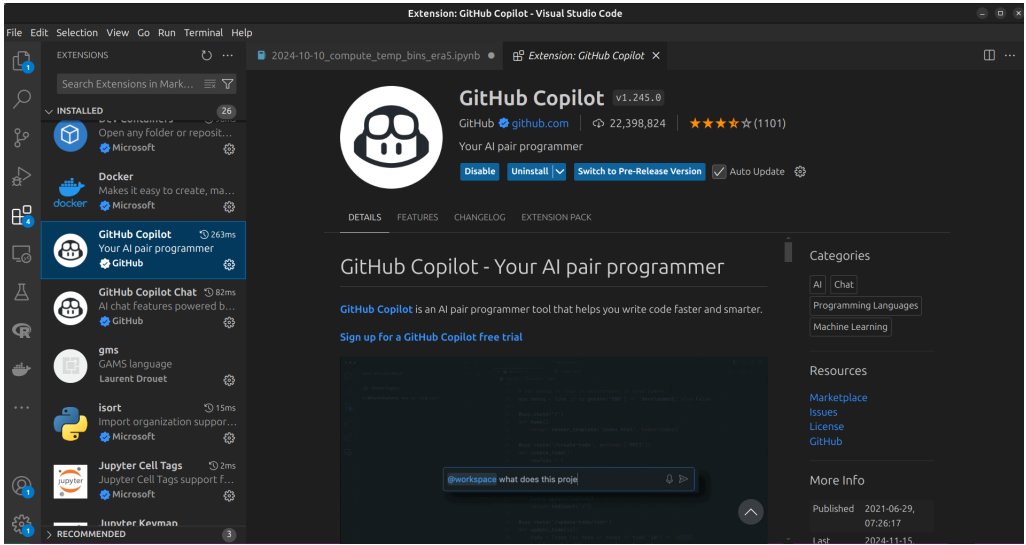
Benefits:

- Accelerates repetitive coding tasks and provides suggestions based on project structure and comments
- The suggestions are often really good!

Warning:

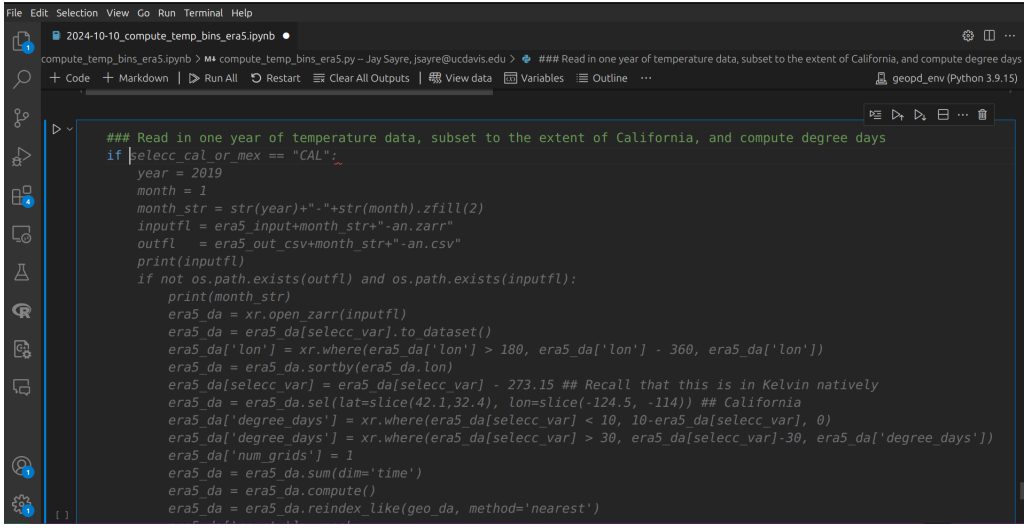
- Makes it almost too easy to write code – can make sometimes large mistakes, should not be a substitute for careful thinking

