SIMULATIONS

TEAM POST-CHAIRNOBYL

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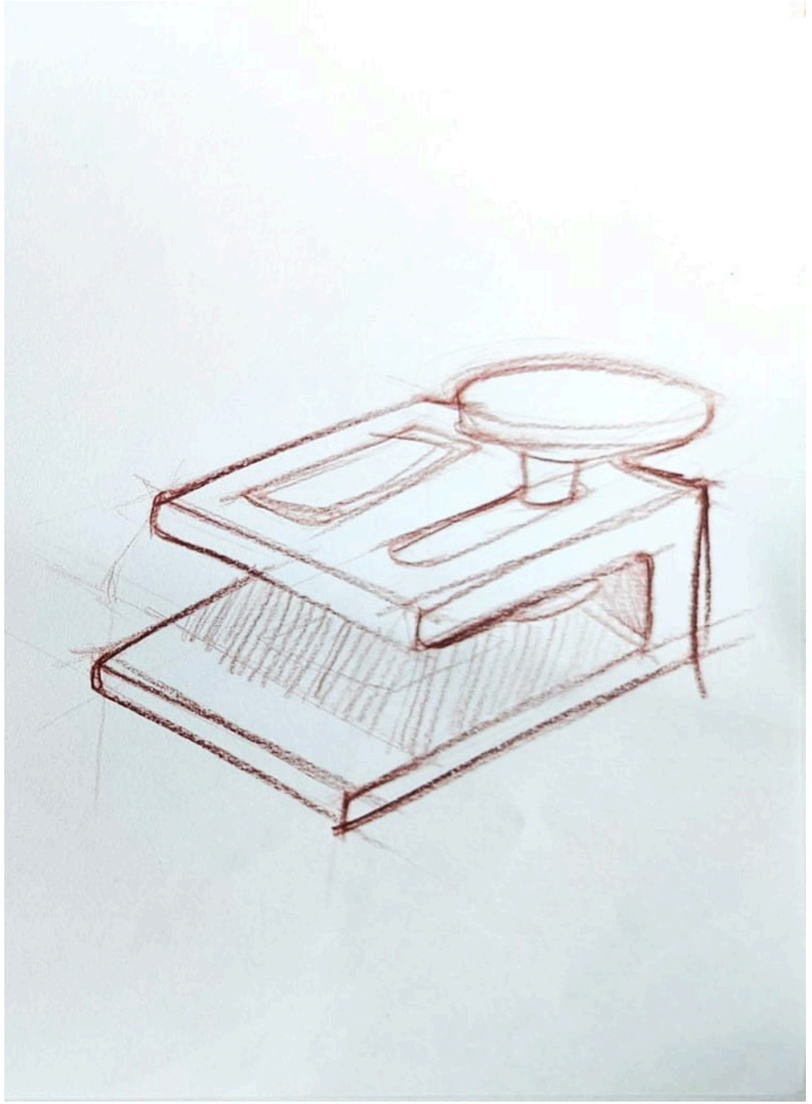
CONTENTS

- Simulation of concepts for 3 different requirements
- Math model
- Virtual simulation
- Physical simulation (prototype)
- Evaluate and give results
- Change design

CONCEPT 1

ERGONOMIC SORTING AND SEALING ASSISTANT

- ocr recognition through camera (placing it manually in the container)
- computer screen validates (black- unvalid), assigns segregation method based on color, displays color (10).
- authenticate it manually
- put in the colored bin
- ocr recognition. (pincode + Address)
- code for displaying color according to address.
- stamp it by pumping it
- colored bins



MATHEMATICAL SIMULATION

INPUT PARAMETER CALCULATION

Seal Force:

The force required for a seal stamp depends on the following factors:

- **Material of the letter:** The thickness and type of paper affect how much force is needed.
- **Indentation depth:** The depth of the indentation or ink impression desired.
- **Contact area:** The size of the seal (e.g., a circular seal with diameter).

