Lecture 2: September 3

ML Project Design

ACM September GBM

When: Friday (9/5), 4:00 - 5:00 PM

Where: SEH B1270

THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON, DC

acm

Agenda

- Senior Design High Level Timeline
- Github Projects Setup & Sprint Progress Expectations
- ML Project Design
- Tech Lab Overview

Agenda

- **Senior Design High Level Timeline**
- Github Projects Setup & Sprint Progress Expectations
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Month	Expected Status	Monthly Focus	Deliverables
September	N/A	- Figure out teams - Brainstorm projects	- Create teams - resume
Mid-September	- Teams selected - Handful of project ideas	- Final project selection - Begin meeting w/ mentors	- Project proposal - Hardware/software request - Writing: Team Charter
October	- Project selected & approved	- Begin technical investigations (services, apis, language, etc) - Flesh out project functionality & requirements - Coding should start (scaffolding, ci/cd, prototyping)	- Writing: Technical summary - Presentation: Elevator pitch
November	- Main technologies selected - project is well-defined - Everyone is actively coding	- Answer all questions needed to complete TDD - Lot's of coding for alpha review	- Writing: PRD/TDD - Presentation: Project Design
December	- Code complete for alpha review	- more coding for demo 2 - Formalize design discussions into proper TDD	- Alpha review - Presentation: Alpha prototype - Writing: revised PRD/TDD
January	- Continued focus on project development	- continued development for demo 2 - focus on proper testing & integration	- Website Design - demo 2
February	- Code complete for demo 2	- Refine code from a prototype into a fleshed out project -- testing, integration, polishing - continued development for prelim prototype (get as close to finished as you can here)	- Presentation: skill refinement - demo 3
March	- Code complete for demo 3	- final code polishing to wrap up project - complete any necessary integration work - add extra features if possible	- demo 4
April	**- Code 99% complete for final demo**	- finishing touches for final project submission - ideally you are done with coding by this point	- Final demo - Presentation: Final demo
May			- Final package due

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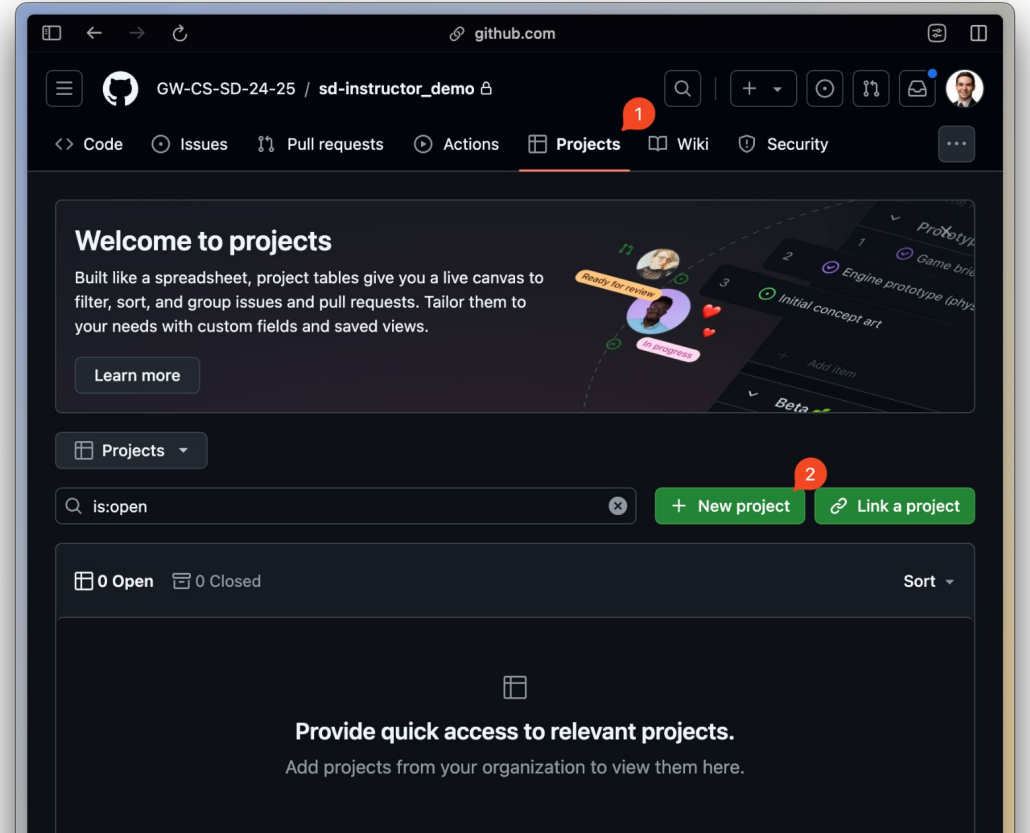
Sprint Progress - Components

