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June 14, 2024

2

Problem & Research Question

As the world shifts into digital means, pen and paper writing is becoming increasingly less popular.

However, research indicates that traditional writing offers significant advantages over typing, particularly in memory retention.

Because rather than transcribing lectures, students paraphrase it to something that makes sense to them.

→ The Pen is Mightier than the Keyboard
Pam A. Mueller and Daniel Oppenheimer.

- Why can't we have both?

This project seeks to merge the digital convenience of typing with the cognitive benefits of handwriting by developing a pen that digitizes writings without external components - like a screen or encoded notebook found in other smart pens (e.g. Livescribe).

very inconvenient and costly to buy their specialized notebooks

- No external components = more practicality and accessibility, encouraging widespread adoption.

- Research Question:

How can a pen without external components effectively digitize handwritten notes in real time.

- What about Leds? Not enough evidence and copy-paste tools likely lower effectiveness of note taking.

Hypothesis

It is hypothesized that the synergy of low-cost sensors embeded in a pen along with customized and open source algorithms can ensure an accurate digital replica of handwriting on paper/drawing page without external components.

- How will the pen work?

What internal components/sensors could be used?

- | | |
|---|---|
| - Accelerometer - is accurate | Acceleration in direction |
| - Gyroscope | Angular velocity (rotation) |
| - Compass | Direction based on Poles |
| - Mouse sensor (laser or optical) | To detect movement on paper |
| - Camera/optical sensor | Could compare writings/correspond to track position by frame. |
| - Proximity sensors - will need alot of them/ not very useful, only for distance to paper | not where |

- Microcontroller

To process the sensor data and derive the location

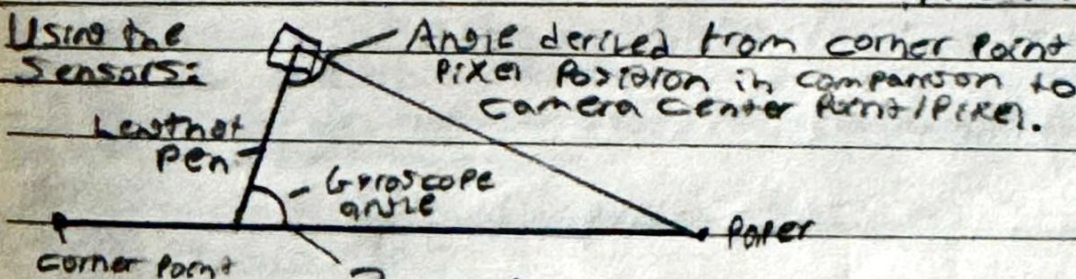
- Battery

To facilitate a wireless flow of power

- Bluetooth module

To transmit the data of coordinates for output/other processing.

Using the Sensors:



3 unknowns are needed to solve a triangle (at least one must be a length, and 1 must be an angle)

I then constructed a 3d Pyramid using skewer sticks and a give 3m for further brainstorming of the formulas.

* Further brainstorming can be found towards the end of the logbook (It is viewed from many angles and I did not want space to be a limitation).

The Design

- Components Needed for Positioning:

Camera: To detect the page's corner points

Compass and gyroscope: To track the Pen's 3 dimensional orientation to the paper

Microcontroller: To process the data collected by the sensors

Bluetooth module: To send the digitized replica to an external device for output or further processing.

Battery: To allow for wireless usage of the Pen.

- Compass vs. Gyroscope:

A Compass determines the Pen's direction along the X-axis, this displacement can also be detected by a gyroscope, however compasses are less prone to have bias/drift in their output over time as they are comparing their orientation to Earth's Poles rather than angular velocity displacement based on previous outputs.

- Goals for Design #1

- Good visibility from the camera (at the top)
- Similar dimensions as a normal Pen, 15cm tall and a maximum 1.5 cm width.
- Easy to 3d print the frame
- Enough space for components, like the mouse sensor
- The microcontroller's size should be as big as possible to maximize its speed and ability to run the programs. A clamp holder in the Pen could allow for slightly more space
- Room for a cable connection to the microcontroller
- Arduino for development speed and compatibility is preferred, as well as a Bluetooth module.

- Possible Microcontrollers that can fit into the Pen

1. Seeed Studio Xiao

- Smallest, Cheapest but not powerful nor has many ports/connectors

2. Arduino micro

- Little Power and no Bluetooth.

3. Arduino Nano

- Large and old, so not as powerful as other Arduinos

4. Arduino Nucleo vision, A Best (so far)...

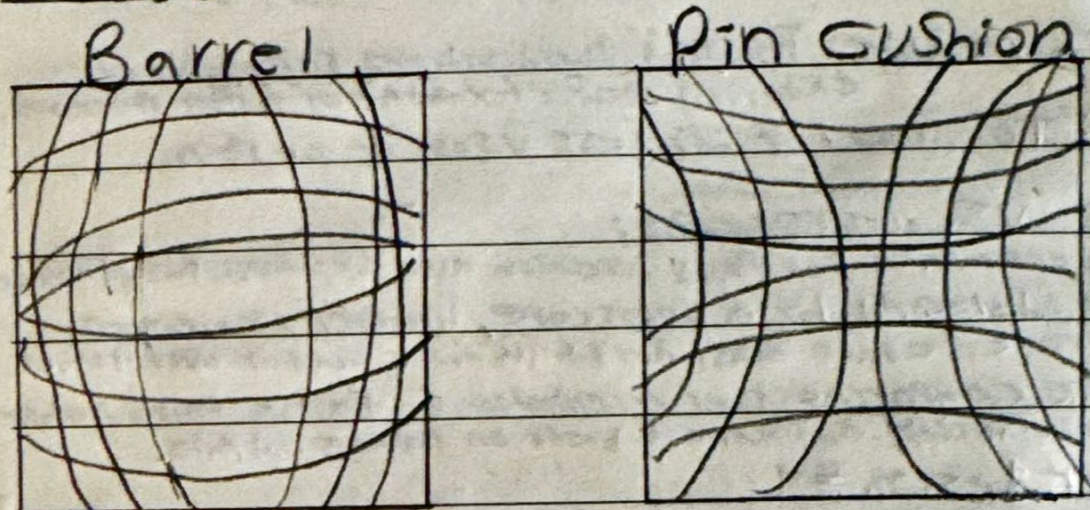
- Expensive but contains a gyroscope, compass, and camera and is also quite powerful. However these parts are not accurate as others in the market and the camera will have to be away from the microcontroller (on the top of the pen).

June 20, 2024

Correcting Camera distortion

Camera distortion is especially relevant in ultrawide cameras and can lead to significant errors in the positioning.

Kinds of distortion: (Both exist in ultrawide lenses)

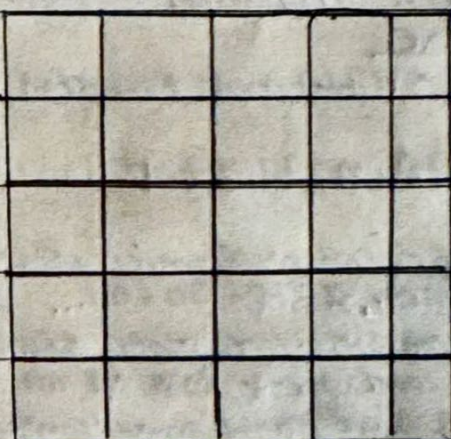


To prevent this, the camera will need to be calibrated through a camera configuration of a checkerboard grid to find the distortion coefficients of the image.

- Outlined in LearnOpenCV.com - Understanding lens distortion, by Koushik Sadakur. (citation on the back)

* Comment:

- This principle inspired me to use the image rectification in the positioning section. Suggests its validity.



(No distortion)

June 19, 2024

5

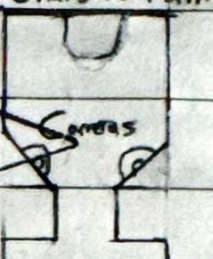
Design #1

Design #2

1:1 scale

(It's space allows)
Charging Point

- Multiple Cameras for Maximum POV



★ Reflection

- Multiple cameras is a good idea however combining the images will be difficult because of added distortion in this very large image taken from multiple locations.

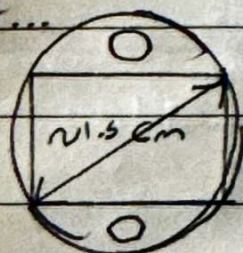
Arduino Microcontroller

Gyroscope & Compass

Compass

Battery

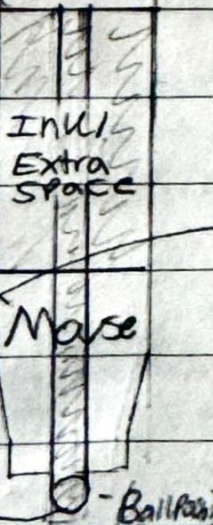
- Most components will be flat...



Therefore, extra space can accommodate for the wires.

- Ways for mouse to work

1. Sensor facing down beside ballpoint
2. Mechanical components to detect movement on the ballpoint like a trackball mouse
3. Sensor, probably laser to detect more contrast focus the pen's ballpoint



(Ballpoint)

1:1 scale

- Might need to be convex for larger POV.

★ The mirror exists because putting one singular camera facing down on the center of the pen would not be possible due to the wires and support obstructing the view. The mirror is more of a short term theoretical solution that would work if distortion is accounted for. However a commercial product's camera would look more like design #1.

Mirror



Arduino Microcontroller

Gyroscope & Compass

Battery

Charging Port

Detaches magnetically to construct the pen, charge the battery and refill the ink.

Ink

Mouse Sensor + LED

(Ballpoint)

- Due to time and manufacturing constraints (e.g. custom mouse sensor), the pen won't look like this but it's a general goal to work towards.

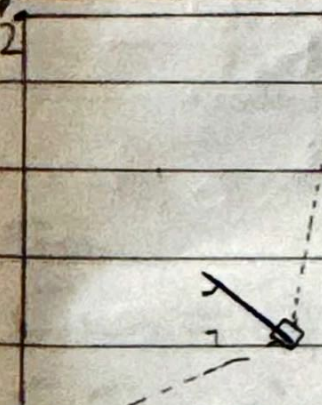
Software

- Initialization

In order for the gyroscope to provide a useful orientation between the pen and drawing page, it has to be measuring its displacement from the paper.

Therefore, before any writing, the orientation of the paper must be measured.