$$F_{seal} = P \cdot A$$

Where,

- P : Pressure required for stamping (depends on the paper and ink type). Let's assume 1.5 MPa (a common pressure for stamping).
- A: Contact area of the seal. For a circular seal of diameter d, $A = \pi \left(\frac{d}{2}\right)^2$
- Assuming a seal diameter of d=2 cm: $A = \pi \left(\frac{2}{2}\right)^2 = \pi\,\mathrm{cm}^2 \approx 3.14\,\mathrm{cm}^2$

$$F_{seal} = 1.5 \times 10^6\,\mathrm{N/m^2} \times 3.14 \times 10^{-4}\,\mathrm{m^2} = 471\,\mathrm{N}$$

MATHEMATICAL SIMULATION

LIST OF INPUT PARAMETERS

Parameter	Symbol	Unit	Value
Number of mails to process	N(mail)	mails	User-defined
Average processing time per mail	T(proc)	seconds/mail	8 - 12 seconds
Camera scanning time	T(scan)	seconds	1 - 2 seconds
OCR and AI sorting time	T(sort)	seconds	1 - 2 seconds
Color code display time	T(color)	seconds	0.5 - 1 second

MATHEMATICAL SIMULATION

LIST OF INPUT PARAMETERS

Parameter	Symbol	Unit	Value
Color code display time	T(color)	seconds	0.5 - 1 second
Manual stamping time	T(stamp)	seconds	2 - 4 seconds
Seal force applied	F(seal)	Newtons (N)	400 - 500 N
Operator efficiency factor	η(op)	-	0.8 - 0.9

MATHEMATICAL SIMULATION

OUTPUT PARAMETER CALCULATION

1) Processing time per mail:

$$T_{proc} = T_{scan} + T_{sort} + T_{color} + T_{stamp} = 1.5 + 1.5 + 0.7 + 3 = 6.7 \text{ seconds/mail}$$

2) Total processing time:

$$T_{total} = N_{mail} \times T_{proc} = 500 \times 6.7 = 3350 \text{ seconds} \approx 55.83 \text{ minutes}$$

3) Throughput rate:

$$R_{throughput} = \frac{N_{mail}}{T_{total}/3600} \times \eta_{op}$$

Including operator breaks:

$$R_{throughput} = \frac{3600 \times \eta_{op}}{T_{proc} + \frac{T_{break}}{60}} = \frac{3600 \times 0.85}{6.7 + \frac{10}{60}} = 417 \text{ mails/hour}$$

4) Effort estimation (Work per mail):