- Sprint Board
- Weekly Updates
- Slack Participation
- Code

Components - Sprint Board

- Team members should create a backlog of tickets to work on
- At the beginning of each sprint, members should pull tickets from their backlog into their sprint
- Tickets should include the following:
  - Description
  - Assignee
  - Epic
  - Due date
  - Sprint
  - Status
- By the end of a sprint, all tickets should be **done**, **won't do**, or moved to the next sprint
- All senior design work should be accompanied by tickets (including presentations & writings)
- Tickets should be appropriately scoped to single features/prs
- Sprint boards should be created / populated during monthly sprint planning

Create Github Project Boards



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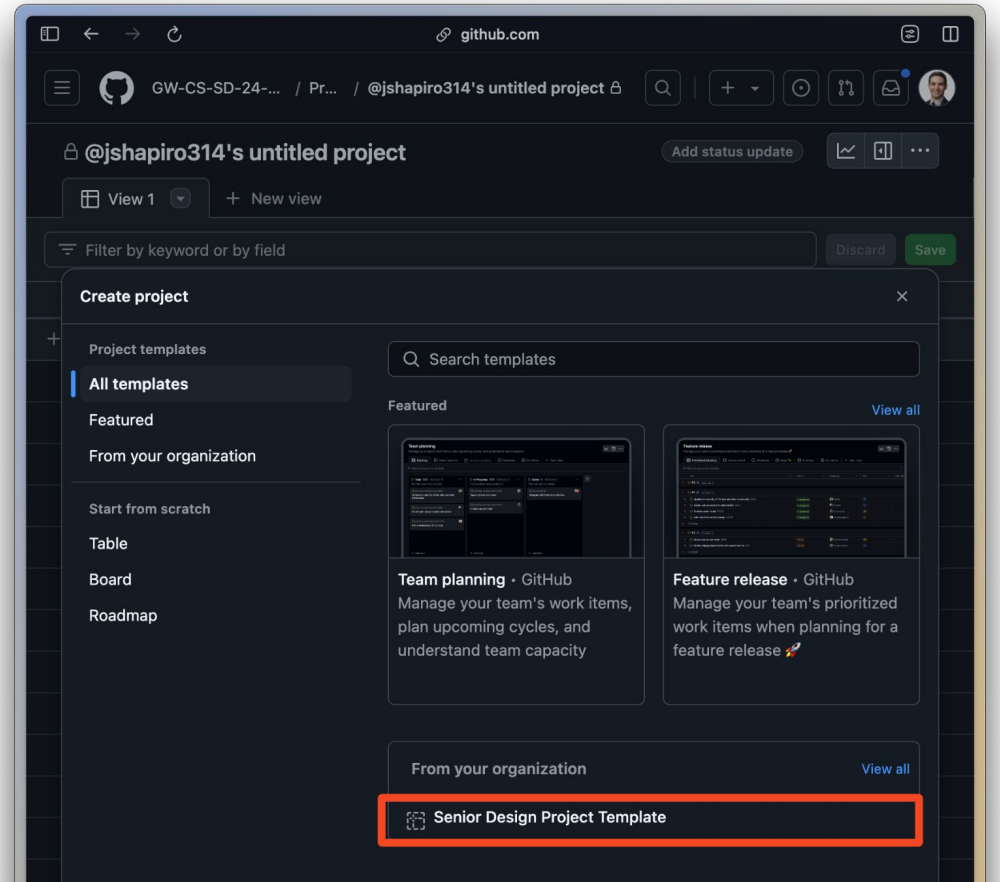

