Powering-Up My Pole Vault Technique

Alex Epstein - 5/21/25 - Senior Project Independent Study

Why This Project?

Build Coding Skills

- My college major
- Love of coding

Combining Passions

- Pole vault
- Coding
- Math/physics/science

Future Impact

- Can build on the code
- Others can build on and improve it
- Can help new & advanced pole vaulters

Objective 1:

Researching the Biomechanics of Pole Vault

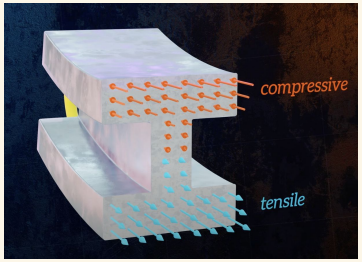
What did I do?

Research Papers

- The Biomechanics of Pole Vault
- A New Way of Looking at the Biomechanics of the Pole Vault

Videos

- AI Golf Swing Analyzer - What Can We Learn
- An Introduction to Stress and Strain
- The meaning of the dot product | Linear algebra makes sense

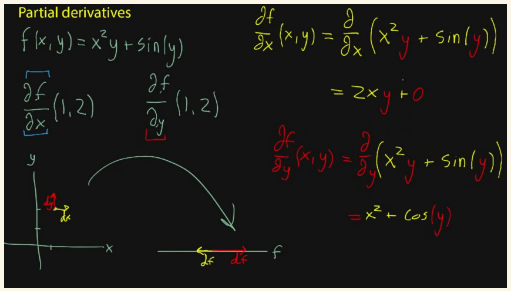


Articles

- Estimating 3D Poses of Athletes at Live Sporting Events, NY Times

What did I learn?

- Necessary math concepts
- How past AI sports devices work
- Physics equations for modeling a jump
- The different phases of a pole vault



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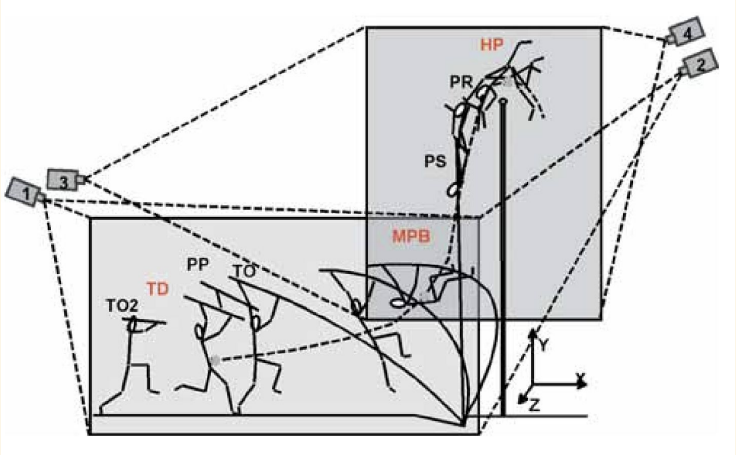
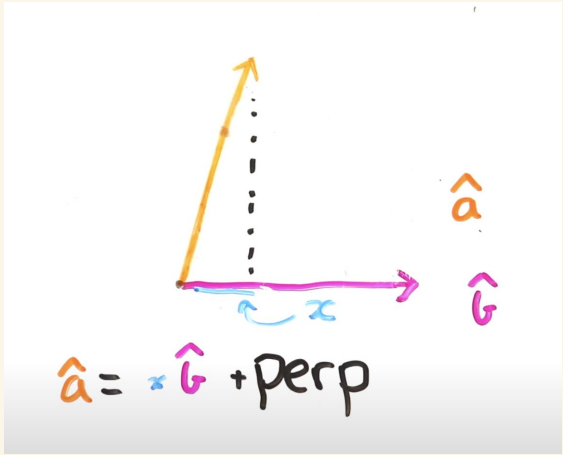
What did I learn?



Many phases make up a pole vault jump

$$E_{tot} = \sum_{i=1}^{12} m_i g h_i + \sum_{i=1}^{12} \frac{m_i \mathbf{v}_i ?}{}$$

COE equation



Dot product

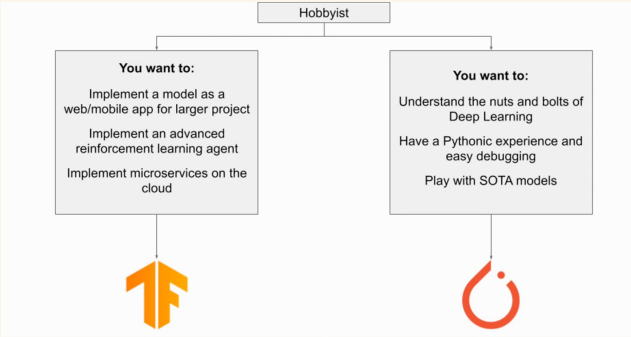
>>>>>

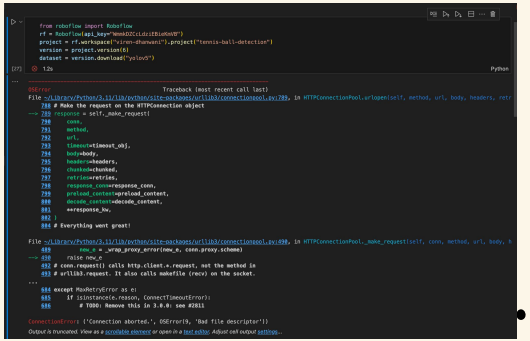
Objective 2:

To learn AI and machine learning video recognition

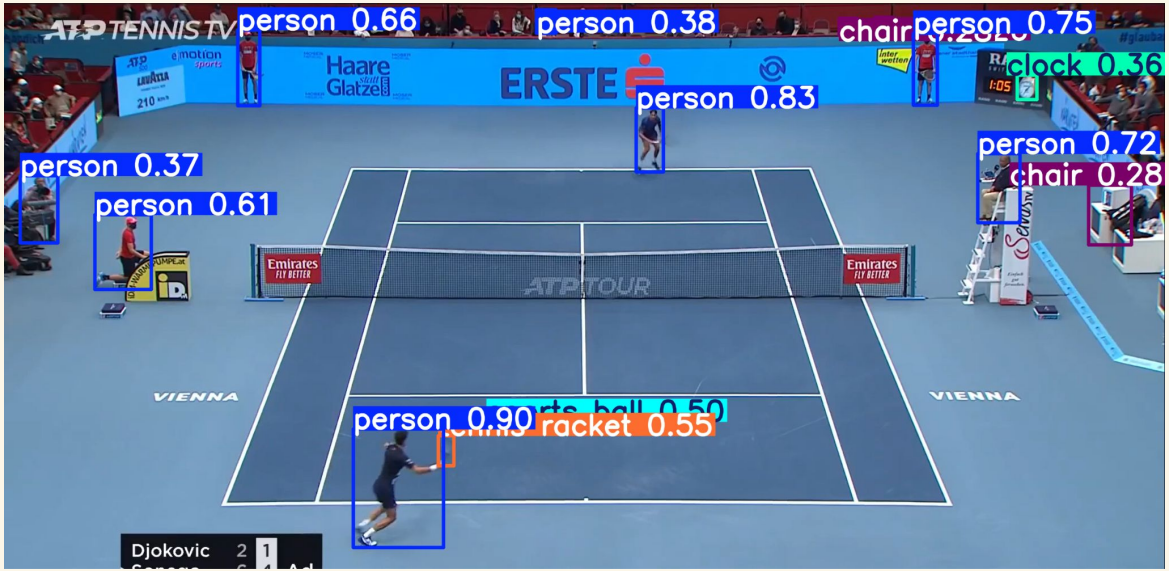
What did I do?

- Researched pose estimation libraries
- Started a mini-project analyzing tennis swings
- Debugged...intensely...
- Touched up on related coding concepts



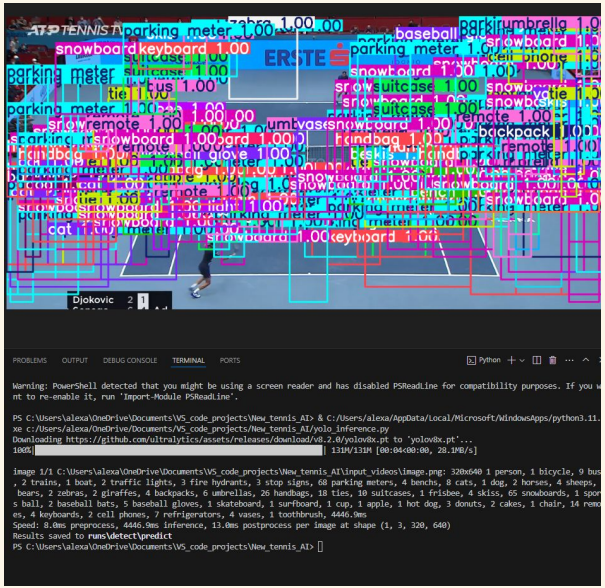


What did I do?


ATP TENNIS TV
person 0.66
person 0.38
person 0.75
clock 0.36
person 0.83
person 0.72
chair 0.28
person 0.37
person 0.61
Emirates
ATP TOUR
VIENNA
person 0.90
racket 0.55
Djokovic

What did I learn?

- How to apply machine learning to sports
- Working with YOLO v8
- Isolating certain elements
- Debug and manage coding frustration

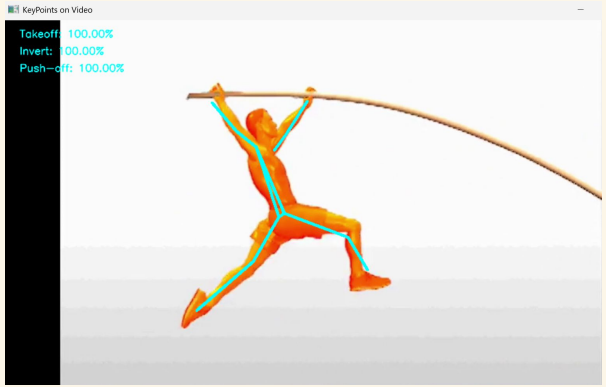


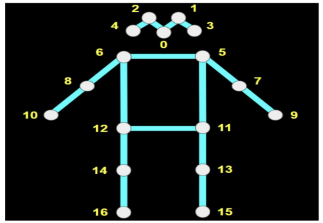
Objective 4:

To develop and train an AI-powered pole vault technique analyzer application

What did I do?