$$W_{effort} = F_{seal} \times d_{seal} = 400 \times 0.015 = 6 \text{ Joules}$$

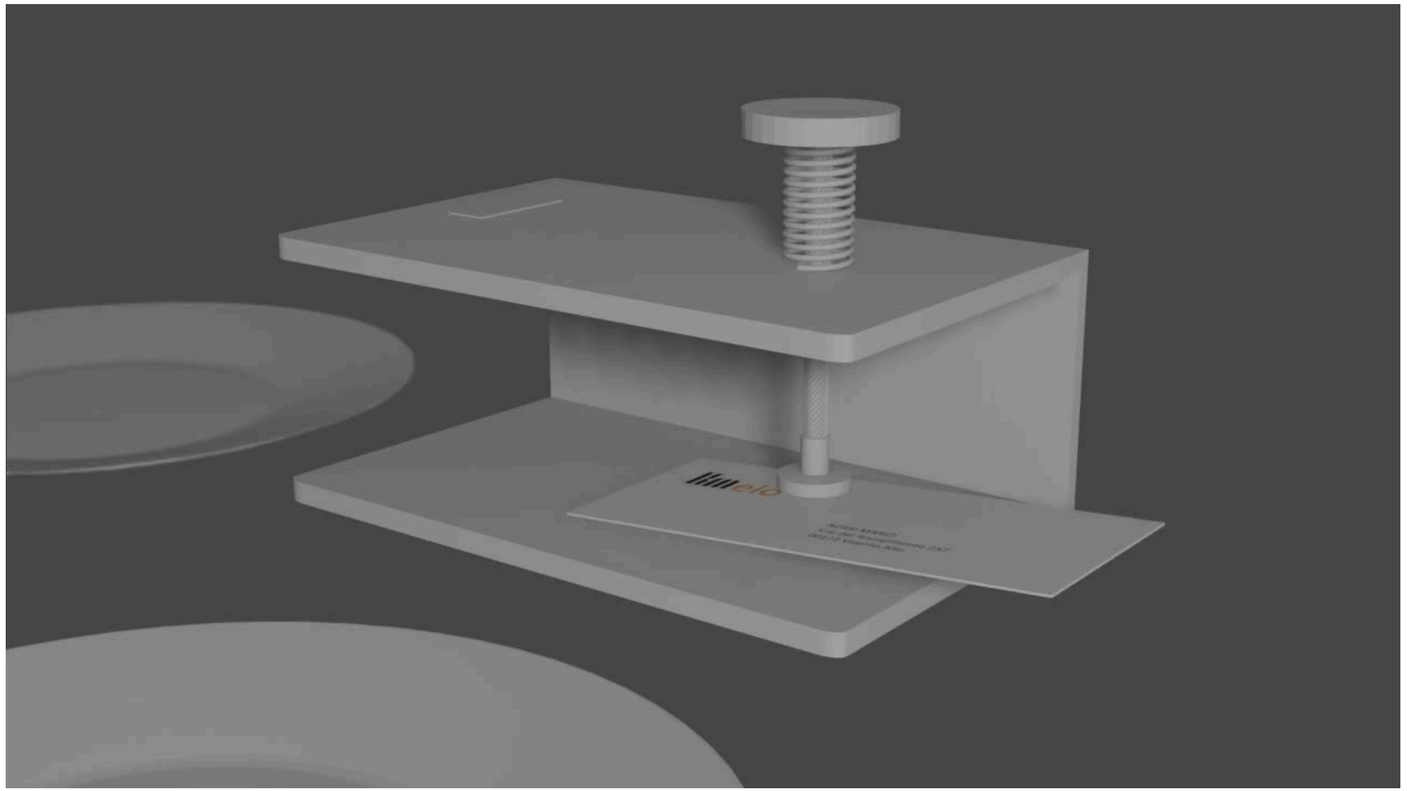
Where dseal is the estimated displacement of the manual press handle in meters, around 0.01 - 0.02m

5) Total work done:

$$W_{total} = W_{effort} \times N_{mail} = 6 \times 500 = 3000 \text{ Joules}$$

VIRTUAL SIMULATION

ERGONOMIC SORTING AND SEALING ASSISTANT



- placing all (30) the letters in the loading tray
- ocr recognition through camera on bottom
- authenticate if valid
- dispatch roll it out to the correct tray (10).
- 30 letters.

OBSERVATIONS

ERGONOMIC SORTING AND SEALING ASSISTANT

- Sorting of the mail is done manually
- Handle is to be made wider to distribute pressure of contact area, making a mroe comfortable operation.
- Customised data set must be trained to have a lesser error rate and higher throughput value for validating the mail.
- Ink reservoir must be contained within the stamp.