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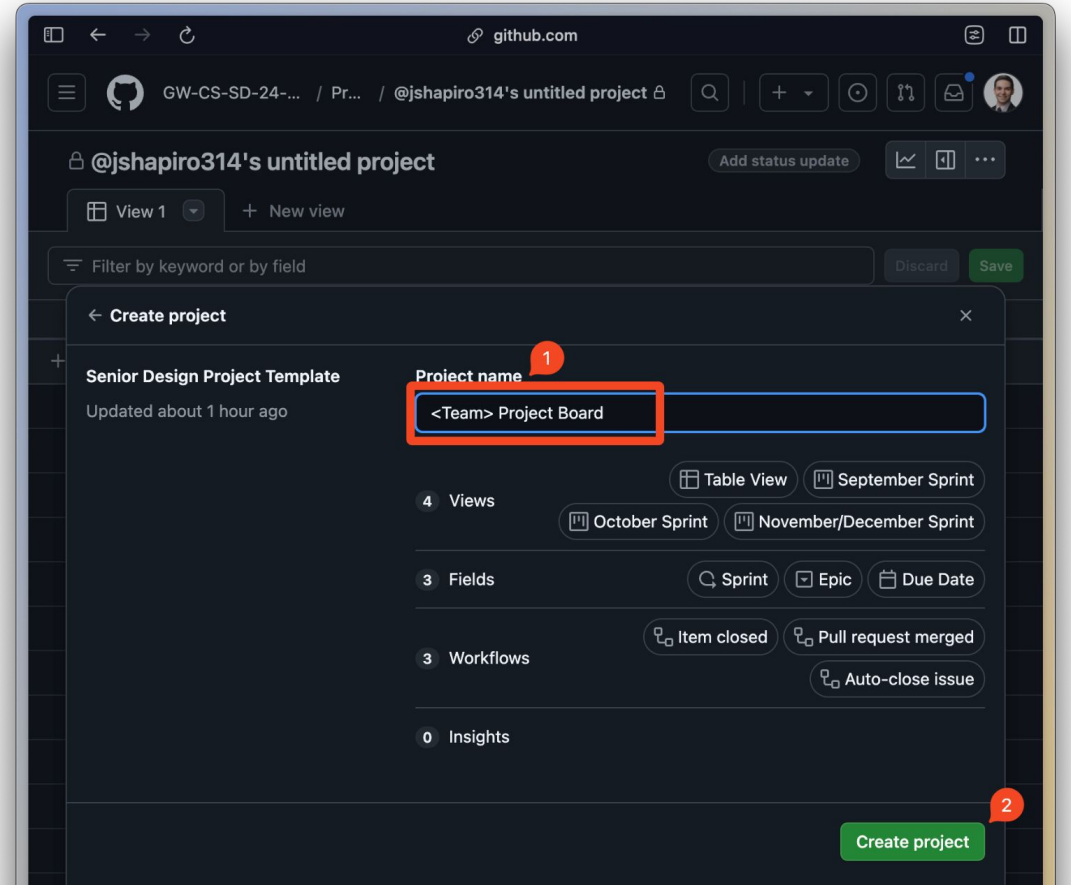

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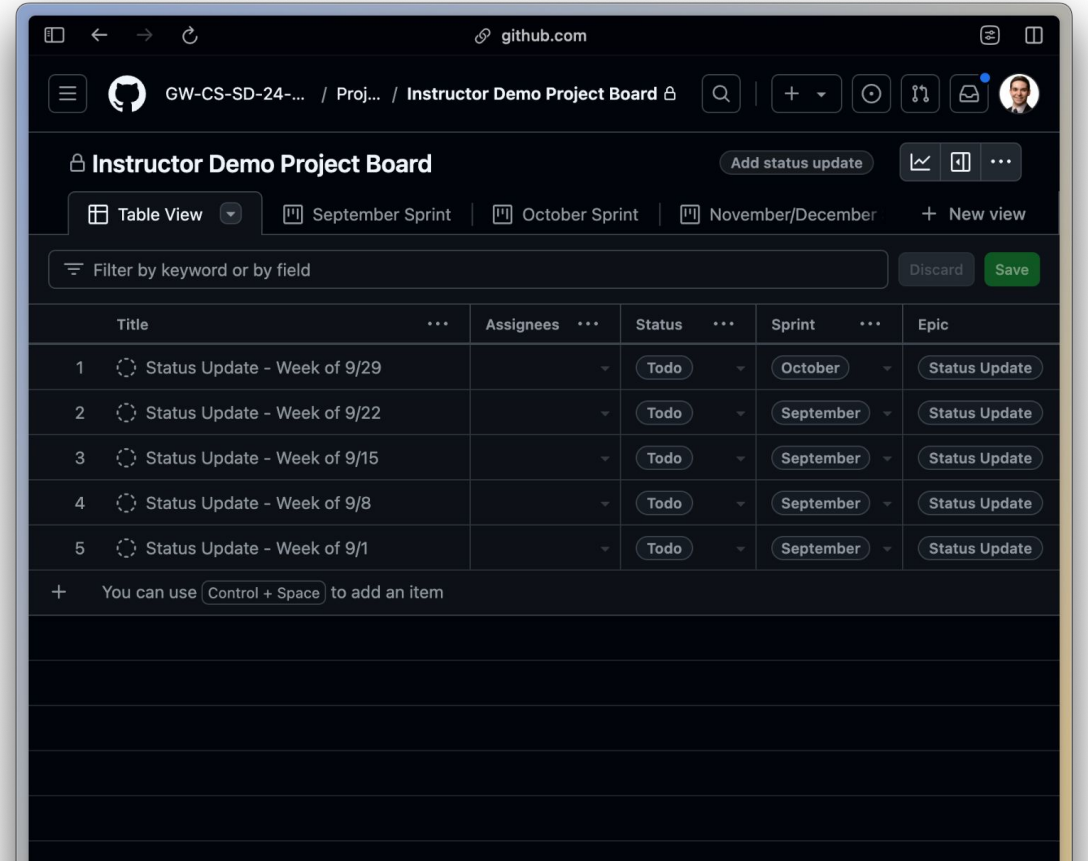