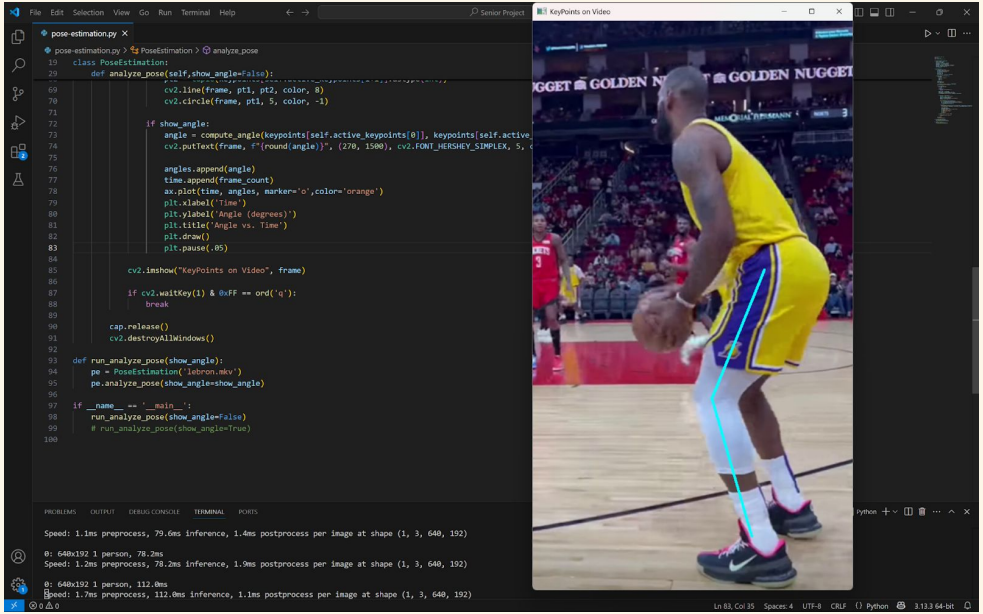
- Developed an algorithm to track a pole vault jump
- Integrated the pose estimator with OpenCV for visual feedback
- Tracked key joint angles during the vault
- Addressed issues with fluctuating keypoints and missing detections
- Scored each phase of the vault based on confidence levels





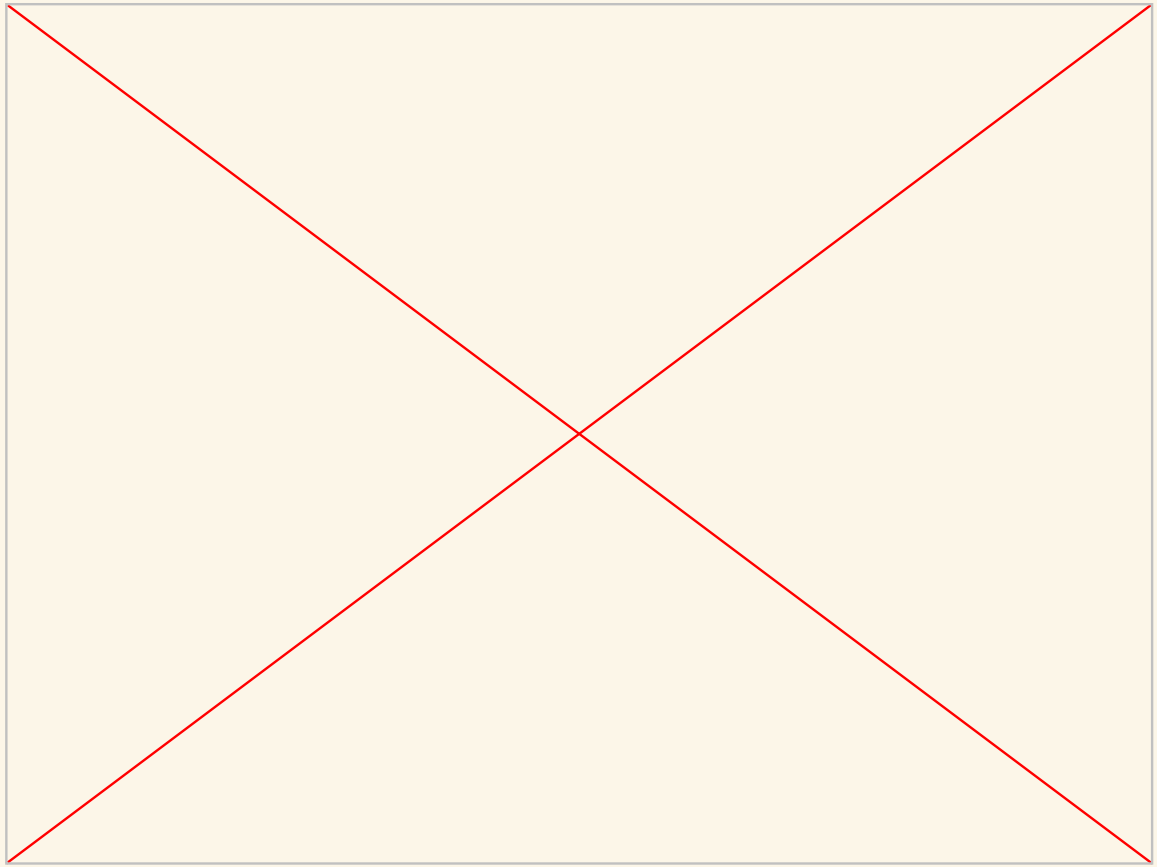
Pose Estimation Code

What did I do?


pose-estimation.py
class PoseEstimation:
def analyze_pose(self,show_angle=False):
cv2.line(frame, pt1, pt2, color, 8)
cv2.circle(frame, pt1, 5, color, -1)
if show_angle:
angle = compute_angle(keypoints[self.active_keypoints[0]], keypoints[self.active
cv2.putText(frame, f"{round(angle)}", (270, 1500), cv2.FONT_HERSHEY_SIMPLEX, 5,
angles.append(angle)
time.append(frame_count)
ax.plot(time, angles, marker='o',color='orange')
plt.xlabel('Time')
plt.ylabel('Angle (degrees)')
plt.title('Angle vs. Time')
plt.draw()
plt.pause(.05)
cv2.imshow("KeyPoints on Video", frame)
if cv2.waitKey(1) & 0xFF == ord('q'):
break
cap.release()
cv2.destroyAllWindows()
def run_analyze_pose(show_angle):
pe = PoseEstimation('lebron.mkv')
pe.analyze_pose(show_angle=show_angle)
if __name__ == '__main__':
run_analyze_pose(show_angle=False)
# run_analyze_pose(show_angle=True)
Speed: 1.1ms preprocess, 79.6ms inference, 1.4ms postprocess per image at shape (1, 3, 640, 192)
0: 640x192 1 person, 78.2ms
Speed: 1.2ms preprocess, 78.2ms inference, 1.9ms postprocess per image at shape (1, 3, 640, 192)
0: 640x192 1 person, 112.0ms
Speed: 1.7ms preprocess, 112.0ms inference, 1.1ms postprocess per image at shape (1, 3, 640, 192)
KeyPoints on Video