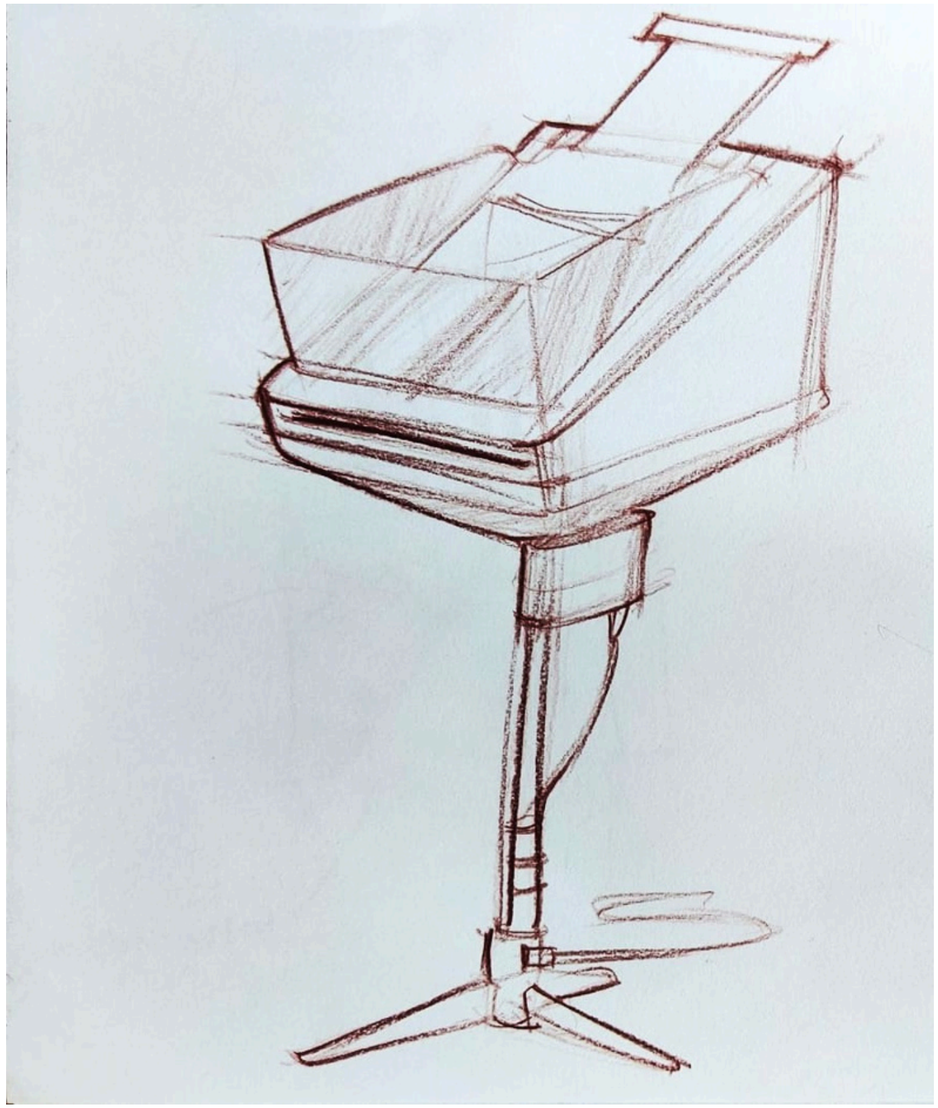
CONCEPT IDEA 2

ROTATING HEAD DISTRIBUTER WITH A SCANNING HEAD

- placing all (30) the letters in the loading tray
- ocr recognition through camera on bottom
- authenticate if valid
- dispatch roll it out to the correct tray (10).

30 letters.

- ocr recognition. (pincode + Address)
- compare it with the existing database, and validate it.
- authenticate the mail with printed label on the envelope
- adjust the opening of machine to the correct tray
- rolls out the letter



MATHEMATICAL SIMULATION

LIST OF INPUT PARAMETERS

Category	Parameter	Symbol	Unit	Value
System Input	Number of compartments	N	-	12
	Letters per batch	M	letters	10
	Letter length	L	cm	20
	Letter width	W	cm	10
	Letter thickness	h	cm	0.2

MATHEMATICAL SIMULATION

LIST OF INPUT PARAMETERS

Category	Parameter	Symbol	Unit	Value
Motion Parameters	Roller speed	v(roller)	cm/s	To be calculated
	Servo speed	RPM(servo)	RPM	3000-5000
Scanning and Sorting	Scanning time	T(scan)	s	0.3
	OCR processing time	T(ocr)	s	0.5
	AI sorting time	t(sort)	s	0.2

MATHEMATICAL SIMULATION

LIST OF INPUT PARAMETERS

Category	Parameter	Symbol	Unit	Value
Printing Parameters	Inkjet printing speed	v(print)	m/min	130
Rotating Head Distributor	Max rotational speed	ω(max)	degrees/s	180
	Angular displacement	Θ	degrees	Variable (0-360)
	Rotation time	t(r)	s	Variable
Mail Pushing	Pushing speed	v(push)	cm/s	8

MATHEMATICAL SIMULATION

OUTPUT PARAMETER CALCULATION

1)Printing time

- The Skyfire SF600 has a printing speed of 130 m/min, which is 216.67 cm/s.
- Width of the letter (W) = 10 cm.
- Printing time per letter: $t_{print} = \frac{W}{v_{print}} = \frac{10\,\text{cm}}{216.67\,\text{cm/s}} \approx 0.046\,\text{s}$