GitHub Copilot Installation



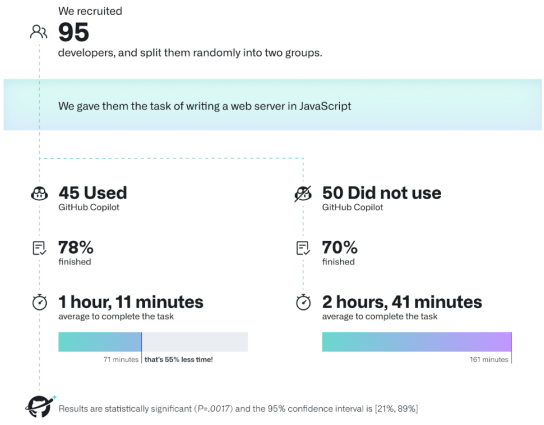
- Requires a GitHub account to access Copilot (educational plan is free)

GitHub Copilot in Action



- All of the code in gray is predicted based on preceding document

Research on GitHub Copilot



- Pandey et al. (2024) – 33-36% reduction in time spent in coding related tasks
- Song et al. (2024) – 6.5% increase in project level productivity with no decrease in code quality, larger increases for developers with *more* subject expertise

Replicability of code

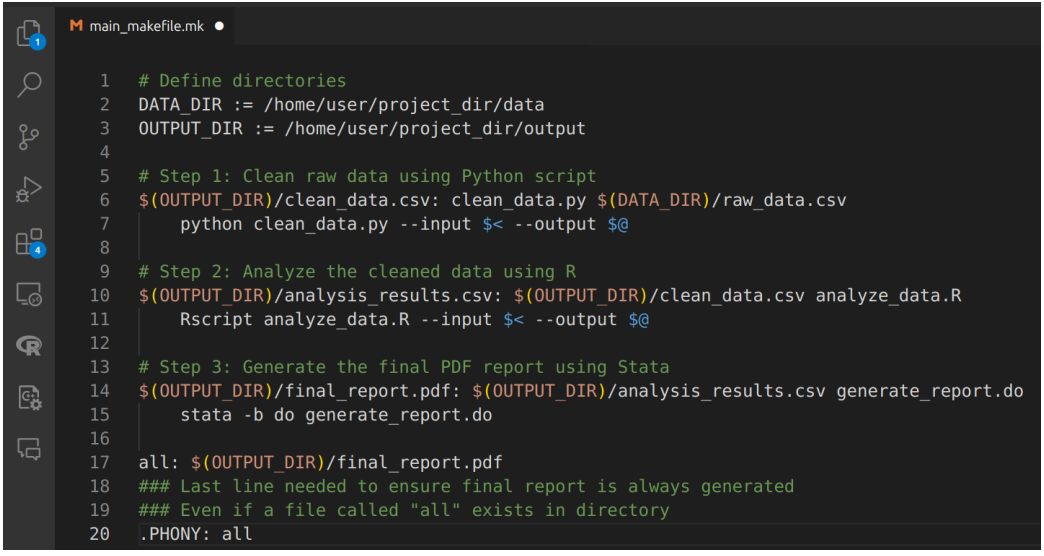
- Many journals now require code and some will even do basic replication of the package
- One common way to facilitate this is a script that will run all of your other scripts

- If your project is simple and in only one programming language (e.g. R), perhaps a quick R script that runs all your R scripts is sufficient