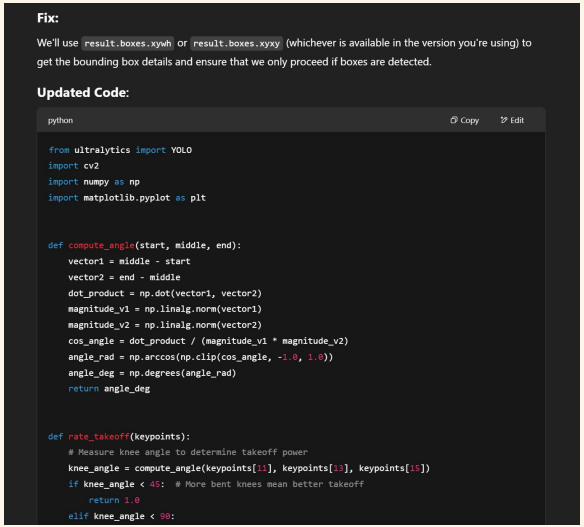
What did I do?

```
if largest_bbox is not None:
    x1, y1, x2, y2 = largest_bbox
    # Calculate the center of the bounding box
    x_center, y_center = (x1 + x2) / 2, (y1 + y2) / 2

    # Motion tracking: Compare the current and previous bounding box centers
    if prev_center is not None:
        prev_x, prev_y = prev_center
        movement_threshold = 50  # Adjust this threshold to account for the speed of movement
        if abs(x_center - prev_x) > movement_threshold or abs(y_center - prev_y) > movement_threshold:
            # This indicates that the person has moved significantly, likely the main subject
            self.center_x, self.center_y = x_center, y_center
    prev_center = (x_center, y_center)

    # Ensure detection confidence is high enough before processing
    confidence = result.boxes.conf.cpu().numpy()[0]
    if confidence > confidence_threshold:
        keypoints = result.keypoints.xy.cpu().numpy()[0]
```



What did I learn?

- Practical experience in coding and debugging
- Understood how AI can be applied to sports performance analysis
- How to use YOLO for pose estimation
- ChatGPT can be very helpful with debugging



Fix:

We'll use `result.boxes.xywh` or `result.boxes.xyxy` (whichever is available in the version you're using) to get the bounding box details and ensure that we only proceed if boxes are detected.

Updated Code:

python Copy Edit

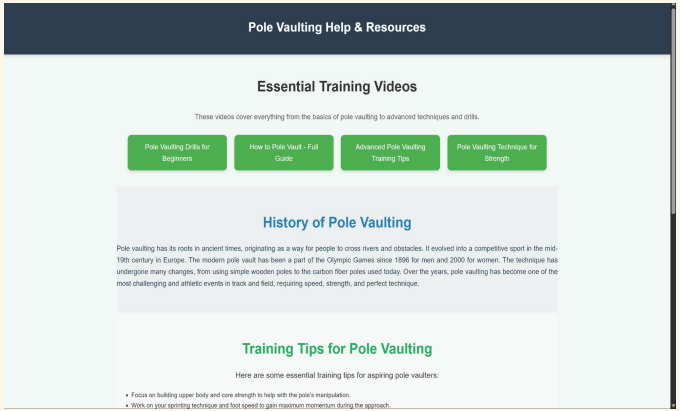
```python
from ultralytics import YOLO
import cv2
import numpy as np
import matplotlib.pyplot as plt


def compute_angle(start, middle, end):
    vector1 = middle - start
    vector2 = end - middle
    dot_product = np.dot(vector1, vector2)
    magnitude_v1 = np.linalg.norm(vector1)
    magnitude_v2 = np.linalg.norm(vector2)
    cos_angle = dot_product / (magnitude_v1 * magnitude_v2)
    angle_rad = np.arccos(np.clip(cos_angle, -1.0, 1.0))
    angle_deg = np.degrees(angle_rad)
    return angle_deg


def rate_takeoff(keypoints):
    # Measure knee angle to determine takeoff power
    knee_angle = compute_angle(keypoints[11], keypoints[13], keypoints[15])
    if knee_angle < 45:  # More bent knees mean better takeoff
        return 1.0
    elif knee_angle < 90:
```

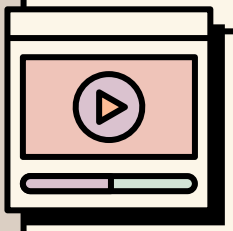
Objective 3:

To create a help website for new pole vaulters

What did I do?