2) Roller speed

- Since printing occurs as the letter moves, the roller speed must match or be slightly lower than the printing speed
- For a conservative approach, the roller speed can be set slightly lower than printing to ensure consistent printing without smudging,

$$v_{roller} = 200\,\text{cm/s}$$

3) Rotational Head Alignment

- Angular displacement θ to reach the desired compartment: $\theta = \frac{360^\circ}{N} \times k,$ where k is the index of target compartment
- Time $t(r)$ for the distributor head to rotate: $t_r = \frac{\theta}{\omega_{max}}$ - For k = 6, $\theta = \frac{360}{12} \times 6 = 180^\circ, \quad t_r = \frac{180}{180} = 1\,\text{s}$

MATHEMATICAL SIMULATION

OUTPUT PARAMETER CALCULATION

4) Total processing time per letter

Considering the time for scanning, OCR, sorting, printing, rotating, and pushing:

$$t_{total} = T_{scan} + T_{ocr} + t_{sort} + t_{print} + t_r + t_{roll}$$

$$t_{total} = 0.3 + 0.5 + 0.2 + 0.092 + 1 + 2.5 = 4.592\,\text{s}$$

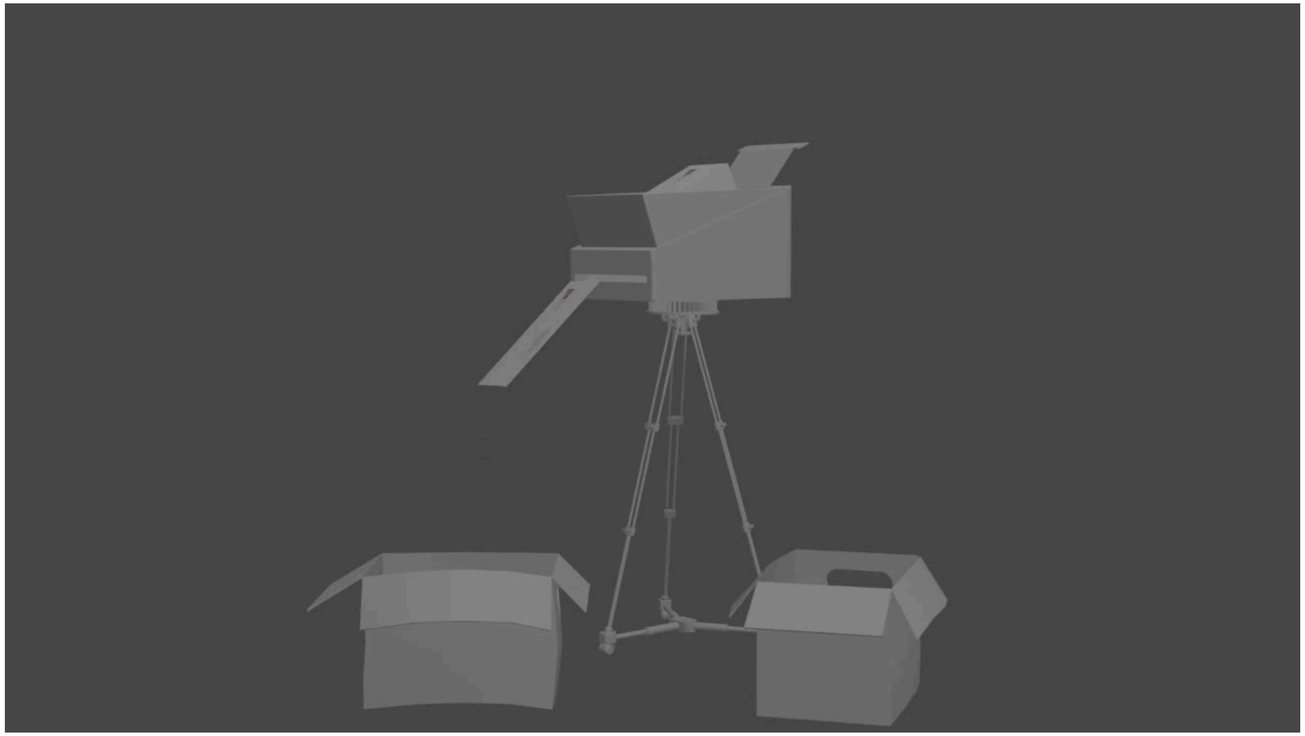
5) Throughput rate:

Throughput in letters per second: $R = \frac{1}{t_{total}} = \frac{1}{4.592} \approx 0.218\,\text{letters/s}$

Throughput per hour: $R_{\text{hour}} = 0.218 \times 3600 \approx 785\,\text{letters/hour}$

VIRTUAL SIMULATION

ROTATING HEAD DISTRIBUTER WITH A SCANNING HEAD



- placing all (30) the letters in the loading tray
- ocr recognition through camera on bottom
- authenticate if valid
- dispatch roll it out to the correct tray (10).

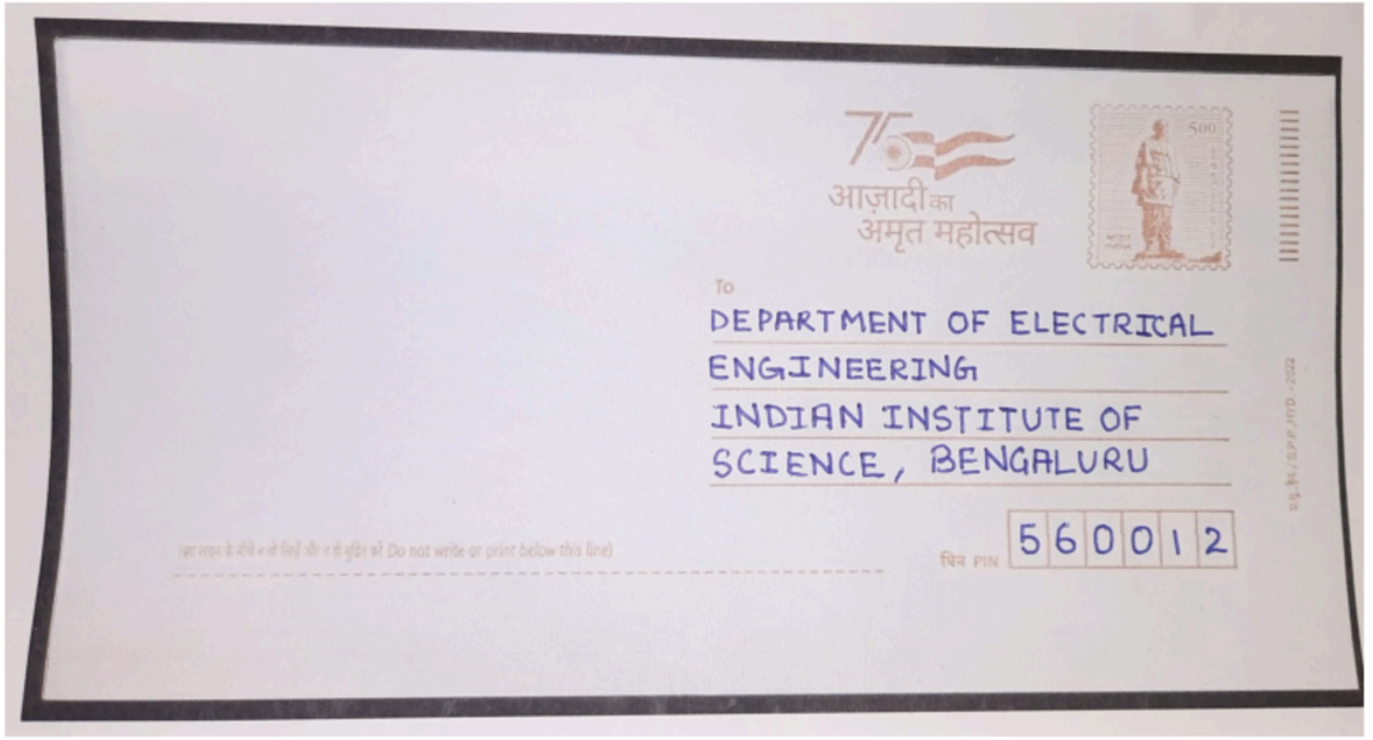
30 letters.