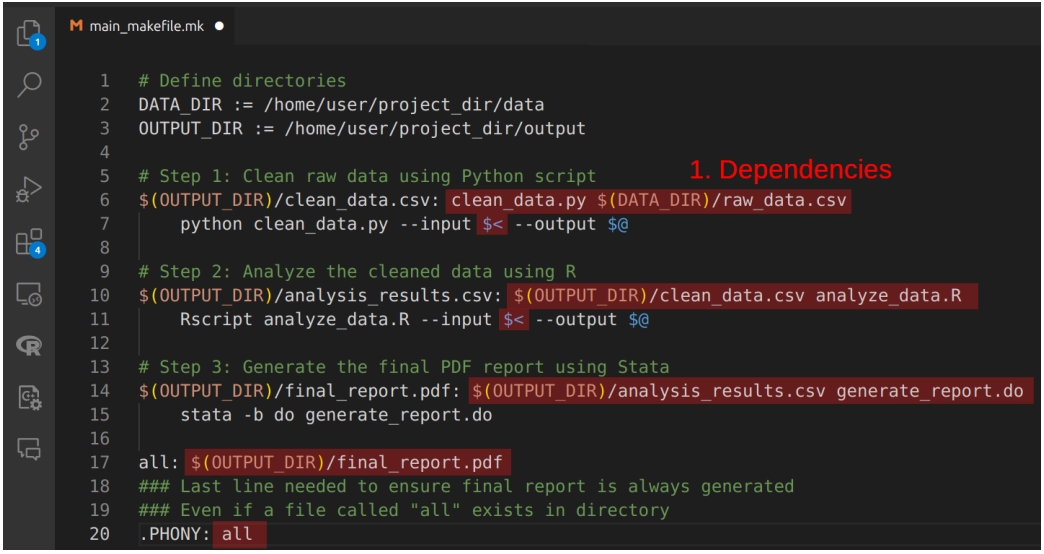
Arguments for makefiles

- Many projects now use mutliple programming languages (Julia, Matlab, Python, R, Stata) and the replication code should be multimodal and agnostic to the type of program used
- A *makefile* accomodates this, and can help manage the research process, especially if you need to iteratively update parts of your analysis as new data comes in
- Suppose you collect new data from a survey, and you want to update your regression analyses accordingly, but don't need to rerun other parts of your analysis (e.g. pre-treatment balance tables)
- With a normal script, you'd either need to rerun everything or manually figure out what to rerun
- A *makefile* automates this process, tracking changes in inputs and which outputs depend on them