- Created a simple, clean website using HTML for novice vaulters
- Added educational content - video tutorials, training tips
- Embedded my code for others to use / build from





Senior Project Website.txt | SP.html

File Edit View

```
</header>

<div class="content">
    <section class="section">
        <h2>Essential Training Videos</h2>
        <p>These videos cover everything from the basics of pole vaulting to advanced techniques and drills.</p>
        <div class="video-buttons">
            <a href="https://www.youtube.com/watch?v=KZ-MCujnjcA" target="_blank" class="video-button">Pole Vaulting Drills for Beginners</a>
            <a href="https://www.youtube.com/watch?v=2ByLsiNcsv0" target="_blank" class="video-button">How to Pole Vault - Full Guide</a>
            <a href="https://www.youtube.com/watch?v=z-Occerj2yA" target="_blank" class="video-button">Advanced Pole Vaulting Training Tips</a>
            <a href="https://www.youtube.com/watch?v=pQFctRtmZM0" target="_blank" class="video-button">Pole Vaulting Technique for Strength</a>
        </div>
    </section>

    <section class="section">
        <h3>About Pole Vaulting</h3>
        <p>Pole vaulting is a track and field event where athletes use a pole to jump over a high bar. It combines strength, technique, and agility,
requiring athletes to master the pole's use while also timing their takeoff and release. Pole vaulting is one of the most challenging events in
track and field, as it demands both explosive power and refined technique.</p>
    </section>

    <section class="section">
        <h3>Training Tips</h3>
        <p>Here are some essential training tips for aspiring pole vaulters:</p>
        <ul>
            <li>Focus on building upper body and core strength to help with the pole's manipulation.</li>
            <li>Work on your sprinting technique and foot speed to gain maximum momentum during the approach.</li>
            <li>Incorporate flexibility exercises to improve your range of motion for better technique.</li>
            <li>Practice with a coach to refine your form and work on specific skills like takeoff, pole planting, and clearance.</li>
        </ul>
    </section>

    <section class="section">
        <h3>Code Sharing and Community</h3>
        <p>I've uploaded my pole vaulting algorithm's code to the website for others to use and improve upon. This open-source approach allows
```

Pole Vaulting Help & Resources

Essential Training Videos

These videos cover everything from the basics of pole vaulting to advanced techniques and drills.

Pole Vaulting Drills for Beginners

How to Pole Vault - Full Guide

Advanced Pole Vaulting Training Tips

Pole Vaulting Technique for Strength

History of Pole Vaulting

Pole vaulting has its roots in ancient times, originating as a way for people to cross rivers and obstacles. It evolved into a competitive sport in the mid-19th century in Europe. The modern pole vault has been a part of the Olympic Games since 1896 for men and 2000 for women. The technique has undergone many changes, from using simple wooden poles to the carbon fiber poles used today. Over the years, pole vaulting has become one of the most challenging and athletic events in track and field, requiring speed, strength, and perfect technique.

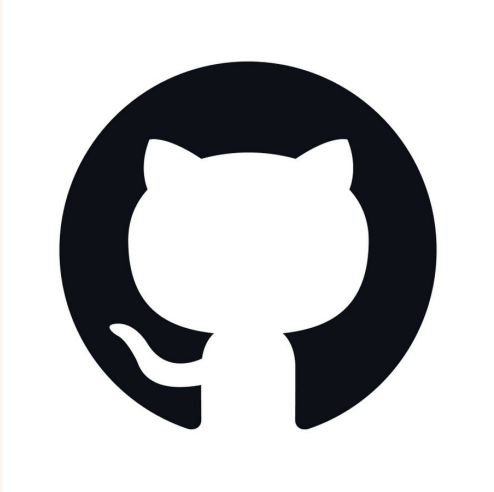
Training Tips for Pole Vaulting

Here are some essential training tips for aspiring pole vaulters:

- Focus on building upper body and core strength to help with the pole's manipulation.
- Work on your sprinting technique and foot speed to gain maximum momentum during the approach.
- Incorporate flexibility exercises to improve your range of motion for better technique.
- Practice with a coach to refine your form and work on specific skills like takeoff, pole planting, and clearance.

What did I learn?

- How to write in HTML (again)
  - Links
  - Buttons
  - colors
- Basics of website design and functionality for educational purposes
- How to share code to the public (GitHub)