Create September Tickets

Title	Epic	Due Date	Assignees	Sprint	Status
Submit Resume	Writing	9/7	Individual	September	TODO
Draft Project Proposal	Design	9/14	all	September	TODO
Refined Project Proposal	Design	9/21	all	September	TODO
HW/SW Requests	Design	9/21	all	September	TODO
Writing 1	Writing	10/5	all	October	TODO

Components - Status Updates

- Students should post weekly status updates covering:
  - What they completed (can link out to tickets)
  - What they are blocked by
  - What they are currently working on
  - **Each student must leave their own comment**
  - It is ok for the update to reflect no work
- These updates should be captured on **Status Update** tickets
  - Move ticket from TODO to DONE as week progresses
  - Leave comment BEFORE DUE DATE to receive credit
- Complete these updates prior to end of week (use to lead discussion w/ mentors & instructors)
- Create new status update tickets as sprints progress
  - Title should be **Status Update - Week of MM/YY (monday)**
  - Due date should be following Sunday

Components - Slack / Participation

- Use slack as the main communication method between teammates and:
  - Other teammates
  - Mentors
  - Instructors

Components - Code

- We expect all students to write code for senior design
- Only code pushed to main/master will be evaluated
- Code should be written in branches & PRed into master
- PR reviews are **highly encouraged** during the fall and **required** in the spring
- Code PRs should be well-scoped to single features and tied to sprint tickets

Sprint Progress Rubric

Fall Semester

Full credit

- Tickets addressed as either “done”, “won’t do”, or moved to next sprint.
- Weekly standup updates & slack participation
- Code is PRed & merged to master. Branches & PRs are well-scoped.

Partial credit

- Majority of tickets addressed as either “done”, “won’t do”, or moved to next sprint.
- Occasional standup updates & moderate participation
- Code is committed, PRs are sometimes present and sometimes well-scoped

Minimal credit

- Few tickets addressed as either “done”, “won’t do”, or moved to next sprint.
- Minimal standup updates & rare participation
- Minimal code is committed, PRs are missing or not well-scoped.

No credit

- No sprint board activity
- No standup updates
- No slack participation
- No code committed to master/main

Sprint Schedule

Fall Semester Sprints

September Sprint

October Sprint

November / December Sprint

Spring Semester Sprints

January Sprint (2 weeks!)

February Sprint

March Sprint

April Sprint (2 weeks!)

Agenda

- Senior Design High Level Timeline
- Github Projects Setup & Sprint Progress Expectations
- **ML Project Design**
- Tech Lab Overview

A brief detour

1. There are lots of ai-powered coding tools (cursor, copilot, chatgpt, claude, etc)
2. These tools can make it difficult to evaluate projects from the perspective of student understanding.
3. These tools are now part of a software engineer’s toolkit

For Senior Design:

1. Use whatever AI tools you want, but please include them in your team charter
2. Our expectations are higher for what you need to accomplish
3. We want to see code understanding – PR reviews will be important to measure this
4. A word of caution – ai tools on shared codebases come with their own set of challenges.

Context

1. We anticipate many teams will explore some form of machine learning as part of their senior design project

2. Implementing ML in a product is not easy. It's also not a skill set typically taught in class.

3. These are the problems I focus on day to day, and I’ve found success in this approach.

Goals

- Know when to apply ML to a problem
- Know how to build out an ML solution
- Understand what different ML roles in industry entail

Non-Goals

- Explain how to train models
- Explain how to productionize models

What makes an idea good for ML?

1. Can the problem be uniquely solved by ML?
   a. Can a human solve this task manually?
   b. Does a rules-based approach work?
   c. What are the existing bottlenecks to solving this problem?

2. Do you have data / can you get data?

3. The **IVO** test: can the user **immediately validate** the **output**?
   a. Change the user
   b. Make validation easier
   c. Change the output format

https://cloudonair.withgoogle.com/events/startup-school-ai/watch?talk=emea-amer-talk2

Agenda

- How to tell if a problem is well-suited for an ML solution
- **How to approach an ML solution (an ML Technical Design Doc)**
  - Defining the input/output
  - What is your data
  - What are the metrics
  - Establishing baselines & benchmarks
  - Model training/exploration
  - Approaching ML in Senior Design
- Different roles in the ML field

Approaching an ML Solution: **Inputs & Outputs**

1. Identify the interface of your product user experience
2. Identify the interface of your ML model(s)
    a. What is the input?
    b. What is the output?