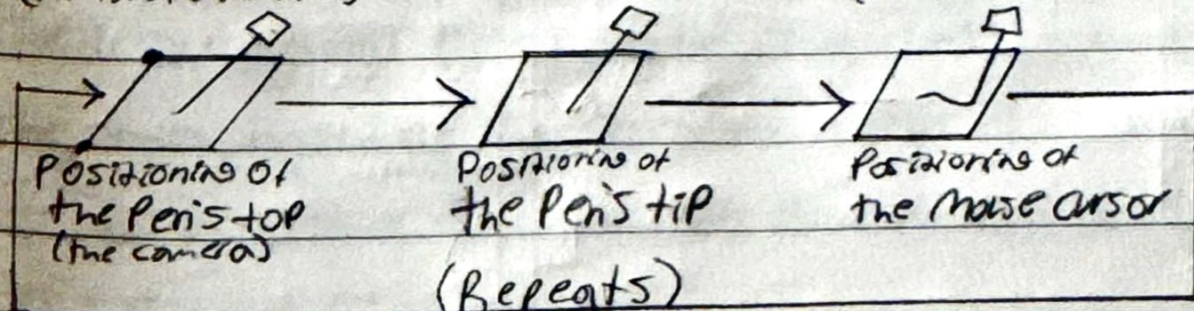
Step #1 (Pen) \ Facing to the relative top to know what side is which.	By placing the pen as shown, the gyroscope can be initialized. (The 3 axis values on the gyroscope will be subtracted by the gyroscope outputs during writing to find the displacement) Edit: This step will also be used to identify the color of the page for corner detection through a photo taken by the camera when this step is happening.
---	---

Step #2 	Though not recommended (because this measurement is used in most of the formulas for Postdetection), if the user does not know the dimensions of the page, the formula used for the Postdetection of the Pen's tip (outlined in the formula section) can be used to find the dimensions of the page, however 3 corner points must be visible (rather than 2).
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Once the initialized values are determined (above), the pen is ready for digitization. The following diagram shows how the Postdetection is executed.

(Tip touches the paper)

(Writing mode)



September 22-30, 2024

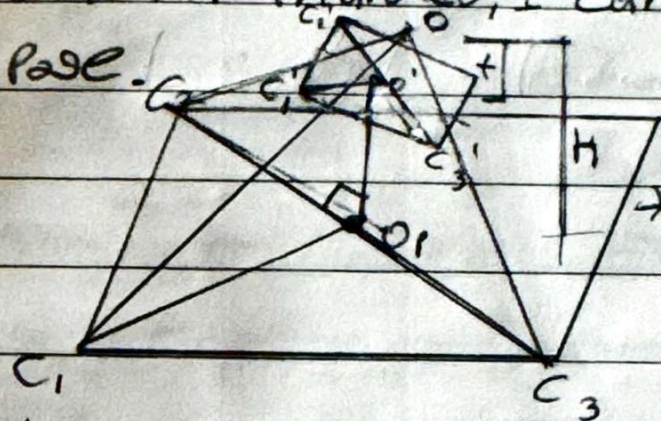
* Brainstorming towards
the end of the 105 book
due to space/organization. 7

Determining the dimensions of the drafting page

- When the Pen is Perpendicular

Given the camera's focal length f positioned at a height h from the drafting page pointing perpendicular to Point O , the three corner points C_1, C_2 , and C_3 will be projected onto points C'_1, C'_2 , and C'_3 in the image.

Using similar triangles, I can derive the dimensions of the page.



* I've made a more
clear diagram in a digital
format (on the GYSF paper)
* The camera will need to face
down on the center of
the pen for this to work.
(A mirror would work as it
reprojects it downwards)

Formula

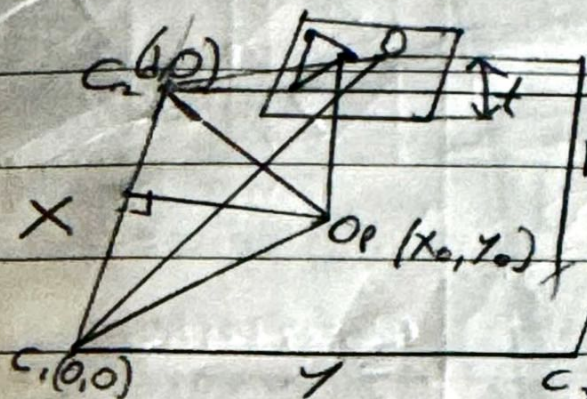
$$C_1 C_2 = C'_1 C'_2 \frac{h}{f}$$

$$C_2 C_3 = C'_2 C'_3 \frac{h}{f}$$

- In general the pen is not perpendicular to the page during handwriting. In order for the scanner to work the image will need to be rectified by warping the image based on the orientation derived from the gyroscope.
* This is further explained on Page 10 as it is relevant to the next step as well.

Positioning of the Pen's top

From the formula/diagram in the initialization phase one can determine the coordinate of the pen's top using 2 points given that the dimensions of the page are known.



Formula

$$C_1 O_1 = C_1 O_1' \frac{h}{d}$$

$$C_2 O_1 = C_2 O_1' \frac{h}{d}$$

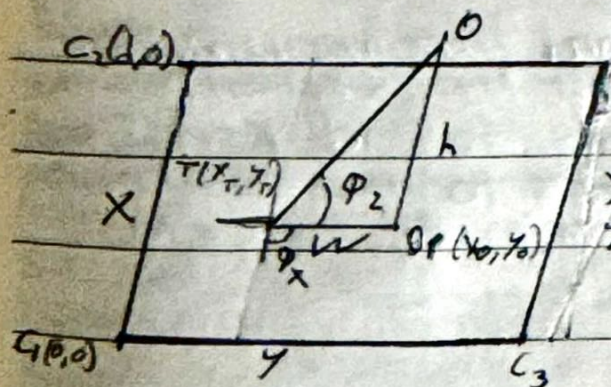
$$C_1 = \arccos \left[\frac{C_2 O_1'^2 - C_1 O_1'^2 - d^2}{2 C_1 O_1' d} \right]$$

$$X_0 = C_1 O_1 \sin C_1$$

$$Y_0 = C_1 O_1 \cos C_1$$

Positioning of the Pen's tip

Given the projection of the camera's center point on the page $O_p(x_0, y_0)$, and the adjusted tilt provided by the goniometer φ_2 , the coordinates of the pen's tip $T(x_T, y_T)$ can be determined.



Formula

$$h = l \sin \varphi_2$$

$$w = l \cos \varphi_2$$

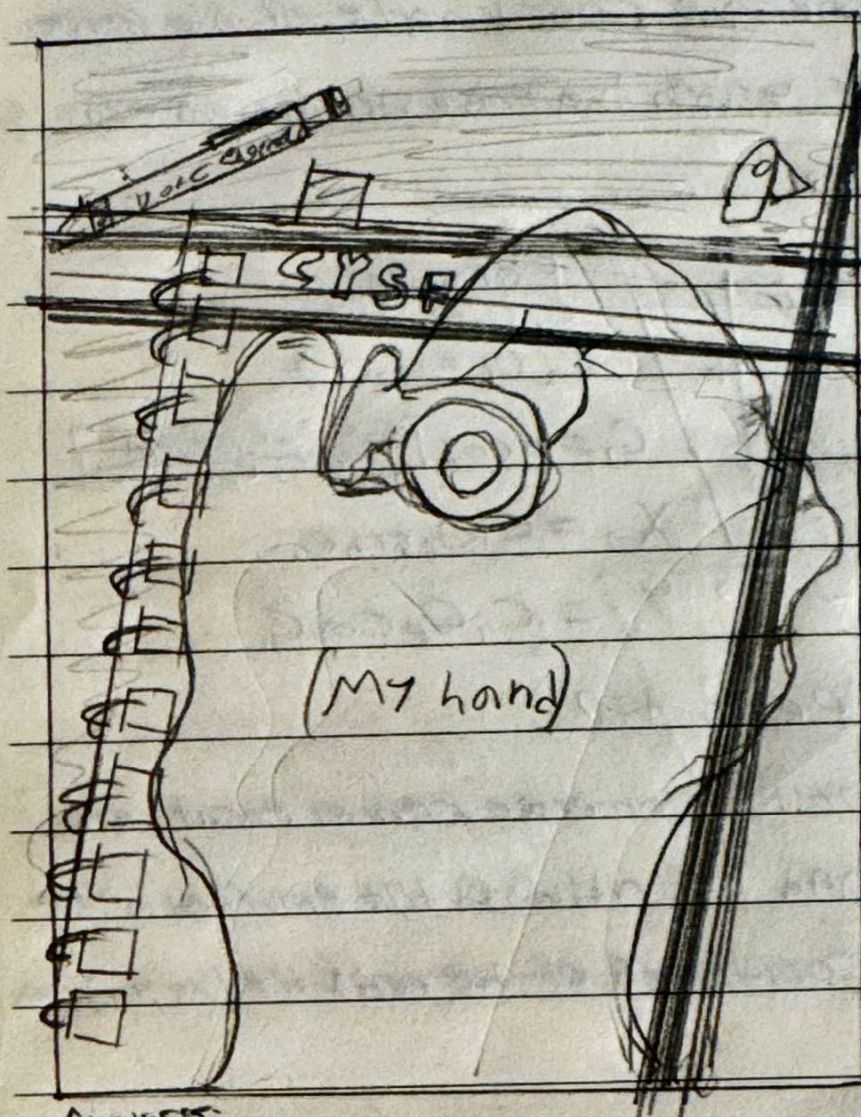
$$x_T = x_0 + w \cos \varphi_x$$

$$y_T = y_0 - w \sin \varphi_x$$

- Images will be available at the fair (these are sketches)

* I tried to put alot of horse/donkeys in the background to make sure it worked under different conditions

Failed attempt: Canny edge detection



- On other images the result is much worse



← Some original image

Observations

- 3 main areas are detected as edges
- All seem to be around 3 lines however there is no pattern on their distribution and a line of best fit would still be incorrect.

Analysis:

Very sensitive to noise and there are hundreds of lines overlapping, a line of best fit would still be wrong. Adversely the sensitivity still leads to bad results and it would depend on 2 right lines to intersect for a best corner which would lead to a significant source of error.

December 8-25, 2024

9

Corner detection Program

To accurately detect the corners of the page, the image captured by the camera must be processed and filtered down to 2-3 best points (depends on the formulas explained earlier). I will develop this program on a Google Colab python notebook.

Test 1. Only Harris corner detection

Original (wood table) (my hand) (pen) → Harris corner detection

53,241 detected corners

Retraction

I'll need to eliminate the noise on the non paper surface.

What is different about it?

- Color
- Texture (cant really be identified)

The corners of the paper

Test 2. Random walker segmentation + Harris corner detection (same image used)

Harris corner detection [220 220 220, 255 255 255] (R-G range: White)

Light retraction on wood

21,430 corners detected

Is this enough to find the corners?

- I'll try to extract polygons using function available in OpenCV library.

Filter corners by angle

Filter by Polygon size

No, too many polygons form

* But most of them are small, I'll try filtering by size 100 pixels sq

* How can I get rid of this point?

5x5 pixel isolation to Harris points

Too large angle

Too small angle

• = still best points

○ = Not valid points

It works but does not know which corner is the page's corner(s). But some angles are very big/small.