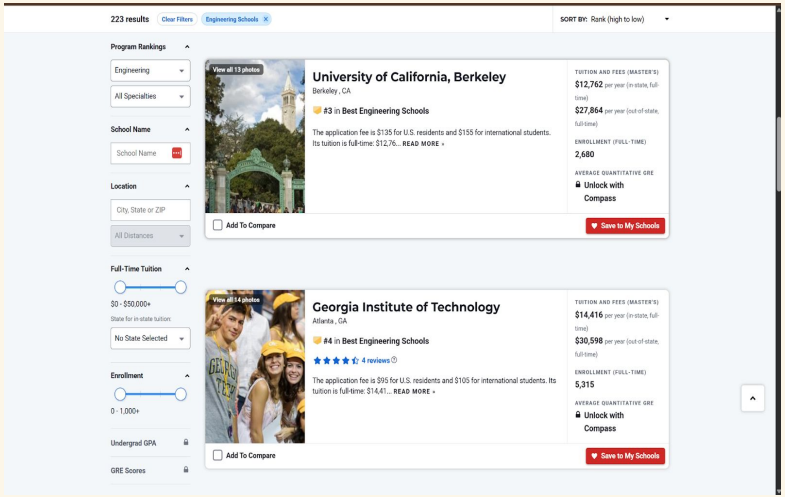


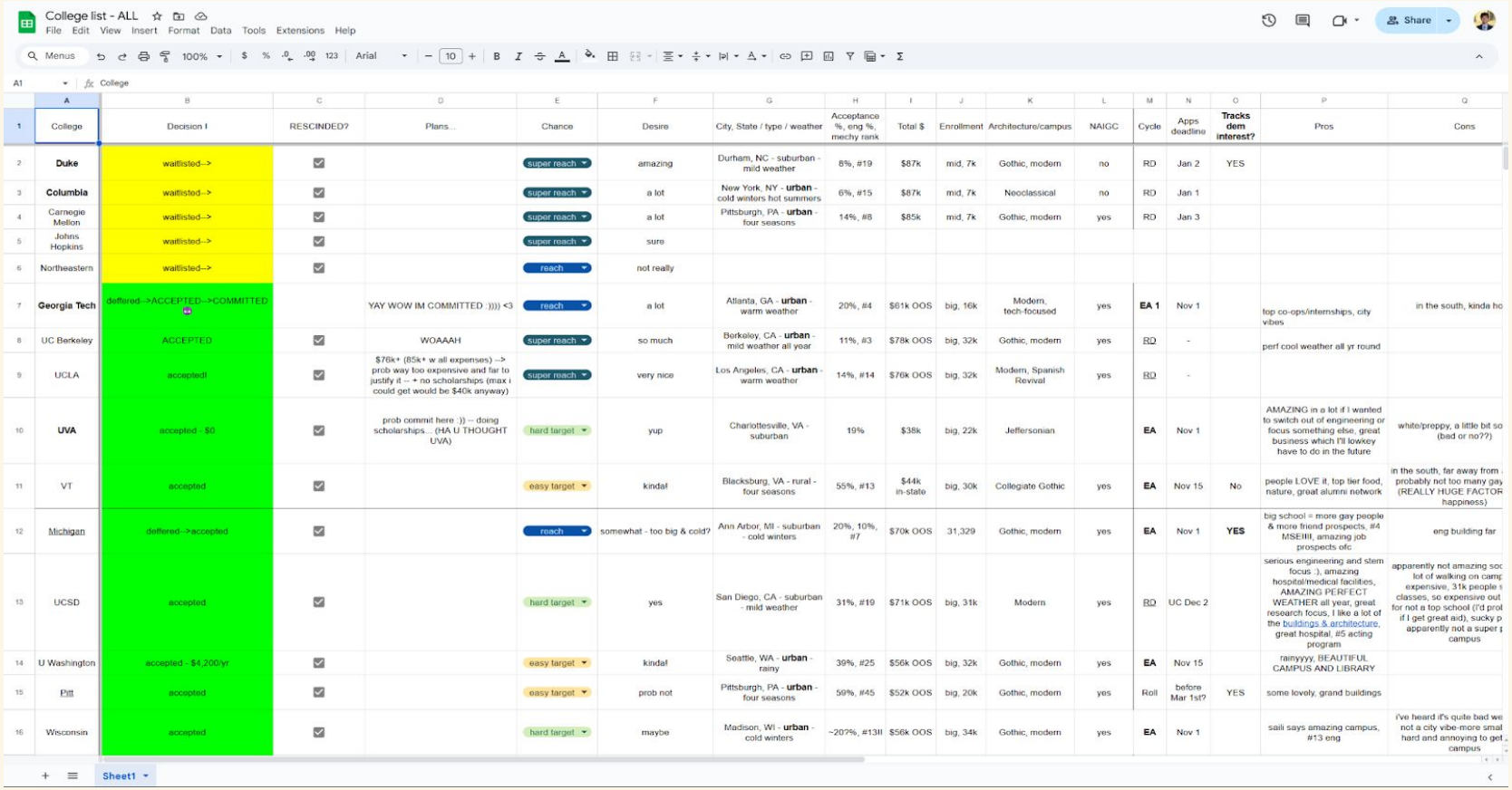
Objective 5:

To research and apply to a 4-year university for engineering

What did I do?

- Researched colleges with good engineering programs
- Made college list
- Complete a common app essay
- Finished supplemental essays for all colleges
- Applied to colleges and paid all college application fees