Reading the letter

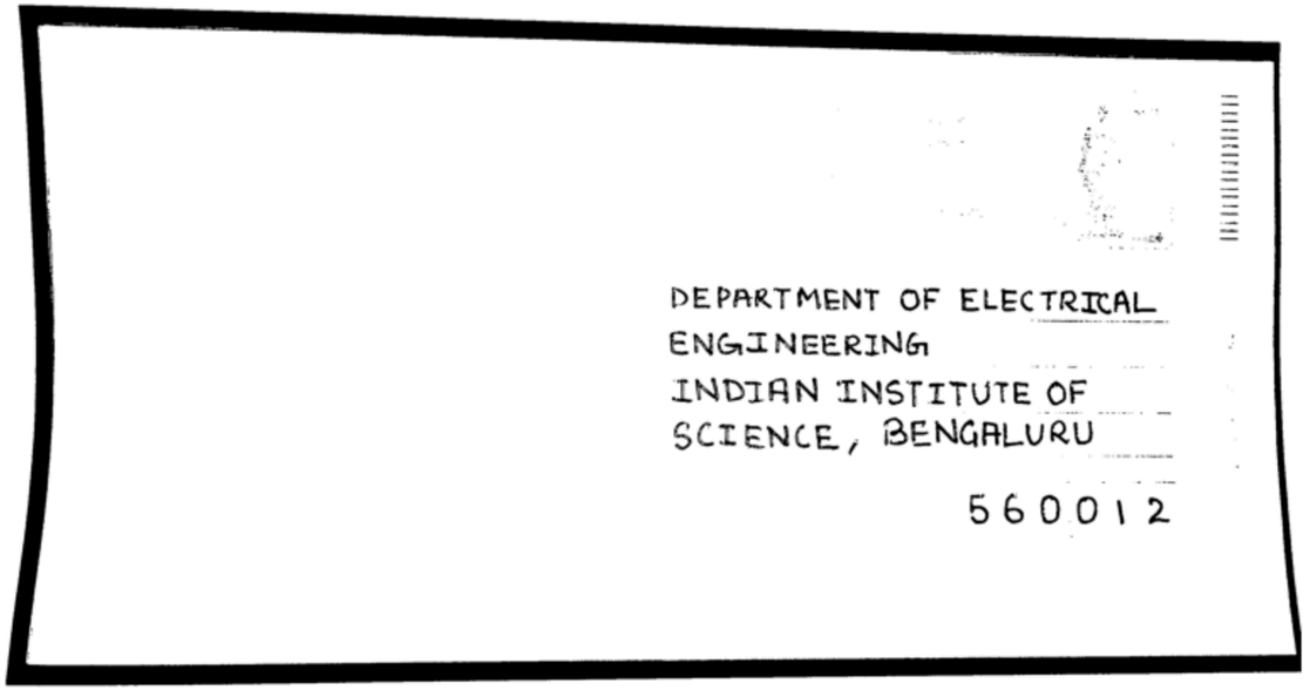
In [100…

```
# Load the image
image_path = image_path1 # Replace with your image file
image = cv2.imread(image_path)
display_image(image, title="Original Image")

# Step 1: Convert to Grayscale
gray = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)
display_image(gray, title="Grayscale Image")

# Step 2: Apply Thresholding
_, binary_image = cv2.threshold(gray, 128, 255, cv2.THRESH_BINARY | cv2.THRESH_OTSU)
display_image(binary_image, title="Binary Image (Thresholded)")

# Step 3: Denoise the Image (Optional)
denoised_image = cv2.medianBlur(binary_image, 3)
display_image(denoised_image, title="Denoised Image")
```

Original Image



Denoised Image



Extracting text

In [103…

```
# Step 4: Perform OCR
text = pytesseract.image_to_string(gray)
print("Extracted Text:\n")
print(text)
```

```
Extracted Text:

HET

DEPARTMENT OF ELECTRICAL
ENGINEERING

INDIAN INSTITUTE OF
SCLENCE, BENGRLU RU
```