Example Makefile for a Research Project

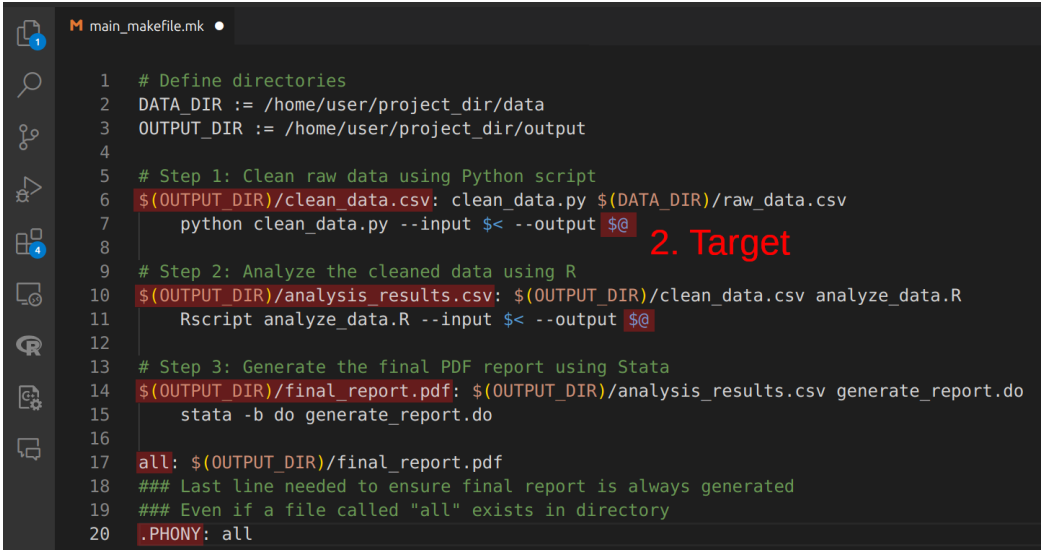


Makefile: defining inputs

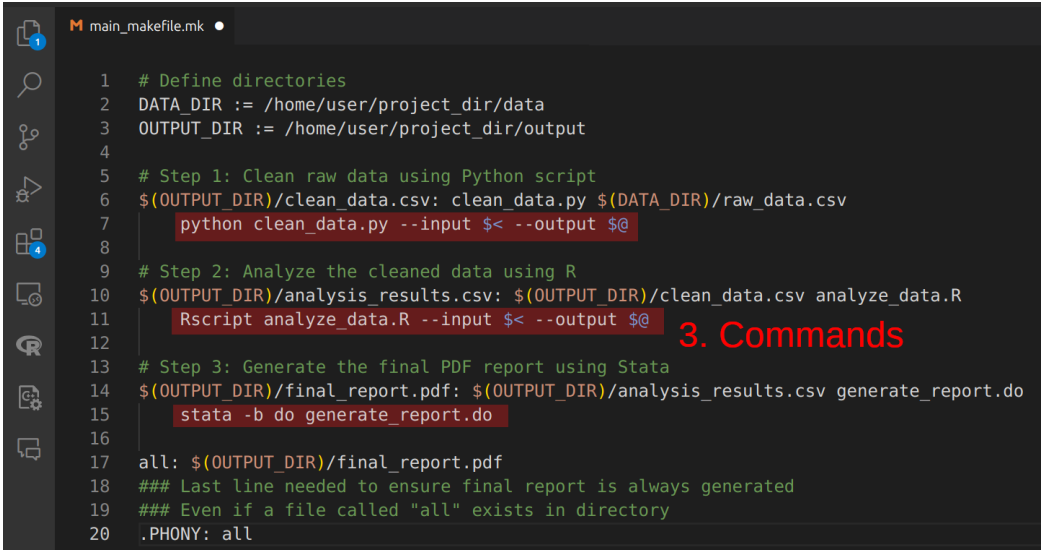



```
1  # Define directories
2  DATA_DIR := /home/user/project_dir/data
3  OUTPUT_DIR := /home/user/project_dir/output
4
5  # Step 1: Clean raw data using Python script
6  $(OUTPUT_DIR)/clean_data.csv: clean_data.py $(DATA_DIR)/raw_data.csv
7      python clean_data.py --input $< --output $@
8
9  # Step 2: Analyze the cleaned data using R
10 $(OUTPUT_DIR)/analysis_results.csv: $(OUTPUT_DIR)/clean_data.csv analyze_data.R
11     Rscript analyze_data.R --input $< --output $@
12
13 # Step 3: Generate the final PDF report using Stata
14 $(OUTPUT_DIR)/final_report.pdf: $(OUTPUT_DIR)/analysis_results.csv generate_report.do
15     stata -b do generate_report.do
16
17 all: $(OUTPUT_DIR)/final_report.pdf
18 ### Last line needed to ensure final report is always generated
19 ### Even if a file called "all" exists in directory
20 .PHONY: all
```

Makefile: defining outputs



Makefile: defining scripts



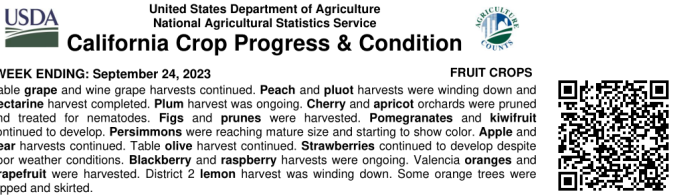
Cons of makefiles

- Makefiles can be slow to write, and tracking all of the inputs to each file can be time-intensive ex-post
- For simple projects probably not worthwhile
- If you start every project by defining inputs and outputs in the makefile and then use it to pass these arguments into your code, this cost is greatly reduced
- Much of the documentation you'd need to do anyway is provided by the steps in the makefile

Using APIs for LLMs in research

- Most likely you (and your students) are already quite familiar with Large Language Models (LLMs)
- However, researchers are realizing how LLMs like GPT-4 and Claude can be used to convert unstructured inputs into structured, quantitative data that can be used for analysis
- Applications range from text analysis, image recognition, and audio transcription
- You can usually test these features one by one in a browser window
- APIs (application programming interfaces) provide a way to use LLMs with large data sources

Some examples: classification of text data



United States Department of Agriculture
National Agricultural Statistics Service

California Crop Progress & Condition

WEEK ENDING: September 24, 2023 **FRUIT CROPS**

Table **grape** and wine grape harvests continued. **Peach** and **pluot** harvests were winding down and **nectarine** harvest completed. **Plum** harvest was ongoing. **Cherry** and **apricot** orchards were pruned and treated for nematodes. **Figs** and **prunes** were harvested. **Pomegranates** and **kiwifruit** continued to develop. **Persimmons** were reaching mature size and starting to show color. **Apple** and **pear** harvests continued. Table **olive** harvest continued. **Strawberries** continued to develop despite poor weather conditions. **Blackberry** and **raspberry** harvests were ongoing. Valencia **oranges** and **grapefruit** were harvested. District 2 **lemon** harvest was winding down. Some orange trees were topped and skirted.