College list - ALL

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	College	Decision I	RESCINDED?	Plans...	Chance	Desire	City, State / type / weather	Acceptance %, eng %, mechy rank	Total $	Enrollment	Architecture/campus	NAIGC	Cycle	Apps deadline	Tracks dem interest?	Pros	Cons
2	**Duke**	waitlisted-->	☑		super reach	amazing	Durham, NC - suburban - mild weather	8%, #19	$87k	mid, 7k	Gothic, modern	no	RD	Jan 2	YES		
3	**Columbia**	waitlisted-->	☑		super reach	a lot	New York, NY - **urban** - cold winters hot summers	6%, #15	$87k	mid, 7k	Neoclassical	no	RD	Jan 1			
4	Carnegie Mellon	waitlisted-->	☑		super reach	a lot	Pittsburgh, PA - **urban** - four seasons	14%, #8	$85k	mid, 7k	Gothic, modern	yes	RD	Jan 3			
5	Johns Hopkins	waitlisted-->	☑		super reach	sure											
6	Northeastern	waitlisted-->	☑		reach	not really											
7	**Georgia Tech**	deffered-->ACCEPTED-->COMMITTED		YAY WOW IM COMMITTED :)))) <3	reach	a lot	Atlanta, GA - **urban** - warm weather	20%, #4	$61k OOS	big, 16k	Modern, tech-focused	yes	**EA 1**	Nov 1		top co-ops/internships, city vibes	in the south, kinda ho
8	UC Berkeley	ACCEPTED	☑	WOAAAH	super reach	so much	Berkeley, CA - **urban** - mild weather all year	11%, #3	$78k OOS	big, 32k	Gothic, modern	yes	RD	-		perf cool weather all yr round	
9	UCLA	accepted!	☑	$76k+ (85k+ w all expenses) --> prob way too expensive and far to justify it -- + no scholarships (max i could get would be $40k anyway)	super reach	very nice	Los Angeles, CA - **urban** - warm weather	14%, #14	$76k OOS	big, 32k	Modern, Spanish Revival	yes	RD	-			
10	**UVA**	accepted - $0	☑	prob commit here :)) -- doing scholarships... (HA U THOUGHT UVA)	hard target	yup	Charlottesville, VA - suburban	19%	$38k	big, 22k	Jeffersonian		**EA**	Nov 1		AMAZING in a lot if I wanted to switch out of engineering or focus something else, great business which I'll lowkey have to do in the future	white/preppy, a little bit so (bad or no??)
11	VT	accepted	☑		easy target	kinda!	Blacksburg, VA - rural - four seasons	55%, #13	$44k in-state	big, 30k	Collegiate Gothic	yes	**EA**	Nov 15	No	people LOVE it, top tier food, nature, great alumni network	in the south, far away from (probably not too many gay (REALLY HUGE FACTOR happiness)
12	Michigan	deffered-->accepted	☑		reach	somewhat - too big & cold?	Ann Arbor, MI - suburban - cold winters	20%, 10%, #7	$70k OOS	31,329	Gothic, modern	yes	**EA**	Nov 1	**YES**	big school = more gay people & more friend prospects, #4 MSE!!!!, amazing job prospects ofc	eng building far
13	UCSD	accepted	☑		hard target	yes	San Diego, CA - suburban - mild weather	31%, #19	$71k OOS	big, 31k	Modern	yes	RD	UC Dec 2		serious engineering and stem focus :), amazing hospital/medical facilities, AMAZING PERFECT WEATHER all year, great research focus, I like a lot of the buildings & architecture, great hospital, #5 acting program	apparently not amazing soc lot of walking on camp expensive, 31k people classes, so expensive out for not a top school (i'd prol if I get great aid), sucky p apparently not a super campus
14	U Washington	accepted - $4,200/yr	☑		easy target	kinda!	Seattle, WA - **urban** - rainy	39%, #25	$56k OOS	big, 32k	Gothic, modern	yes	**EA**	Nov 15		rainyyyy, BEAUTIFUL CAMPUS AND LIBRARY	
15	Pitt	accepted	☑		easy target	prob not	Pittsburgh, PA - **urban** - four seasons	59%, #45	$52k OOS	big, 20k	Gothic, modern	yes	Roll	before Mar 1st?	YES	some lovely, grand buildings	
16	Wisconsin	accepted	☑		hard target	maybe	Madison, WI - **urban** - cold winters	~20?%, #13!!	$56k OOS	big, 34k	Gothic, modern	yes	**EA**	Nov 1		saili says amazing campus, #13 eng	i've heard it's quite bad we not a city vibe-more smal hard and annoying to get campus

Sheet1

FINAL Alex Common App Essay

File Edit View Insert Format Tools Extensions Help

Share

Menus 100% Normal text Arial 11 Editing

Document tabs

Tab 1

Headings you add to the document will appear here.

Prompt 2: The lessons we take from obstacles we encounter can be fundamental to later success. Recount a time when you faced a challenge, setback, or failure. How did it affect you, and what did you learn from the experience?

"Dear Alex–This is Sascha from Etsy's Marketplace Integrity Team. While we thank you for taking an interest in our community, this notice is to inform you that Etsy has elected to revoke your account privileges permanently. It has come to our attention that you are only 11 years old."

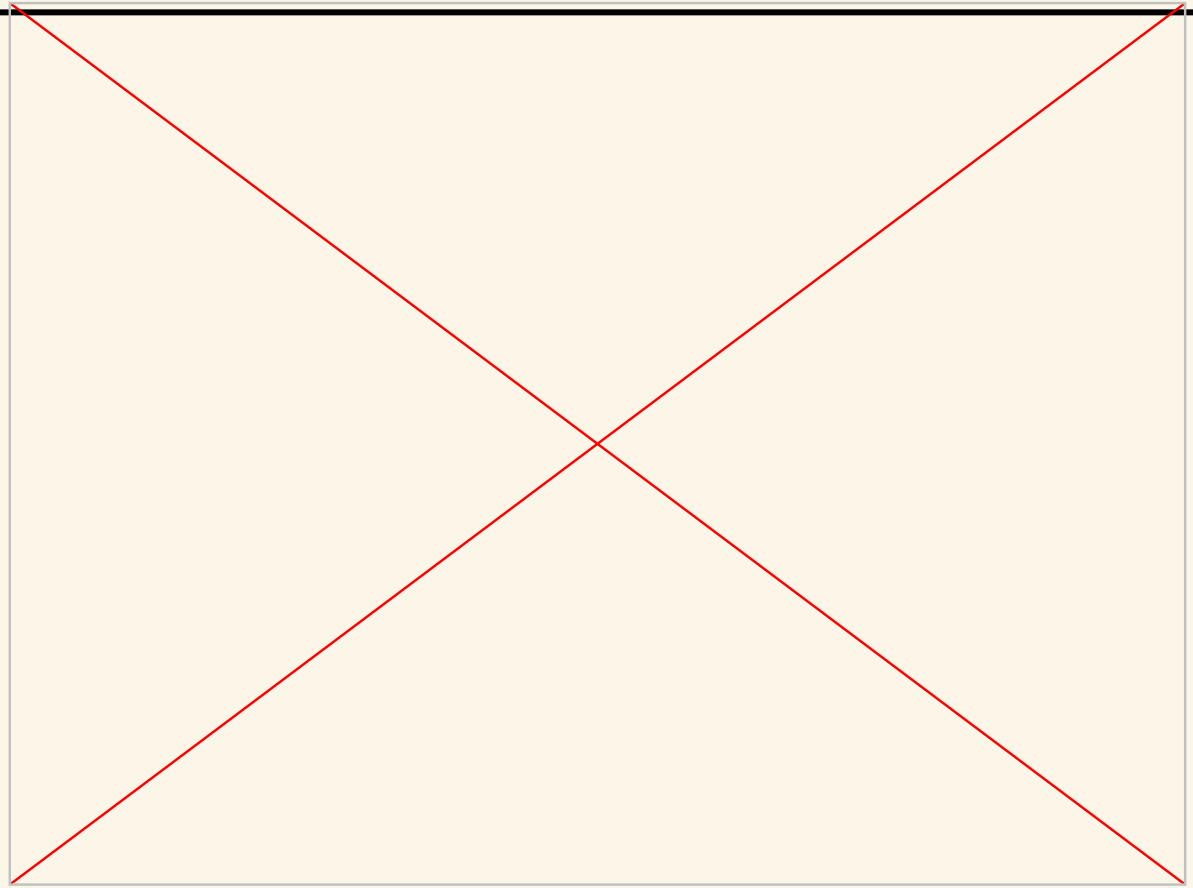
From a very young age, I was obsessed with *making* things: glittery bath bombs that fizzed and made my bathtub water pink; rainbow loom bracelets that lined my wrists; candles that Dad never let me light. Then, I discovered slime. I made it from scratch and gave it out at school. Everyone loved it. I started charging my fellow 6th graders $2 for custom-made slime. Soon, I made plans to expand. With my mom as the frontman, I opened my Etsy store: EverySlimeShop.