Why?

- Adds structure to ambiguity – can't just lean on ML for scope creep
- Engineering is easier with interfaces. ML is hard, isolating from the rest of a system is important.
- Your interfaces will dictate the data you need and the training approach you're using (regression, classification, clustering, generation)

Approaching an ML Solution: **Data**

1. Do you have data that matches your input/output interface?
2. How costly is it to collect labelled data? Are there other ways of getting “labelled” data?
3. Do you have/need unlabeled data?
4. What is your training/validation/test set?
5. What are the characteristics of your data? (amount, biases, etc)

Why?

- If you don’t have data, you’re going to have a bad time.
- Figure out early if ML is not the right approach
- Data needs can change during experimentation

Approaching an ML Solution: **Metrics**

1. What offline “correctness” metrics do you care about?
2. Are there separate online metrics that are important?
3. Are there performance metrics that impact your solution?
4. What is the one metric that matters most?

Why?

- Need a way to objectively measure different approaches
- Need a way to evaluate a system once in production
- Forces you to focus attention on a small number of things to optimize

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Approaching an ML Solution: **Human Performance**

- Using the data & metrics defined previously, how does a human measure on the task?
- What is needed to collect this data?

Why?

- Ensures you can evaluate your system
- Sets a bar for performance to aim for (higher precision, higher recall, faster)

Approaching an ML Solution: **Quick Baseline**

- What is the simplest approach we can take to solve this problem? (Almost always logistic regression, xgboost, non deep learning or ml techniques)
- How does the simple approach measure up?

Why?

- Helps build out pipeline for evaluation without focusing on experimentation
- Can be used as a placeholder while building out the engineering system
- Sets a minimum bar for performance
- Identifies the gap between humans & ml

Approaching an ML Solution: **Upper Bound Baseline**

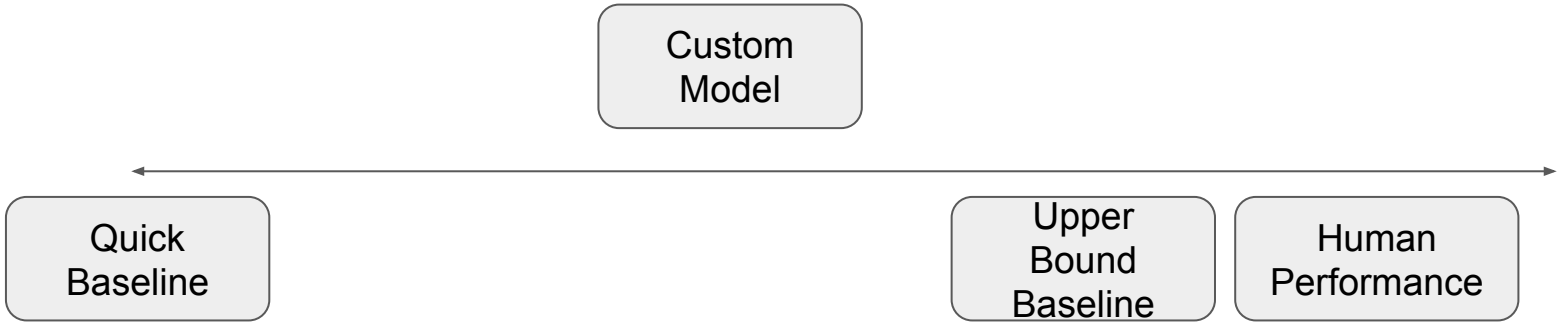
- If compute/money was no object, how would we do? (Throw an LLM at the problem)
- How does zero shot vs few shot affect results?

Why?

- Sets a pseudo-upper bound to expected ML performance
- Helps you understand tradeoffs between “accuracy” metrics & performance metrics

Approaching an ML Solution: **Experiment!**

- You've done your homework, now train your own model



ML in Senior Design

- Identify if ML is the right solution to your problem

- It is not enough to integrate ML into your solution – you must be able to explain why it is necessary / how much it helps

- Creating a full eval pipeline can be time consuming. Up to your team whether or not this is something worth prioritizing.