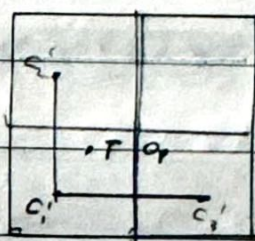
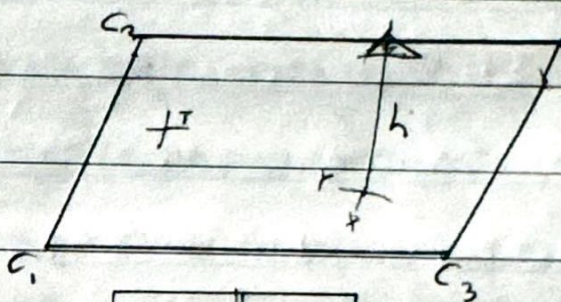
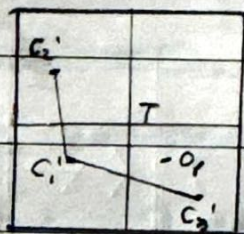
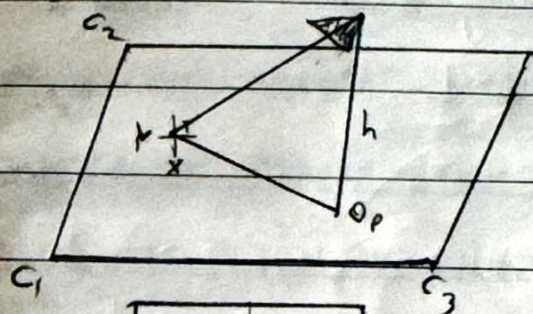
The paper is assumed to be a rectangle, therefore corners will have less corners detected by Harris

Compared to noise like my more curved (more points) hand. True corners are also very isolated from the rest of the page so after segmentation it will be very isolated.

Warp Perspective transformation

In order to maintain the formulas in the initialization and Pen Posture phases, the image captured by the camera must be rectified into a flat paper geometry through the displacement derived from the Pen's gyroscope.

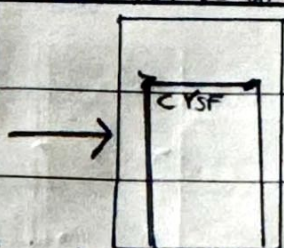
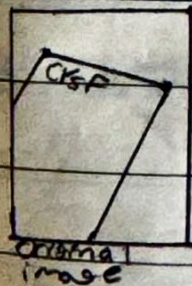
The diagram below shows the sequence of the corner points C_1, C_2 , and C_3 projected as C'_1, C'_2 , and C'_3 on the rectified image.



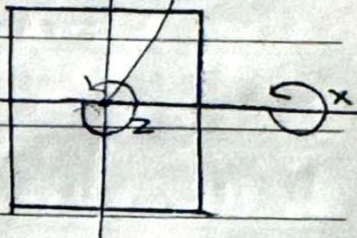
* Notice that the center remains stationary.

Implementation (Program)

* A 3-AXIS gyroscope measures the same way for angular velocity.



Warp Perspective transformation
Rotation Parameters (25, 3, -31) degrees



How the image is warped. Visualized, you can try it on Apple Photos also but it only works for $\pm 30^\circ$ in each direction.

* This Program is attached to the CFSF Platform

However, because the image is flat (2 dimensional) rather than 3d, this is done through stretching the image, interfering with the dimensions, however the camera measures angles for the Pen so that is not a concern.

December 26, 2024

11

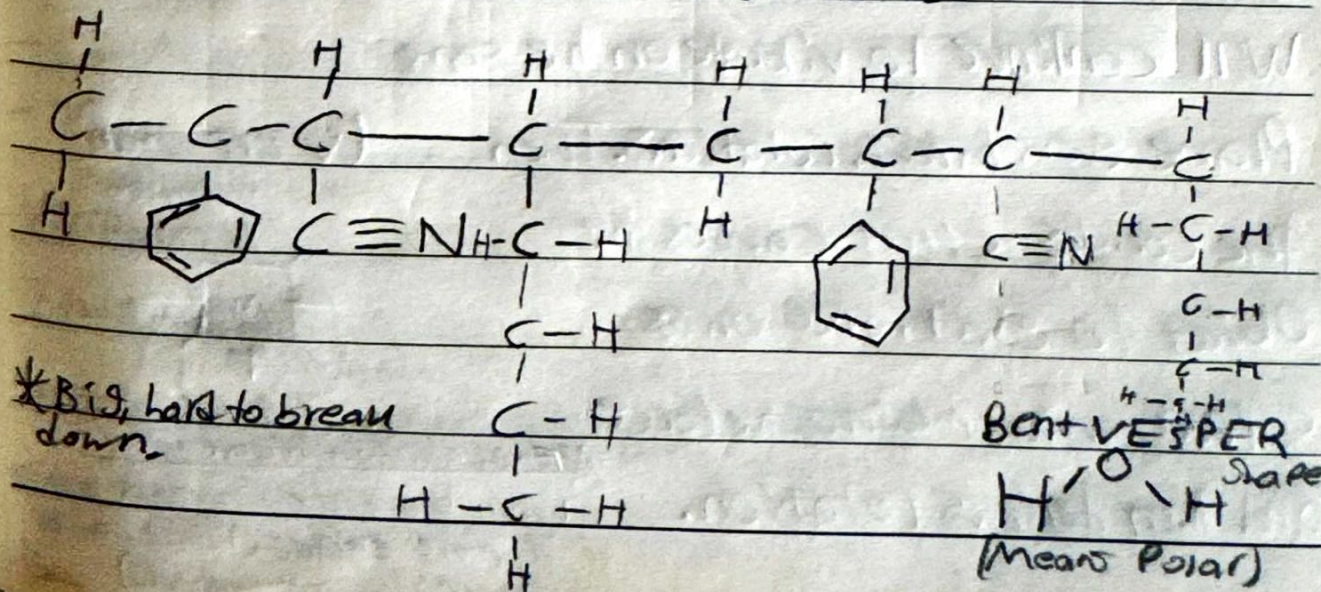
Positioning of the mouse cursor

When the pen is sliding on the Page (writing mode) the pen's ball rotates through friction, releasing ink from the cartridge. This rotation is detected by the optical mouse sensor that will send this displacement data to the microcontroller for further processing. In order for this to work, both the physical size of the drawing page and mouse sensor's resolution are required according to "The optical mouse sensor as a two-dimensional displacement sensor. No, T.W."

What if the mouse sensor gets obstructed by ink?

In theory if the pen was made of a nonpolar material like ABS seen in Lego bricks, and the pen's ball has polar, the polar ink (contains water) would be attracted to the ball causing it to rotate with it - And the mouse sensor detects that movement.

* This was further illustrated on Page 5.



Capacitor: stores electrical energy by accumulating electric charge between 2 closely spaced surfaces

- How does a gyroscope work?

There are 2 kinds of gyroscopes

1. Mechanical gyroscopes

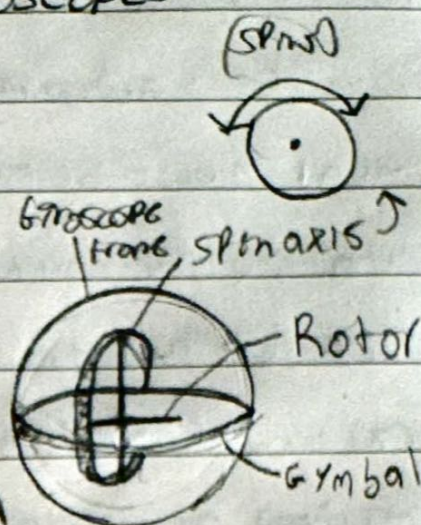
- The rotor spins on its axis so is unaffected by other rotation according to the conservation of angular momentum.

Newton's third law of motion:

"In a closed system, no torque can be exerted on any matter without the exertion of some other matter of an equal and opposite torque about the same axis, but total angular momentum before and after an exchange remains constant (conserved)."

→ The faster the spin → greater angular momentum

More resistance to changes in orientation



2. Digital Micro-Electro-Mechanical systems - (The one I bought)

- Uses vibrating structures to determine the rate of motion

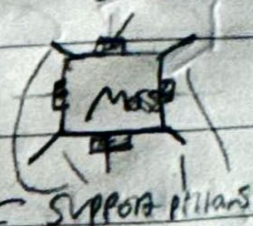
Based on the principle that a vibrating object will continue to vibrate on the same

Plane even through rotations. Then

The Coriolis effect causes the object to exert force on its

Support - which measures the force and then derives rotation.

(Very small) system



★ Each contains a capacitor

When the plate vibrates towards it, more electric charge can be stored (then is translated)

February 15, 2024

12

Testing Gyroscope accuracy

A ^(digital) gyroscope measures angular velocity rather than directly measuring angles. By integrating angular velocity data over time one can determine the angular displacement.

Accurately measuring the gyroscope's precision using manual methods, such as a protractor introduces a significant margin of error.

Therefore this experiment will not focus on the immediate accuracy of angular displacement measurements but will assess the long term drift of my chosen gyroscope - Arduino Nicla vision's gyroscope (LSM6DSOXTR gyroscope from ST microelectronics).

This experiment will provide insight to a gyroscopes stability/reliability for a period of this precision.

Materials

- Arduino Nicla vision LSM6DSOXTR 3-axis gyroscope
- Computer with openMV installed (to record the measurements)
- Thermometer (to ensure a consistent temperature environment)

Variables

Independent: Time

Dependent: Angular drift outputs in the 3-axis gyroscope

Controlled: Temperature and stability of the device (gyroscope and cable)

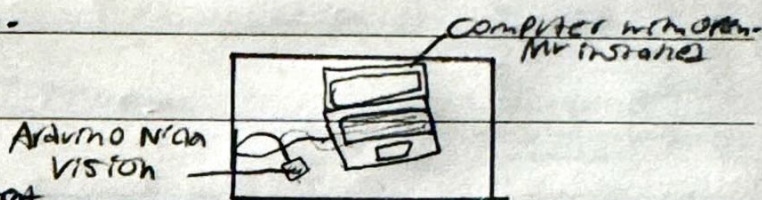
Testing Gyroscope accuracy

Setup

I secured the Nida vision on a stable, non moving surface to eliminate any external influences on its orientation. I also monitored the room's temperature as I know it can effect the gyroscopes performance and left it unobstructed to measure its orientation.

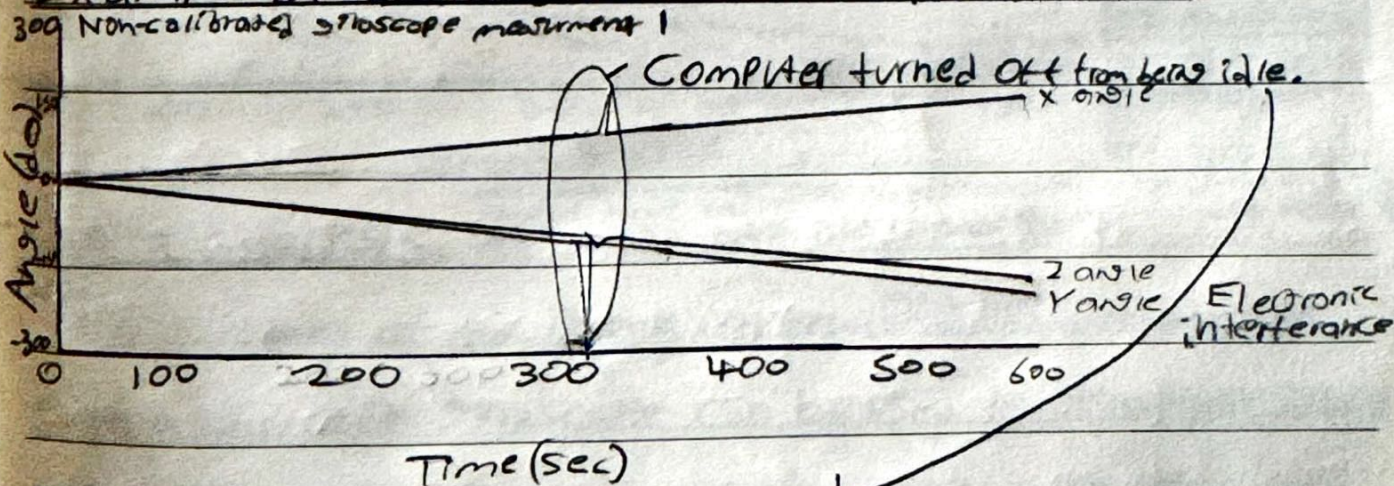
Data collection

I performed the experiment



5 times to ensure a consistent and reproducible result of the 6000 3 dimensional rotation values over 10 minutes (10 readings per second) - a fast frequency in relation of the fast movements of the users hand during handwriting.