	A	B	C	D	E	F	G	H	I	J
1	crop	planting	harvesting	developing/growing/maturing	soil preparation	irrigation	pruning	county	date	type_crop
1362	table grape	0	1	0	0	0	0		2023-09-24	fruit_crops
1363	wine grape	0	1	0	0	0	0		2023-09-24	fruit_crops
1364	peach	0	1	0	0	0	0		2023-09-24	fruit_crops
1365	pluot	0	1	0	0	0	0		2023-09-24	fruit_crops
1366	nectarine	0	1	0	0	0	0		2023-09-24	fruit_crops
1367	plum	0	1	0	0	0	0		2023-09-24	fruit_crops
1368	cherry	0	0	0	0	0	1		2023-09-24	fruit_crops
1369	apricot	0	0	0	0	0	1		2023-09-24	fruit_crops
1370	fig	0	1	0	0	0	0		2023-09-24	fruit_crops
1371	prune	0	1	0	0	0	0		2023-09-24	fruit_crops
1372	pomegranate	0	0	1	0	0	0		2023-09-24	fruit_crops
1373	kiwifruit	0	0	1	0	0	0		2023-09-24	fruit_crops
1374	persimmon	0	0	1	0	0	0		2023-09-24	fruit_crops
1375	apple	0	1	0	0	0	0		2023-09-24	fruit_crops
1376	pear	0	1	0	0	0	0		2023-09-24	fruit_crops
1377	table olive	0	1	0	0	0	0		2023-09-24	fruit_crops
1378	strawberry	0	0	1	0	0	0		2023-09-24	fruit_crops
1379	blackberry	0	1	0	0	0	0		2023-09-24	fruit_crops
1380	raspberry	0	1	0	0	0	0		2023-09-24	fruit_crops
1381	valencia orange	0	1	0	0	0	0		2023-09-24	fruit_crops
1382	grapefruit	0	1	0	0	0	0		2023-09-24	fruit_crops
1383	lemon	0	1	0	0	0	0	District 2	2023-09-24	fruit_crops
1384	orange	0	0	0	0	0	1		2023-09-24	fruit_crops

OCRing PDF scans

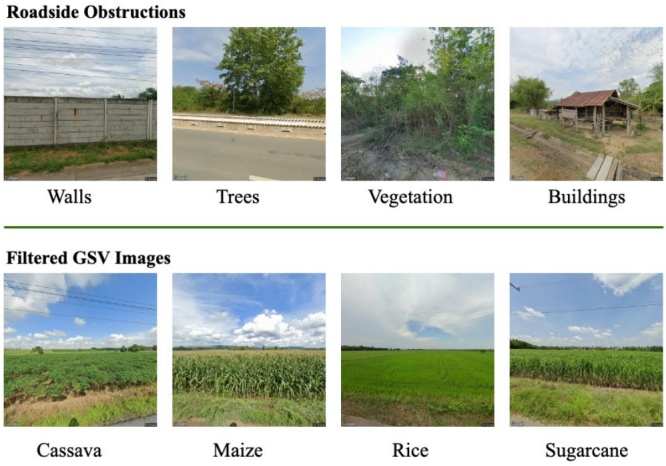
1a. FECHA DE INSPECCIÓN DATE INSPECTED	1b. FECHA DE EXPEDICIÓN DATE ISSUED	1c. LUGAR DE EXPEDICIÓN PLACE OF ISSUE
MARZO 02 DE 2020	MARZO 10 DE 2020	TIJUANA, B.C., MÉXICO

DESCRIPCIÓN / DESCRIPTION

2. NOMBRE Y DIRECCIÓN DEL EXPORTADOR NAME AND ADDRESS OF EXPORTER	3. NOMBRE Y DIRECCIÓN DECLARADOS DEL DESTINATARIO DECLARED NAME AND ADDRESS OF CONSIGNEE
LIMONES MONICA S.A. DE C.V. ANDADOR DEL REY #20051-C COL. RANCHO EL AGUILA, TIJUANA, B.C., MEXICO	LIMONIK PRODUCE INC. 3200 E. GUASTI RD, SUITE 100 ONTARIO CA. 91761, E.U.A.
4. CANTIDAD DECLARADA Y NOMBRE DEL PRODUCTO NAME OF PRODUCE AND QUANTITY DECLARED	
568.75 KG DE LIMON MEXICANO	
5. NOMBRE BOTÁNICO DE LAS PLANTAS BOTANICAL NAME OF PLANTS	6. LUGAR DE ORIGEN PLACE OF ORIGIN
Citrus aurantifolia	TECOMAN, COLIMA
7. NÚMERO Y DESCRIPCIÓN DE LOS EMPAQUES NUMBER AND DESCRIPTION OF PACKAGES	8. MARCAS DISTINTIVAS DISTINGUISHING MARKS
35 CAJAS	FANCY LIMES
9. MEDIOS DE TRANSPORTE DECLARADOS DECLARED MEANS OF CONVEYANCE	10. PUNTO DE ENTRADA DECLARADO DECLARED POINT OF ENTRY
TERRESTRE/TRAILER	MESA DE OTAY, CA.