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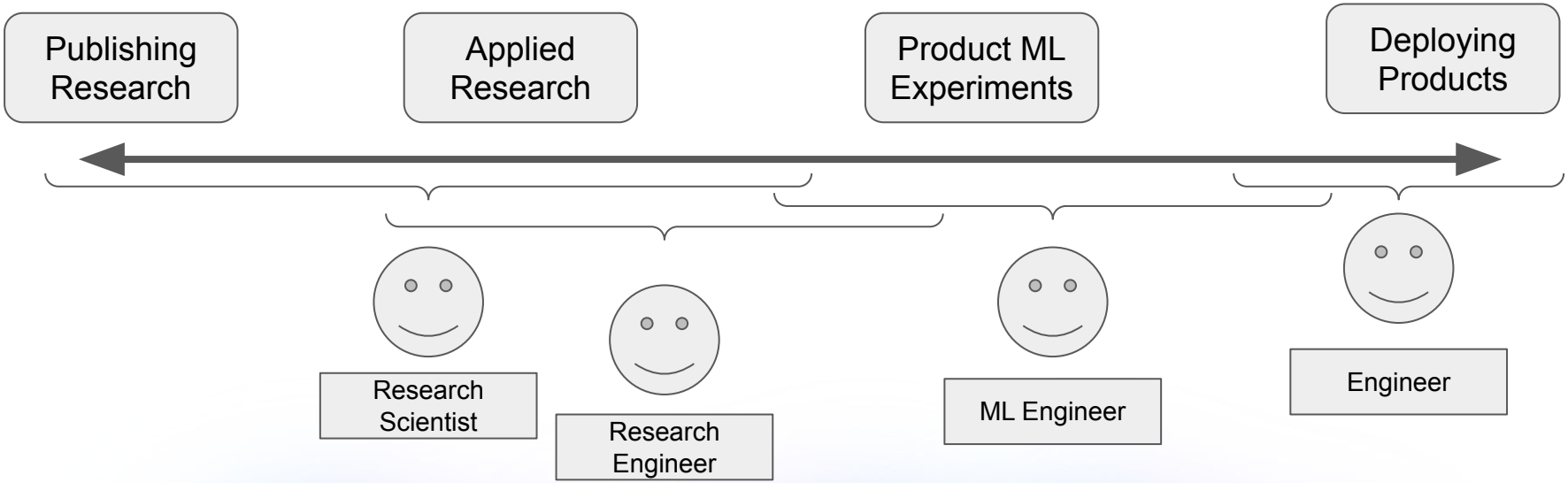
- **Different roles in the ML field**

Roles in the ML field



Research Scientist

Expectations:

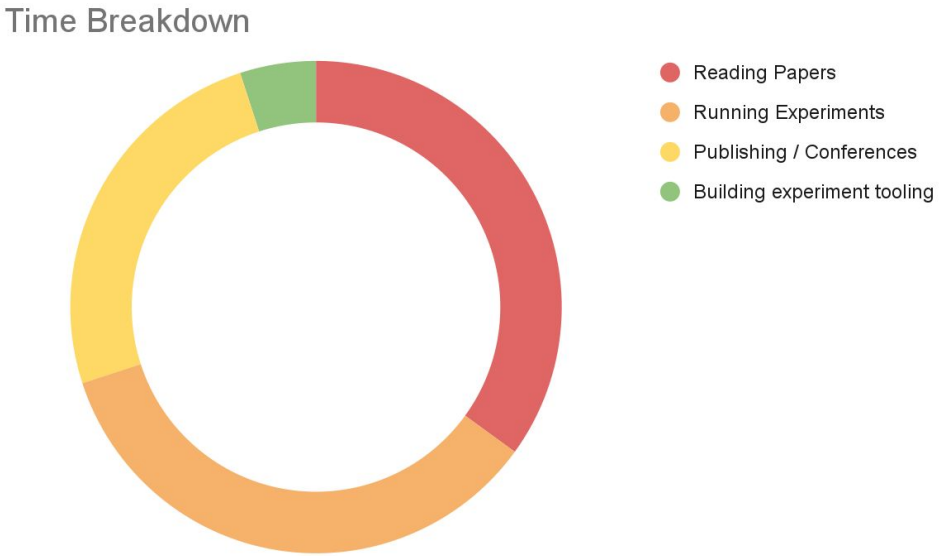
- Publish papers
- Create patents
- Novel ideas 1-2 years out

Challenges:

- Running lots of experiments & analyzing results
- Getting eng / infra help for experimentation
- Compute
- Working with teams to get data

Teams:

- Research engineers
- ML engineers
- Data science



Research Engineer

Expectations:

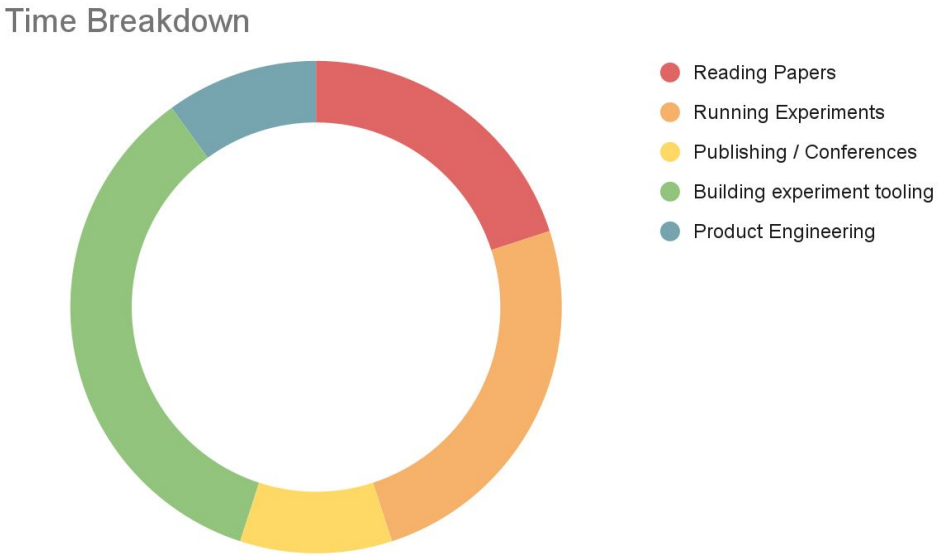
- Make experimentation easier
- Novel ideas 6-12 months out
- Publish papers/patents

Challenges:

- Build infra for research scientists
- Act as liaison between ml & research

Teams:

- Research scientists
- ML engineers
- Data science
- Product



ML Engineer

Expectations:

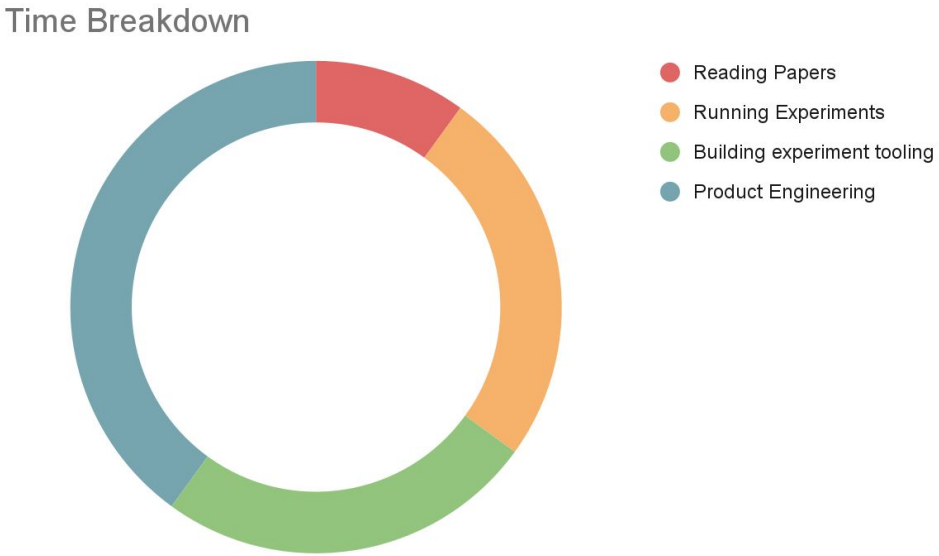
- Productionize applied research
- Build ml services
- Short-term experiments (1-2 months out)
- Monitor ml services

Challenges:

- Convert product ideas to ml problems
- Identify how to safely deploy ml models

Teams:

- Research engineers
- Data science
- Product engineers
- Product



Tools & Technologies used

Programming Languages: Python, C++, Cuda

ML Frameworks: PyTorch, Jax, sklearn

Common Libraries: Hugging Face, Pytorch Lightning, Pandas, Numpy

Experiment Tracking: Weights & Biases, MLFlow, Tensorboard

Other Technologies: Docker, Kubernetes, SQL, Airflow/Prefect

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Tech Labs

- You'll likely be using technologies you aren't familiar with to complete your SD project
- It can be difficult knowing where to start and finding time to go through introductory tutorials
- Individuals usually run into similar problems with setup, but hit them at different times during the project.
- Setting up your development environment can take time, this forces you to do so early on in the semester.

You'll spend next week's lab choosing a high-level topic to focus on, and spend a few hours completing a tutorial.