Example of excluded result due to human errors



Therefore next time, I raised the timeout settings on my computer not to turn off from being idle in the time frame.

Other sources of error

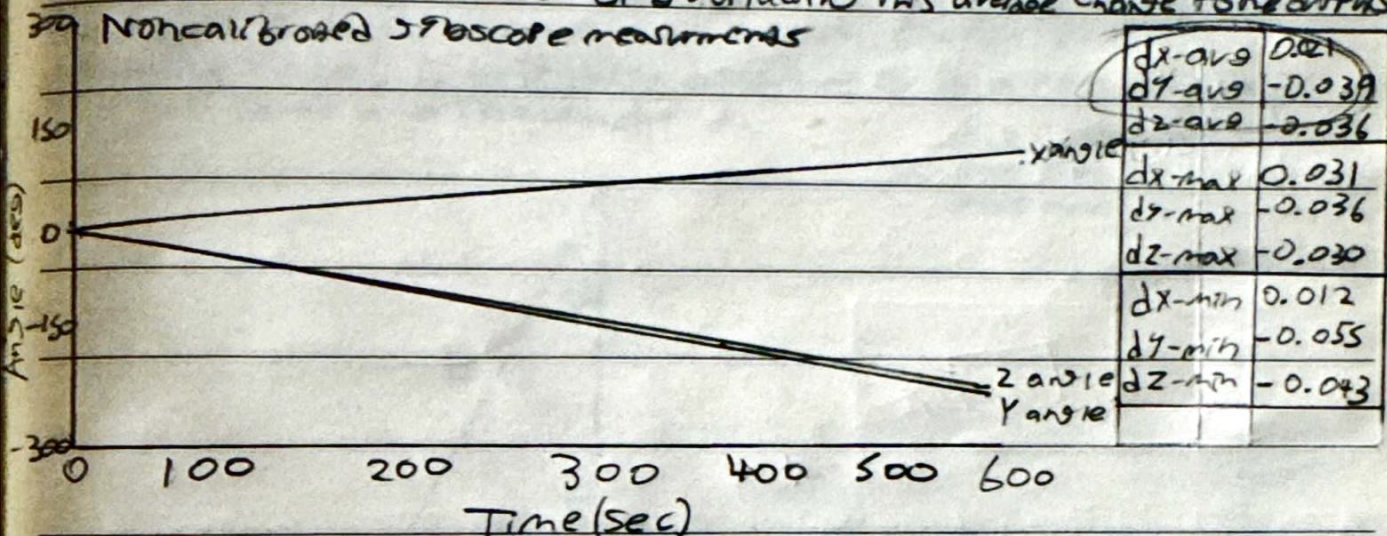
- Temperature could not be fully controlled as the microcontroller heated up.
- External vibrations like noise and appliances/vehicles near it.

Testing Gyroscope accuracy/drift

Before Calibration

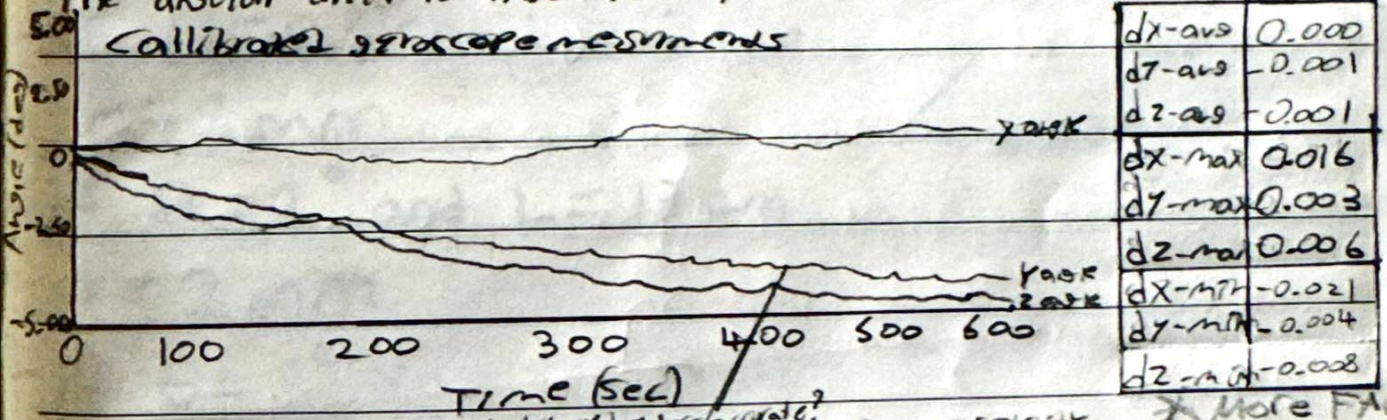
I was not expecting this level of drift, I expected around 5 degrees as this is how much drift relatively fitted gyroscopes have.

The graph seems very linear/consistent in error, it turns out gyroscopes have to be calibrated by subtracting this average change to the outputs.



After calibration

The angular drift is much lower, never exceeds 5 degrees after 10m.



Data analysis

What other factors? Might have variations in sensitivity or the calibration was rounded poorly.

More FAQs on Page 93

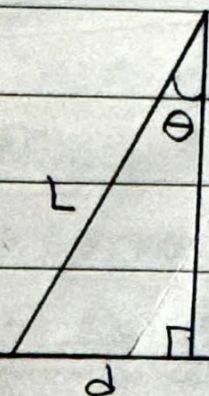
The outcomes of the above experiments demonstrate that even a low-cost gyroscope can be used to effectively control the pen's orientation. However, it will need to be calibrated during initialization to keep angular errors at a minimum.

Why this form of graph? The trend is not discrete so a graph is better to show this linear trend.

Estimated accuracy

- Gyroscopes are prone to angular errors in all 3 axes.
- I need to estimate the displacement of the pen caused by an angular error θ .
- Let L be the height of the pen from the tip to the camera. For simplicity, I will assume that the pen stands perpendicular to the drafting page. I will also assume θ in a random direction that will cause a displacement d .

d is proportional to L :
 ★ The smaller the L , the more accurate is the pen.



$$d = L \sin \theta$$

- if $\theta = 0.5^\circ$ and $L = 13 \text{ cm}$

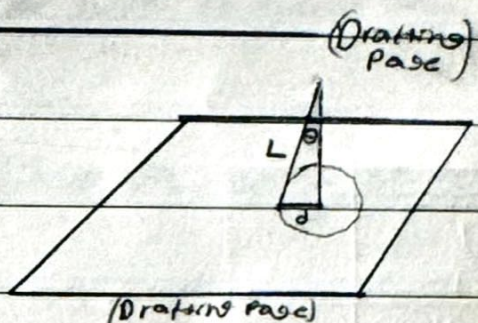
$$d = 1 \text{ mm}$$

- if $\theta = 1^\circ$ and $L = 13 \text{ cm}$

$$d = 2 \text{ mm}$$

- if $\theta = 5^\circ$ and $L = 13 \text{ cm}$

$$d = 11 \text{ mm}$$



Implications

Beyond the implication of improved memory retention from writing notes letter by letter compared to typing on a keyboard. This project improves online learning in remote communities through instantaneous sharing and collaborating notes between students and educators.

In addition to academic domains, this can also be useful for detecting movement abnormalities in handwriting data, the embedded gyroscope - aiding in early diagnosis / monitoring of patients with Parkinson's disease or those recovering from severe head injury or stroke.

* Source analysis's are available on pages 89-90 supporting these implications.

December 2, 2023 and February 3, 2024

17

Interview: Spiros Ratsiotos (Computer Scientist)

Contact information: +30 699-342-4860

Q: "My camera captures an image that includes the pen, page, and part of the table. How could I create a new image that will only show the page?"

A: This problem is known as "image segmentation", you can try the Open CV Python library. Try an image segmentation algorithm.

Q: "After I get the image segmented, how could I find the location of the page's corner points?"

A: There are algorithms that do that in Open CV library. Usually those algorithms generate many points, think of a way to filter them.

Q: I have developed a Python Jupyter notebook that can do the image segmentation, rectification, and location of the corner points. How can I make it run on a microprocessor?"

A: There is an image processing IDE called OpenMV that has embedded libraries to OpenCV.

Q: "How do I collect the microscope measurement?"

A: There should be some example codes that do that, some for the camera.

February 4, 2025

18

Interview: George Tritakis (MD)

Contact information: 403-475-5840

Q: "I am in the process of developing a pen that transcribes handwritten notes using a camera, mouse, and gyroscope. I need your guidance to see if there are any medical implications or associated with the pen."

A: The gyroscope and mouse sensor could detect abnormal shakes in user's hands like with those with Parkinson's disease - specifically large and recurring tremors in users hands. These illnesses are often takes time to be noticed by patients so diagnosis and treatment begins very late. This pen could speed up this process.

Q: "Are there any other cases where this pen could be useful?"

A: Yes, people recovering from stroke and head injuries also suffer from abnormal movement in their hands. There are plenty of resources that describe these movements in more detail.

Limitations

Positioning errors.

As described on page 14, though the sensors in the pen can provide accurate measurements, they have some limitations that can lead to random or systematic errors.

Moving the drafting Page

It is assumed the drafting page will remain stationary during handwriting as it is a reference plane when finding the pen's angular displacement/orientation.

Computational Power

The computational power of the microcontroller is limited, it takes seconds to run the image processing program on a PC, real time capabilities will have to rely on some computation to be migrated to an external device.

Battery capacity and size of the pen.

Though not a top priority, all the high refresh rate sensors, data processing, and wireless communication will drain the battery. To reduce footprint size, the volume of the battery would need to be maximized, however this would come at the cost of the size/ergonomics of the pen.

The Paper used has to be a rectangular/square shape

This is because both the formulas and image processing methods assume this to determine the position of the pen to the corners of the page.

Conclusion

In conclusion, this project successfully demonstrates feasibility for a pen that digitizes handwritten notes on paper in real-time without external components, integrating low-cost sensors and algorithms accurately. Thereby combining the existing benefits of handwriting and digital convenience.

It is worth noting that this project is currently under active development, with the primary emphasis on establishing proof of concept.