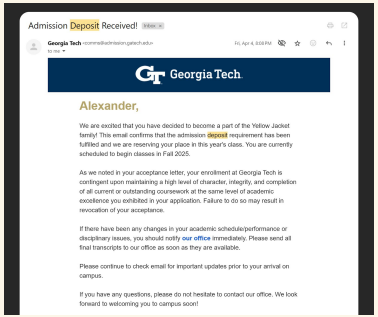
On Sept 29, 2018, I made my first sale: 10 oz of Orangesicle Cloud Slime to Candi in Reagan, Texas for $6. I couldn't believe it. Gallons of glue and empty containers soon arrived at our doorstep. Dad would peek his head in and wonder why my bedroom was set up like a factory assembly line. Many nights I'd stay up mixing Elmer's glue with my water-borax solution until small tendrils started to latch onto the spoon.

"Another order!" Susan from Blountville, Tennessee. Two days later, Janet from Gardena, California. I was ecstatic. I invested the $27 I'd earned into new listings: Cotton Candy Cloud Slime and Piña Colada Glossy Slime. I even began to offer a complimentary Mystery Slime Box with every purchase.

I became well-known at the Etsy customer support line. In the next 3 months, in my best businessman voice and despite Mom's warnings to lay low, I barraged Laisha, Jackie, Autumn, Destini, Jakob, and Laura with my many questions.

I learned the hard way about profit margins (at the time what I called "why am I not making more money!?"), and hidden costs ("what do you mean Etsy gets a cut!?"). I peppered Dad with questions. We had long conversations about how to improve my business. Soon, people started to notice me. YouTuber "DoveSlimes" reached out asking to sample my products.





Admission Deposit Received!

Georgia Tech

Alexander,

We are excited that you have decided to become a part of the Yellow Jacket family! This email confirms that the admission deposit requirement has been fulfilled and we are reserving your place in this year's class. You are currently scheduled to begin classes in Fall 2025.

As we noted in your acceptance letter, your enrollment at Georgia Tech is contingent upon maintaining a high level of character, integrity, and completion of all current or outstanding coursework at the same level of academic excellence you exhibited in your application. Failure to do so may result in revocation of your acceptance.

If there have been any changes in your academic schedule/performance or disciplinary issues, you should notify our office immediately. Please send all final transcripts to our office as soon as they are available.

Please continue to check email for important updates prior to your arrival on campus.

If you have any questions, please do not hesitate to contact our office. We look forward to welcoming you to campus soon!

- My future home ❤️❤️❤️
- Georgia Tech 2029
- Computer Engineering

What did I learn?

- 30+ colleges I never knew about, and tons of majors
- Myself - through writing essays
- How to write about myself
- Insane discipline and time management
- To not overextend myself for no reason
- Apply to less colleges

Obstacles

>>>>>

Problems & Solutions

Time management / scheduling

- Started in summer
- Juggling with college apps

Debugging / code not working

- Versions of YOLO
- Macbook restrictions
- Dependency issues
- Key points detecting wrong

Wanting to give up

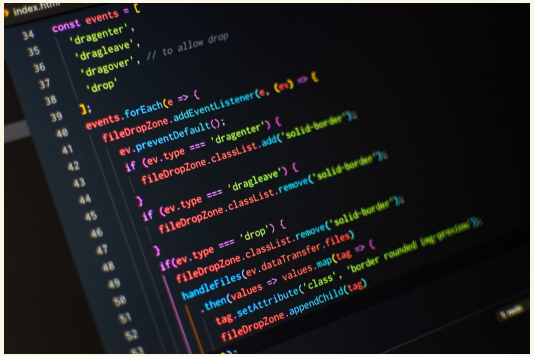
- Code not working → even ChatGPT can't help → felt not smart enough

- **Solutions**
  - Venv for dependencies
  - Got python from the web instead
  - YOLO→Focused on the largest model (confidence score)
  - YouTube tutorials (YOLO)
  - Bought code ($5) to get started

Positive Takeaways

- **Learned importance of staying ahead**
  - Got ahead, then fell behind, stress me the whole year

- **Relearned Python, working in Terminal, VS Code, Git/Github**
  - For my major!



- **Explored a whole new area of computer science**
  - Computer vision! (future: self-driving cars?)
- **Became a better writer / self-reflection**
  - Supplementals
  - Common App essay
  - SP essay

Questions?

Me pole vaulting :)

Mondo Duplantis!
(World Record Holder)

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