Tech Labs - Requirements

1. You can work on these labs together, but each student must submit their own code
2. Each team must complete at least 2 different tutorials (not everyone can work on the same thing)
3. You can choose one of the suggested topics, or choose your own

Tech Labs - Topics

1. Backends:
    a. Python backend web app (django, flask, fastapi)
    b. Node.js / Express.js
2. Frontends:
    a. React
    b. iOS
    c. Android
3. ML
    a. Google Colab
    b. Pytorch
    c. sklearn
4. IoT, Raspberry Pi, Arduino

Tech Labs - Python Web Apps

Common python frameworks for creating backends

1. Django
    - Full-featured all-in-one web framework. Includes ORM, authentication, admin UI, etc
    - Suitable for complex web applications, but comes with a steep learning curve
2. Flask
    - Lightweight library good for rapid development
    - Lacks a ton of built-in features, relies on additional extension libraries
3. FastAPI
    - Modern, asynchronous python framework good for rapid prototyping
    - Relies on type annotations for I/O interface, self-documenting
    - Relatively new, might lack mature solutions

Tech Labs - Python Web Apps

Choose a framework and complete at least the first tutorial

1. Django
   - https://docs.djangoproject.com/en/5.0/intro/tutorial01/ (parts 1-4)
   - https://code.visualstudio.com/docs/python/tutorial-django
2. Flask
   - https://flask.palletsprojects.com/en/3.0.x/tutorial/
   - https://code.visualstudio.com/docs/python/tutorial-flask
3. FastAPI
   - https://fastapi.tiangolo.com/tutorial/ (basic & advanced tutorial)
   - https://www.tutorialspoint.com/fastapi/index.htm
   - https://code.visualstudio.com/docs/python/tutorial-fastapi

Tech Labs - Node.js / Express.js

If you’re familiar with javascript, you can write your backend in javascript as well

Node.js: javascript runtime allowing developers to run javascript server-side

Express.js: a minimal, flexible web app framework for Node.js

Choose one of the following (do both if you have time)

- https://codexam.vercel.app/docs/project/xt/xt1
- https://codexam.vercel.app/docs/project/mernchat (fullstack + db + react)

Tech Labs - Front Ends

- **React**: common front end for web-apps, written in javascript

- **iOS**: mobile operating system in the Apple ecosystem. Defines a framework for developing mobile apps, written in Swift. Used for frontend, can also be used for backend.

- **Android**: mobile operating system from Google. Defines a framework for developing mobile apps. Used for frontend, can also be used for backend.

Tech Labs - Front Ends

- **React**: (choose one, do both if you have time)
  - https://react.dev/learn/tutorial-tic-tac-toe
  - https://www.freecodecamp.org/news/react-tutorial-build-a-project/
  - https://codexam.vercel.app/docs/project/mernchat (fullstack + db + react)
- **iOS**: (complete the first, get as far as you can in the second)
  - https://www.swift.org/getting-started/swiftui/ (focused on swift ui)
  - https://developer.apple.com/tutorials/app-dev-training (thorough but very long, won't finish)
- **Android**:
  - https://developer.android.com/get-started/overview

Tech Labs - ML

Complete the intro to Google Colab tutorial. Then choose at least one of the pytorch tutorials OR the sklearn tutorials.

- **Google Colab**: web-based jupyter notebook that provides free access to gpu compute
  - https://colab.research.google.com/# (intro to colab)
- **Sklearn**: library providing non-deep learning ml algorithms + training utilities
  - https://colab.research.google.com/github/jakevdp/PythonDataScienceHandbook/blob/master/notebooks/05.02-Introducing-Scikit-Learn.ipynb
- **PyTorch**: library for deep learning commonly used in industry
  - https://pytorch.org/tutorials/beginner/basics/intro.html
  - https://pytorch.org/tutorials/beginner/deep_learning_60min_blitz.html
  - https://colab.research.google.com/github/phlippe/uvadlc_notebooks/blob/master/docs/tutorial_notebooks/tutorial2/Introduction_to_PyTorch.ipynb
- **Datascience handbook:** useful resource on ml & datascience as a whole
  - https://github.com/jakevdp/PythonDataScienceHandbook/tree/master
  -

Tech Labs - IoT / Raspberry Pi / Arduino / etc

- Any tutorials with a hardware component. Bring your own hardware and we're happy to help!
  - Arduino: https://docs.arduino.cc/built-in-examples/
  - Raspberry Pi: https://tutorials-raspberrypi.com/
- ROS: robotic operating system – used as part of the RTX projects
  - https://www.youtube.com/watch?v=979IZWOXC_0&list=PL8MgID9MCju0GMQDTWzYmfiU3wY_Zdjl5
  - https://www.youtube.com/playlist?list=PLy9nLDKxDN683GqAiJ4IVLquYBod_2oA6

For Next Week

- Complete weekly status update (get into the habit, it's ok if you don’t have much to report)
- Create September sprint tasks that would be useful for your project
- Submit Resume (blackboard)
- Continue refining project ideas
- Schedule weekly meeting w/ instructors (google sheet to be posted EOW)
- Decide which tech lab(s) you’ll focus on next week