Things I learned

- Advanced trigonometry and different relationships between the geometry of rectangles, circles, and triangles.
- How gyroscopes, compasses, cameras, and mouse sensors work
- How to code image processing in python / methods and algorithms for it

Short term tasks for the future

- The migration of the image processing modules (currently on ^{using opencv} ~~python~~ ^{python library} ~~its own library~~ ^{to} ~~code~~ ^{the} ~~open~~ ^{IDE} ~~so~~ ^{there is less dependence on external compilation}
- More experiments on the sensors to understand them better and begin to combine them

Long term tasks

- Make a fully functioning prototype of the pen
- Testing, validation, and commercialization

Feedback CYSF 2024

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- Organized lookbook

* Need more physical testing to validate theory

- By category $\star \rightarrow$ Prototype

1. Problem

✓ - Existing knowledge

X - Direction

] Communicate direction through the scientific method more/
be more clear on motivations

2. Methods

X - Limits

X - Design

X - Testing

] Physical testing/prototype related

3. Analysis/Conclusion

✓ - Existing knowledge

X - Direction

4. Creativity

X - Originality

X - Resourcefulness

X - Application

X - Growth

] Existed but innovation should have more physical testing.

5. Communication

X - Visual] Nothing physical on display

✓ - Oral

- Additional things to improve

- Award judging is quick! (3m)

- Focus more on code/more flowcharts, less text

2. Camera Positioning

I have already ordered the Arduino Nicla Vision which contains
 Nicla vision onboard camera:

2MP GC2445 Color DVP Camera module.

Number of effective Pixels	1616(H) x 1232(V)
Frame Rate	640x480 → 17FPS 320x240 → 27FPS
* Focal Length	2.2 mm
Field of view (FOV)	80°(D)
DFOV = Diameter FOV	

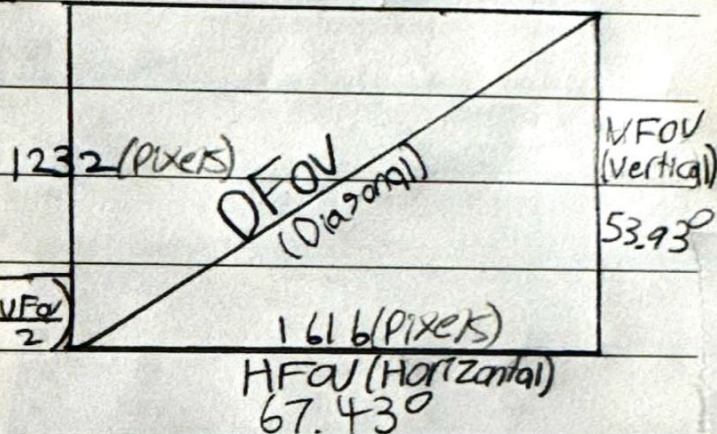
- The image is rectangular:

$$\text{Aspect Ratio} = \frac{H}{V}$$

$$\text{DFOV} = 80^\circ$$

$$\tan\left(\frac{\text{DFOV}}{2}\right) = \sqrt{\tan^2\left(\frac{\text{HFOV}}{2}\right) + \tan^2\left(\frac{\text{VFOV}}{2}\right)}$$

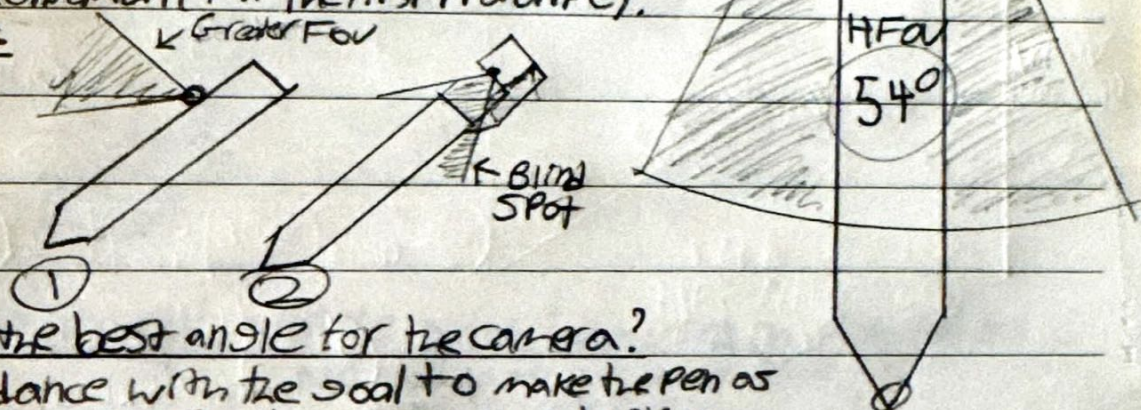
$$\text{Aspect Ratio} = \frac{\tan\left(\frac{\text{HFOV}}{2}\right)}{\tan\left(\frac{\text{VFOV}}{2}\right)}$$



Optimizing the camera's position on the pen is critical to the pen's versatility given the very low DFOV of 80° . Due to this low FOV and the fact that the pen will be very thick because of retail components, placing the camera at the pen's top will not be effective.

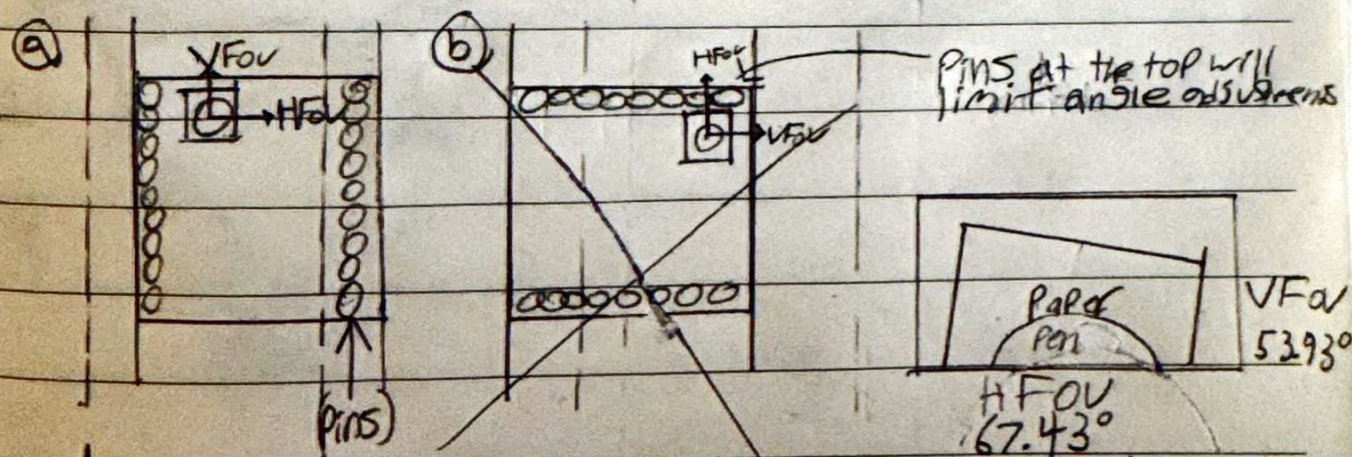
Therefore, the camera will be located at an upper side of the pen and the user will be restricted to a specific hold to maintain the pen's orientation (For the first prototype).

Alternatives:



What is the best angle for the camera?

- ① In accordance with the goal to make the pen as compact as possible to encourage adoption, the Nica vision will need to be in the below orientation:

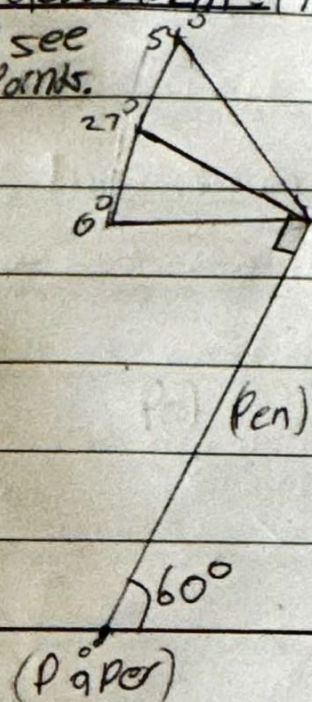


* Camera must be centered to simplify positioning calculations when translating the corner points to the pen's center, and make the FOV balanced while experiencing minimal obstruction. Therefore, the FOV on the X axis relative to the Paper should not be adjusted.

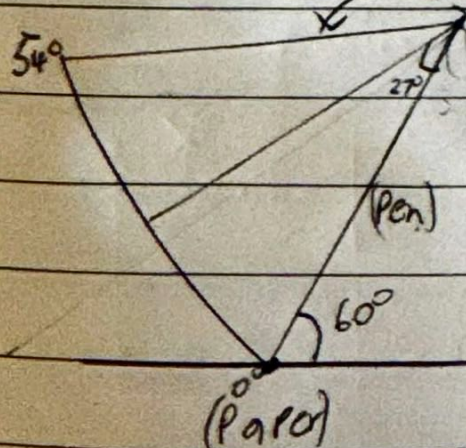
② OPTION (a) was the selected camera orientation (Page 24).

Its γ -axis relative to the drawing page is its VFOV (53.93°). * For simplicity and because of low manufacturing precision, I will round to 54° .

- Without adjustment: (90°) * Avg Pen/Pencil hold = 60°
- Will rarely see the corner points.



② 27° Adjustment - Angle going to be used in Prototype #1
No need to go over unless the paper is very far.



Comparison orientations!

Part dimensions / Specifications Continued...

- Further specifications of the components needed for positioning: (Arduino NDI vision user manual)

- Camera: GC2145 2MP Camera sensor

- 1616x1232 Pixel array, 1.75 μ m Pixel size

- 80° FOV lens

* Focal length: 2.2 mm

- supports RGB output (color)

- Motion Sensor: LSM6DSOXTR IMU accel/gyro

- 3 axis accelerometer (acceleration range $\pm 2, 4, 8, 16g$)

- 3 axis gyroscope (Angular rate range $\pm 125, 250, 500, 1000, 2000$ dps)

- Angular rate range: (sensitive)

The rate of change of angular momentum produced by the applied force.

(angle) (time) Δ = "change in" a variable

$$\rightarrow m = \Delta \theta \Delta t$$

- GY-271 HMX5883L (compass)

Magnetic field $\rightarrow$ Voltage output in 3 axes

- Measuring range: ± 8 GAUSS (Strength of magnetic field)
(Magnetic field strength)

- Pins:

VCC: Power supply (3-5 Volts)

GND: Ground (to prevent short circuit)

SCL: I2C Clock Pin

SDA: I2C Data Pin

DRDY: When there is output, the pin is "0"
(Data Ready) For 250 microseconds (not essential)

(1:1 Scale) sketch

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- Connecting to the Arduino:

(Compass)

(Arduino Pin configuration)

VCC	0
GND	2
SCL	2
SDA	2
DRDY	0

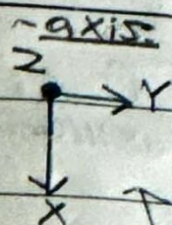
0	0
0	0
0	0
0	0
0	0
0	0
0	0
0	0

VIN

GND

SCL

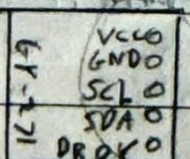
SDA



(Top view)

13.5mm

14.8mm



The back side

February 14, 2025

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Part dimensions / Specifications

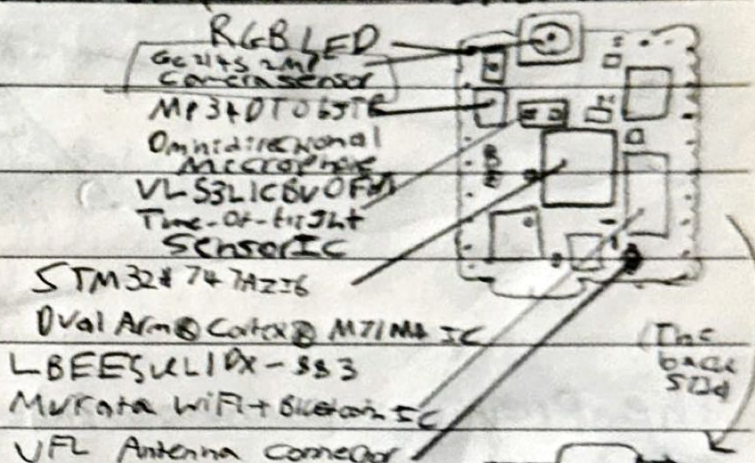
- The gyroscope and Compass have arrived from Amazon.com.