Some examples: classification of image data

Soler, Friedel, and Wang (2024): “Combining Deep Learning and Street View Imagery to Map Smallholder Crop Types”



Soler, Friedel, and Wang (2024): "Combining Deep Learning and Street View Imagery to Map Smallholder Crop Types"

	Street-view Test Set Metrics						
Training Dataset	**Overall Acc**	**Overall F1**	**Rice F1**	**Cassava F1**	**Maize F1**	**Sugarcane F1**	**Other F1**
Baseline: Most common	0.67	0.54	0.80	0.00	0.00	0.00	0.00
WebCC	0.82 ± 0.04	0.82 ± 0.03	0.90 ± 0.03	0.73 ± 0.07	0.62 ± 0.09	0.62 ± 0.04	0.49 ± 0.07
iNaturalist	0.81 ± 0.04	0.82 ± 0.03	0.89 ± 0.02	0.63 ± 0.06	0.68 ± 0.06	0.76 ± 0.04	0.51 ± 0.08
iNaturalist + WebCC	0.85 ± 0.02	0.85 ± 0.02	0.91 ± 0.02	0.75 ± 0.04	0.71 ± 0.06	0.78 ± 0.03	0.62 ± 0.06
GPT-4V (zero-shot)[†]	$\mathbf{0.95 \pm 0.00}$	$\mathbf{0.95 \pm 0.00}$	$\mathbf{0.97 \pm 0.00}$	$\mathbf{0.97 \pm 0.00}$	$\mathbf{0.89 \pm 0.00}$	$\mathbf{0.93 \pm 0.00}$	$\mathbf{0.87 \pm 0.00}$
GPT-4V labeled	0.92 ± 0.01	0.92 ± 0.01	0.94 ± 0.01	0.86 ± 0.03	0.81 ± 0.02	0.90 ± 0.02	0.77 ± 0.06
Expert labeled	$\mathbf{0.93 \pm 0.01}$	$\mathbf{0.93 \pm 0.01}$	0.94 ± 0.01	$\mathbf{0.87 \pm 0.03}$	$\mathbf{0.82 \pm 0.03}$	$\mathbf{0.92 \pm 0.02}$	$\mathbf{0.79 \pm 0.05}$
Combined	0.93 ± 0.01	0.93 ± 0.01	$\mathbf{0.95 \pm 0.01}$	0.86 ± 0.03	0.81 ± 0.03	0.92 ± 0.02	0.77 ± 0.05

Table 4: Performance on crop type classification from street-view images for the four major crops in Thailand. Models were trained on combinations of three different training datasets: WebCC, iNaturalist, GPT-4V labeled, and Expert labeled GSV images. The MHP threshold was set to 0.9. [†]GPT-4V refers to GPT-4V zero-shot performance on the test set. Each model is trained 5 times with different seeds and bootstrapped training sets. Datasets are ordered by increasing labeling cost.

Using a LLM API

- Need to obtain an API key, and set up payment

```python
def analyze_gpt_text(prompt, structured_functions):
    # Define the content with text information (without the function call)
    content = {
        "role": "user",
        "content": prompt
    }

    # Create the response using OpenAI's client
    response = openai.chat.completions.create(
        model="gpt-4o",
        temperature=0,
        messages=[content],
        functions=structured_functions,
        function_call={"name": "extract_soil_certificate_info"}
    )
```

- If an option like “temperature” exists, you should always keep it at 0 (default value)! This influences how random the results are -> 0 is deterministic

- Warning: you probably shouldn’t upload sensitive/restricted information to these APIs. Many say that they won’t store your information, but...

Conclusion

- You can find the code used in this presentation and to access the OpenAI API here: https://github.com/jaysayre/ResearchTools

- Thanks!

- Contact: jsayre@ucdavis.edu