- I will look at the specifications in more detail on the user manual.

- Arduino NICKA VISION (contains a gyroscope)

- Software required:

- Open MV IDE
- Arduino IDE 1.8.10+
- Arduino IDE 2.0+
- Arduino Web editor

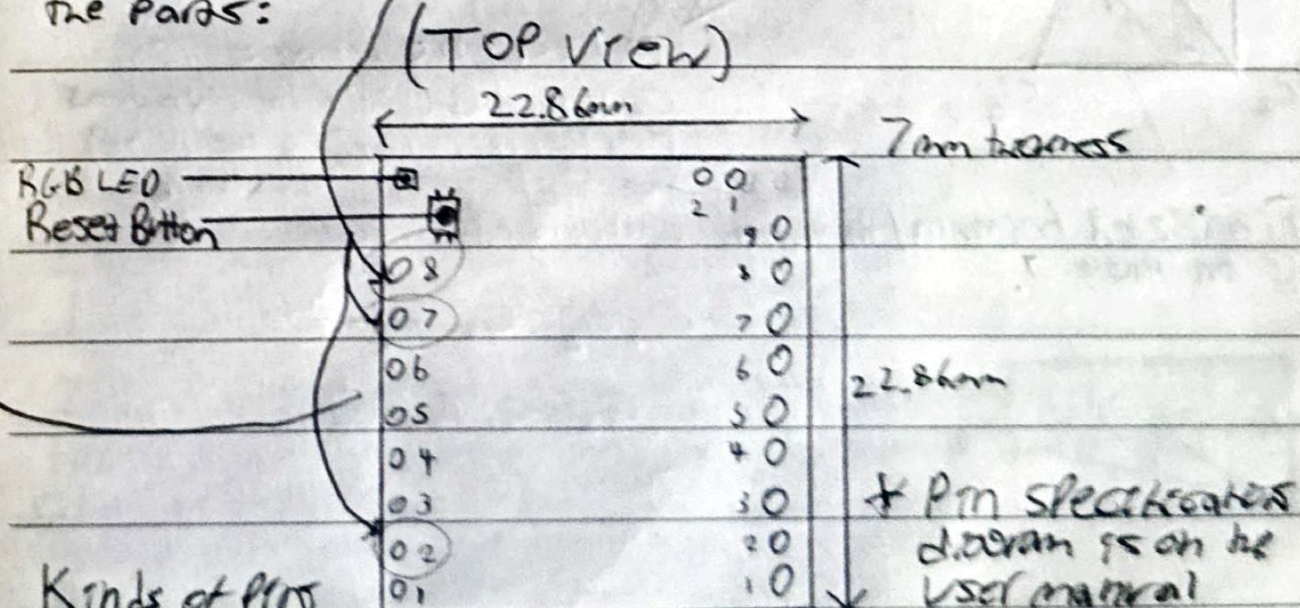


MicroUSB Needed to connect to computer

* 1.8-3.3V reference volts (pins)

- 5V Power supply

- Pinout for future connection to the rest of the parts:

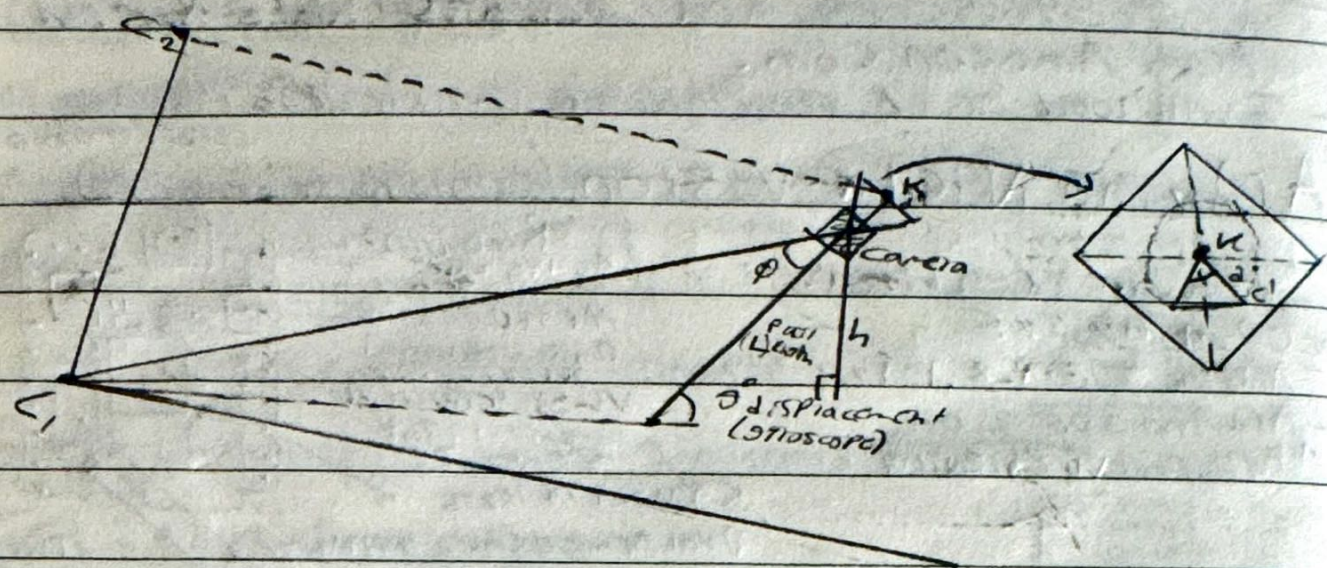


Kinds of pins

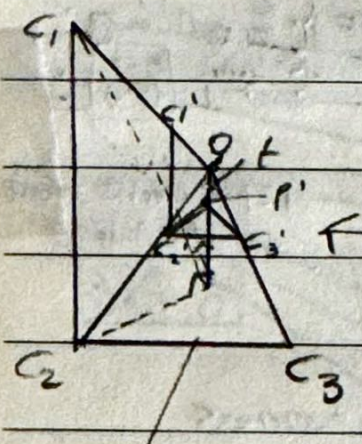
Analog Pins: Examples voltage levels - specially for sensors with continuous outputs

Digital Pins: Have 2 states - Low or High (Vcc)

VOLTS: 0 5 (Depends on component)



The previous formulas needed the side lengths of the page, if the user does not know it, a second initialization step must happen:



* 3 points are needed as 2 triangles are being solved.
- Placing the pen as shown allows this to happen.

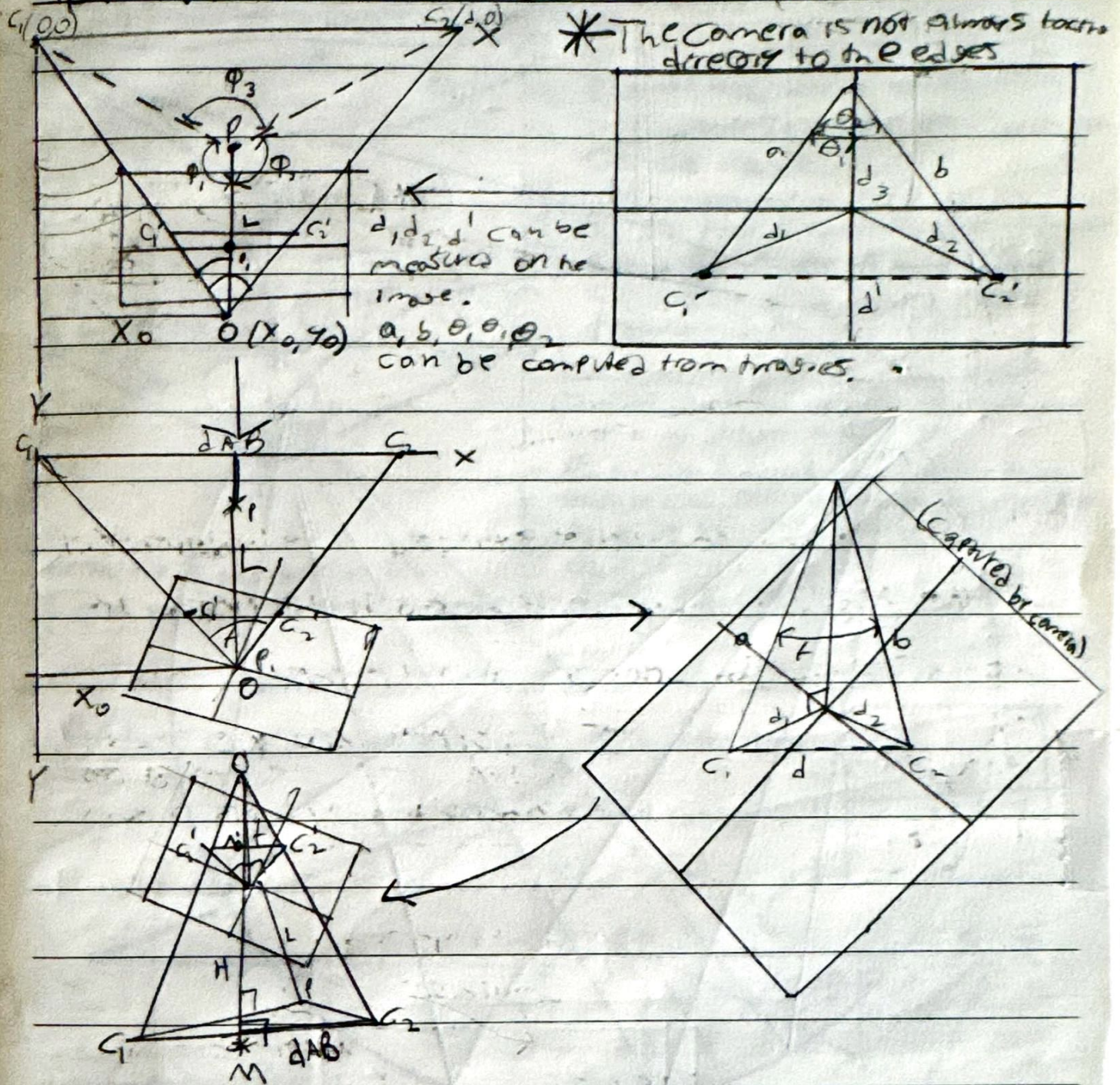
After the image is calibrated (as if the pen was perpendicular to the page) the size of the page can be calculated:

* Finalized formula/drawing is on page 7.

$$C_2 C_3 = C_2' C_3' \cdot \frac{h}{p}$$

$$C_1 C_2 = C_1' C_2' \cdot \frac{h}{p}$$

Brainstorming formulas (positions of the points)

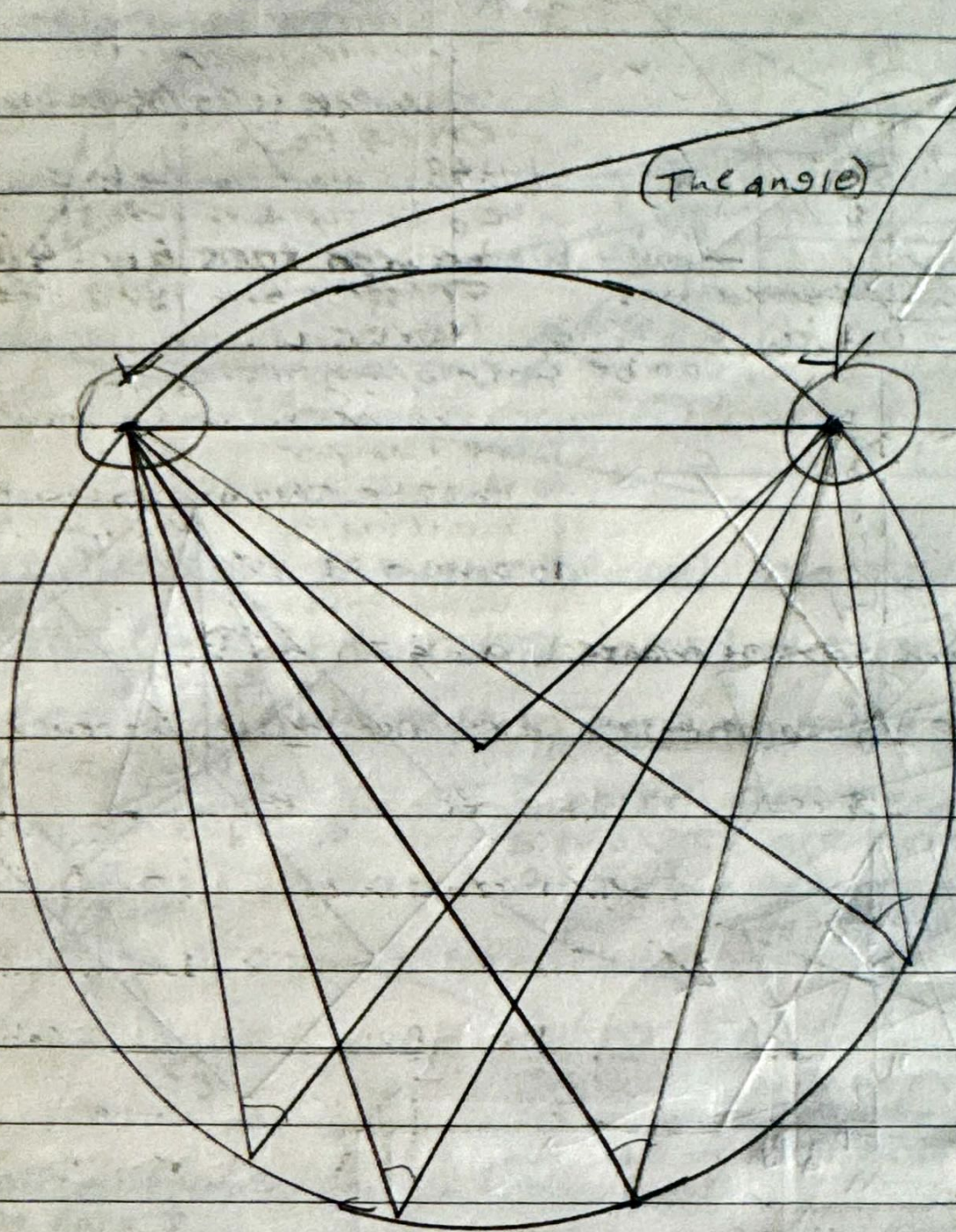


* This method (page 86) Does not work!

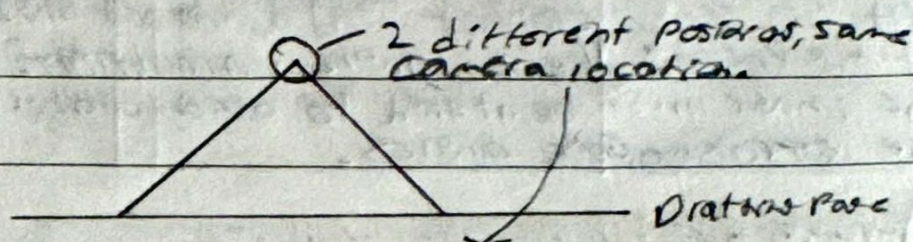
It does not accommodate for the Pen's tilt, so you cannot find the exact angle of the points due to angle variability.

The image must be altered to accommodate for the stereoscope's angles.





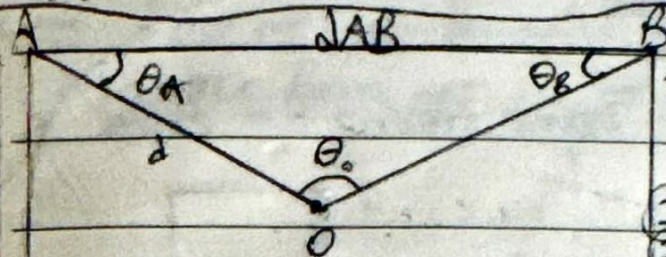
This is for the position of the Pen's camera what it:



The Calculation in Page 87 determines the Pen's trip position, this is only for the top camera.

Brainstorming formulas (Positioning pen's tip)

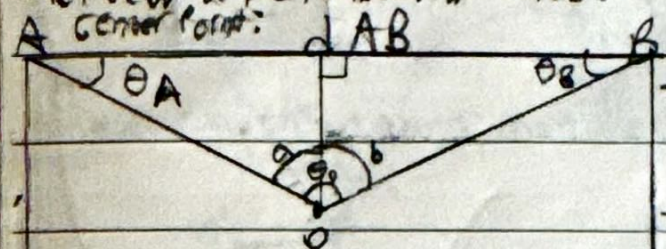
- Move from corner to center point:



* The combination of θ_A and θ_B is unique for a single coordinate on the page.

1. dAB is known from the user
2. θ_0 is found through the distance between pixels A and B (the corners), and found using a protractor.

- Draw a perpendicular line from center point:



- The function derived from $A \rightarrow B$ can be used to get the perpendicular line that passes through O.

- θ_0 is then split based on where the tangent line passes through it. And this

3. gives us the 90° .

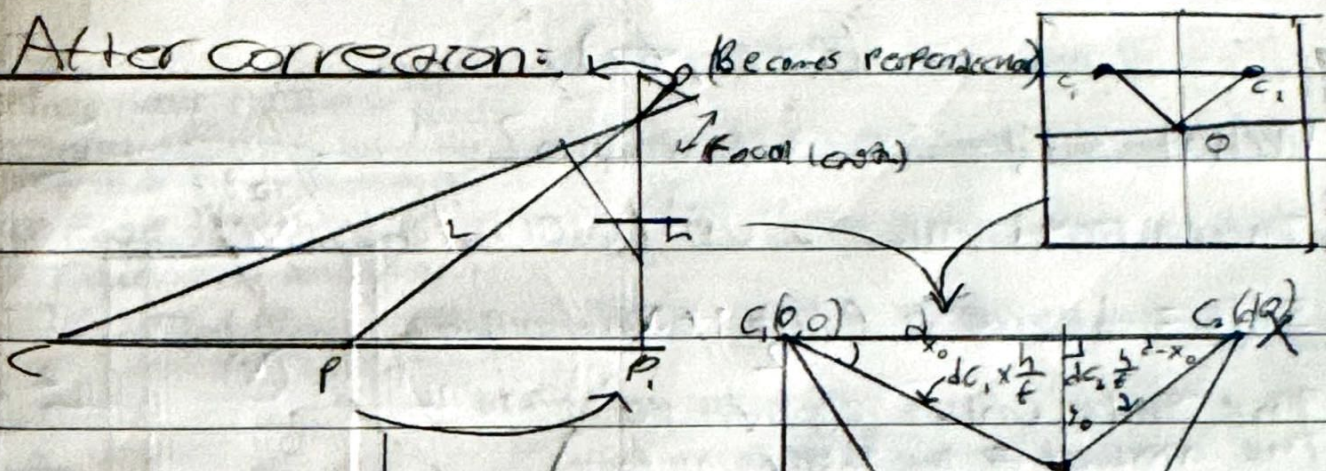
$$\theta_0 = 180 - (b + 90)$$

$$d = dAB \cdot \frac{\sin \theta_B}{\sin \theta_0}$$

With the 3 unknowns, I can now solve the triangle:

* The above method does not work, see page 85.

After correction:



(angle)

$$\hat{C}_1 = \arccos \left[\frac{dC_2^2 - dC_1^2 - d^2}{2 dC_1 \cdot d} \right]$$

$$y_0 = dC_1 \cdot \sin \hat{C}_1$$

$$x_0 = dC_1 \cdot \cos \hat{C}_1$$

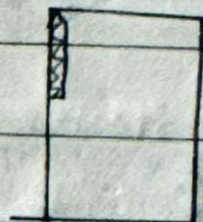
* Finalized formulas/diagrams are on page 8.

JULY 25, 2024

- Initialization Step 1. ←

- Place pen tip on the page facing the top side + 0:

1. Get the orientation of the page
2. Find which direction is "UP"
3. Find the color of the page for image processing



- Gyroscope displacement:

$[\varphi_{xi}, \varphi_{yi}, \varphi_{zi}]$ - Initial measurements

$[\varphi_{xa}, \varphi_{ya}, \varphi_{za}]$ - Actual measurements

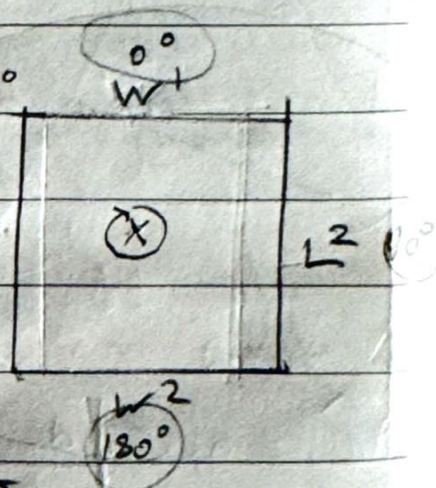
$$\text{Displacement: } |\varphi_{xi} - \varphi_{xa}, \varphi_{yi} - \varphi_{ya}, \varphi_{zi} - \varphi_{za}|$$
$$= (\varphi_x, \varphi_y, \varphi_z)$$

- What side is it facing?

Initialized value = "UP" / North / 0°

Side = $\frac{\text{degree of Point 1} + \text{degree of Point 2}}{2}$

The Side value closest to 270° is the answer = the edge being faced.



* Depending simply on the gyroscope's direction could lead to incorrect results if the angles are not near the center of the camera's FoV.

February 19, 2024

(Citation [197])

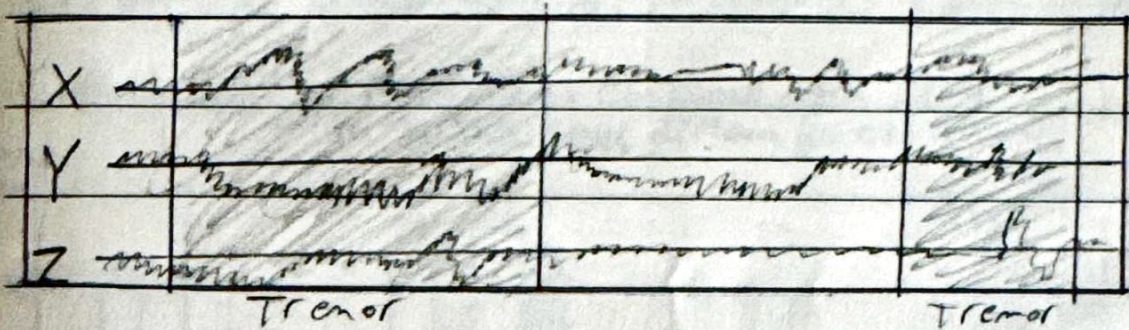
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Source Analysis - "Parkinson's Disease Tremor Detection in the Wild using Wearable Accelerometers"

The Study looks into the detection of Parkinson's disease tremors using wearable accelerometers.

Specifically emphasizing the potential for improving disease monitoring/patient care through sensors and machine learning algorithms in real-world settings.

Figure 1. Automated tremor detection with wearable sensors during everyday activities.



December 9, 2024

(Citation [16])

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Source Analysis: Distance as a factor for First Nations, Métis, and Inuit High School completion

This study from Statistics Canada investigates the impact distance has had on First Nations, Métis, and Inuit students. Based on 2016 census data and a Remoteness Index, it found that students in more remote areas are less likely to complete high school - highlighting how geography impacts the educational outcomes for Indigenous communities.

Chart 2, The proportion of those aged 19-45 with high school diploma (or equivalent)

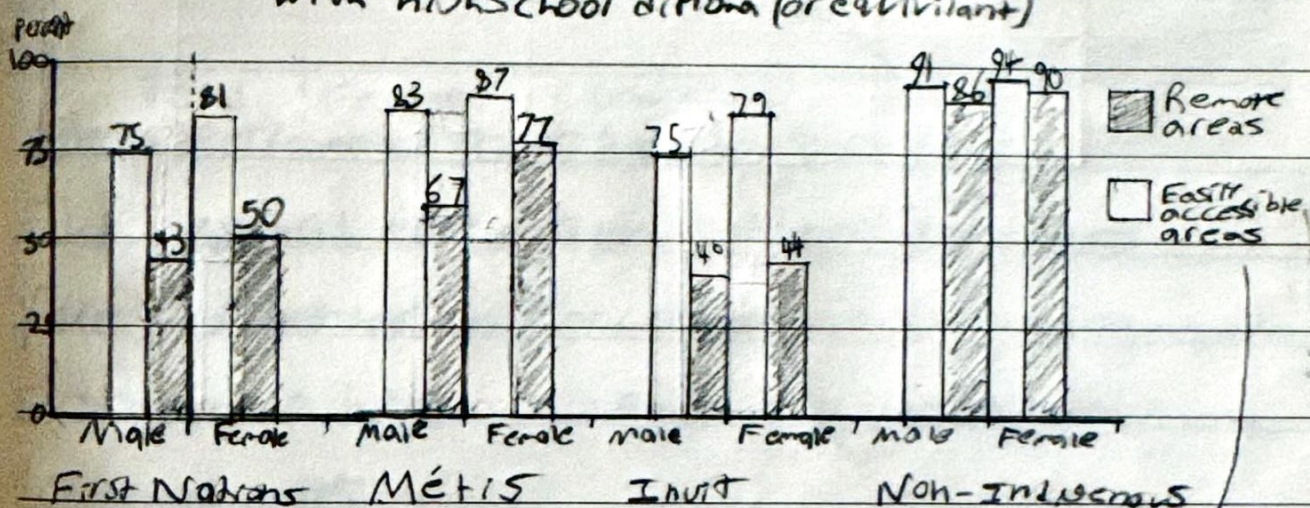
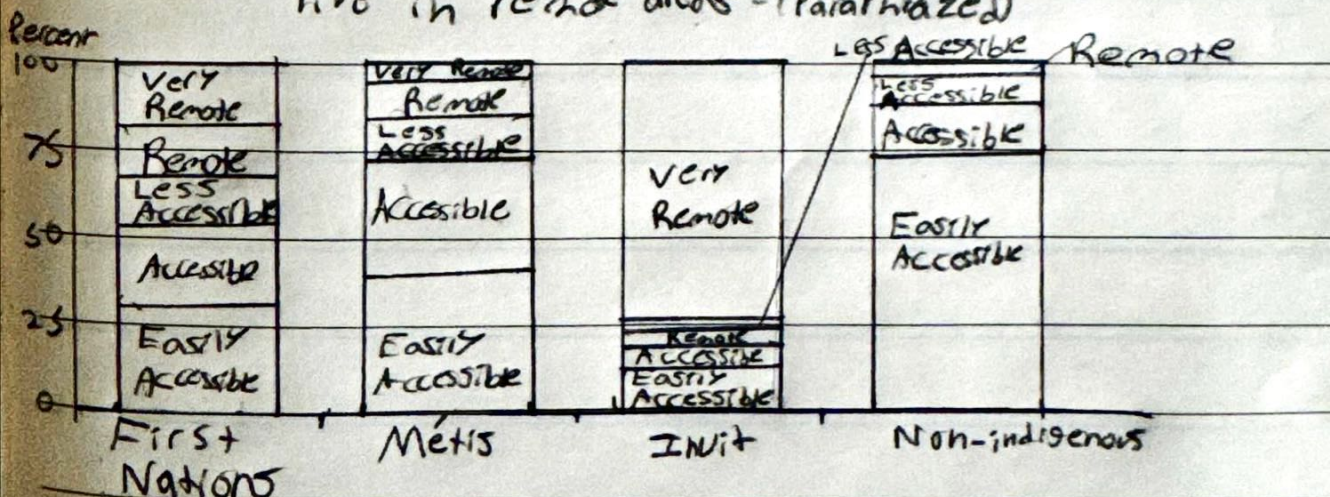


Chart 1, Indigenous people are more likely to live in remote areas - (Paraphrased)



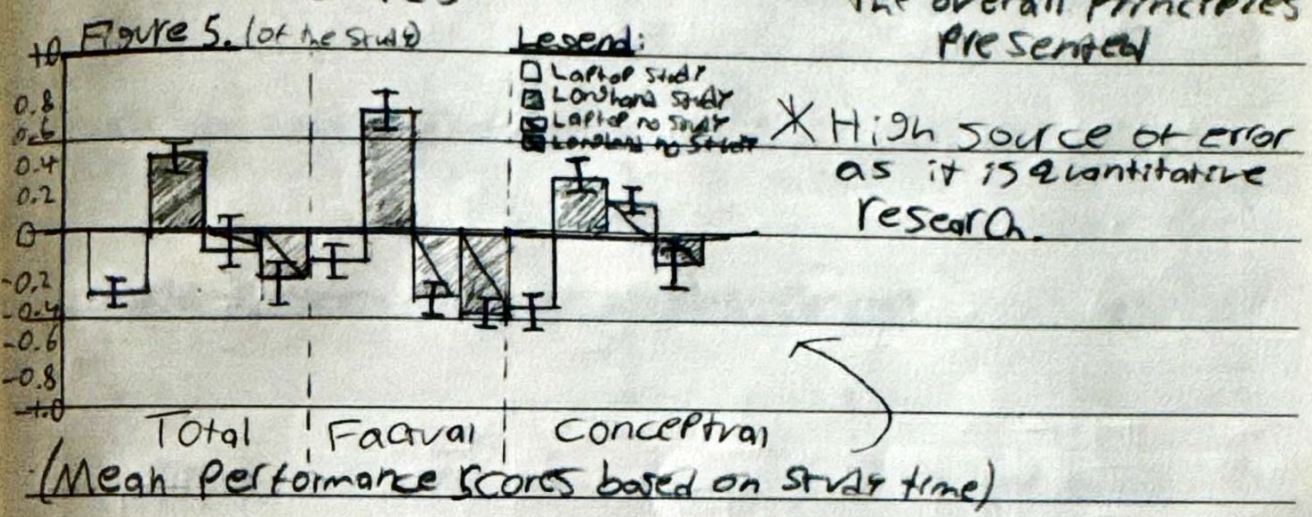
Census subdivision (CSD) = Municipalities

June 14, 2024

Source Analysis: The Pen is Mightier than the Keyboard

This study examines the impact different kinds of note taking (Longhand vs. Typing) has on learning - Split between factual and conceptual performance.

Remembering specific details in lectures The understanding of the overall principles presented



The research found that longhand note-takers performed better in Conceptual and factual examinations suggesting a better understanding is gained when taking longhand notes.

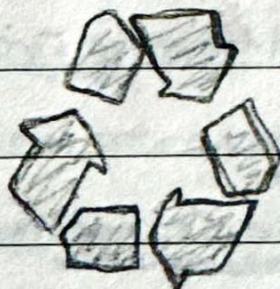
Risk and Safety

Safety will be taken with utmost consideration during the manufacturing and disposal of the pen and its materials. To ensure a safe work environment, proper use and handling of equipment (e.g. soldering irons or box cutters) will strictly adhere to safety guidelines regarding precautions, personal protective equipment, and first aid measures. Furthermore, all activities will be conducted in a closed environment, therefore, proper ventilation will be a top priority, especially during soldering activities. Finally, materials requiring special disposal, such as batteries, wires, and plastics, will be recycled at local drop-off/recycling centers. Any remaining components that do not pose a risk will be disposed of in compliance with environmental standards and regulations.

Reduce

Reuse

Recycle



Acknowledgment

I would like to acknowledge Pantelis Stefanakis, Electrical and Computer Engineer for his advice and support throughout my project. His support included helping me validate my research and find effective experimental methods to test the prototype.

Thank you to Spiros Ratsios, Computer Scientist for walking me through the programming tools used in this project and debugging my programming scripts.

Finally, I would like to thank Gorge Tritakis, Medical Doctor for his insights on the potential implications of my project in healthcare and safety practices.

Scientific Method

Problem | What inspired me?

Hypothesis | Based on research

Collect Data | Conduct an experiment

Analyze Data | What did I learn?

Conclusion | How does this connect to the hypothesis?

Apply and Share Knowledge with others.

Variables

Independant: There should only be one per experiment
Variable that is changed to cause changes in the dependant variable.

Dependant:

Variable that changes when another variable is manipulated.

Controlled: A common source of error

Variables that are kept constant throughout the entire experiment.

Systematic error: Effects accuracy Eg) wrongly calibrated ruler/scale

Random error: Effects precision Eg) Randomly by chance - fluctuating temperature on external temp.