Making decision in which color box to put letter / how much to rotate and eject letter

```python
def process_paragraph(paragraph):
    # Normalize the paragraph: remove extra newlines and spaces, and convert to lowercase
    normalized_paragraph = ' '.join(paragraph.split()).lower()

    # Define the target strings in lowercase
    targets = {
        "electrical engineering": ("blue", (0, 0, 255), "ROTATE 36 DEGREE AND EJECT THE LETTER"),
        "computational and data sciences": ("green", (0, 255, 0), "ROTATE 72 DEGREE AND EJECT THE LETTER")
    }

    found = False
    for term, (color_name, rgb_color, message) in targets.items():
        if term in normalized_paragraph:
            if color_name == "blue":
                blue = r"C:\Users\91810\Downloads\blue.jpg" # Replace with your image file
                image = cv2.imread(blue)
                display_image(image, title="Put the letter in blue box / ROTATE 36 DEGREE AND EJECT THE LETTER")
                found = True
            if color_name == "green":
                green = r"C:\Users\91810\Downloads\green.jpg" # Replace with your image file
                image = cv2.imread(green)
                display_image(image, title="Put the letter in green box / ROTATE 72 DEGREE AND EJECT THE LETTER")
                found = True

    if not found:
        print("No matching terms found.")

# Example input
paragraph = text

# Call the function
process_paragraph(paragraph)
```

Put the letter in blue box / ROTATE 36 DEGREE AND EJECT THE LETTER

EVALUATION:

OBSERVATIONS BASED ON SIMULATIONS

- Physical simulation helped in detailing out the contents of the conceptual design, in terms of process required, steps to be followed and requirements of the mechanisms.

- Virtual simulation helped in testing out the feasibility of the products through coding and settle on the aesthetic value of final product within constraints.

- Mathematical model helped in comparing the efficiency of the two devices effectively.

FMEA - CONCEPT 1

Process Step	Potential Failure Mode	Potential Failure Effect	Potential Causes	SEV	OCC	RPN	Action Recommended
Camera based scanning of address on mail	FOV insufficient to capture entire address.	Address unable to be captured, scanning halted.	Larger envelope sizes with addresses out of FOV of camera.	7	4	28	Mechanism to adjust FOV of camera. Camera with wider FOV to be utilised.
	Illumination insufficient to capture legible address.	Lot of image noise, leading to illegibility of address.	Camera ISO sensitivity not sufficient for the task.	6	3	18	Provide illumination to the envelope by incorporating a light fixture in the device.
OCR by computer	Illegible address	Address unable to be detected. scanning halted.	Low contrast of text, illegible handwriting, orientation of envelope	6	5	30	Enhance software preprocessing to improve text contrast.
	Processor malfunction		Failure of computer, faulty connection to computer	9	2	18	Ensure reliable connections; use a higher-quality processor.

FMEA - CONCEPT 1

Process Step	Potential Failure Mode	Potential Failure Effect	Potential Causes	SEV	OCC	RPN	Action Recommended
Display of colour code based on destination	LED displays wrong destination colour code.	Unreliable sorting of mail	Improper training of AI model. Hardware malfunction	7	4	28	Improve AI training; test against edge case.
Manual stamping for authentication	Mechanical failure	Unable to authenticate	Wear and Tear of mechanical components	6	2	12	Regular maintenance.
	Illegible mark of authentication	No legible proof of authentication	Insufficient force applied, insufficient ink level.	2	3	6	Monitor ink and pressure.
Manual matching of mail to destination compartments	Mail is sorted to wrong compartment	Erroneous sorting of mail	Human error-fatigue, distractions	7	3	21	Introduce alerts for incorrect sorting.

FMEA - CONCEPT 2

Process Step	Potential Failure Mode	Potential Failure Effect	Potential Causes	SEV	OCC	RPN	Action Recommended
Loading stack of letters to tray	Letters are not oriented facing down	Address side of envelope not available to be scanned	Human error in loading correctly	7	3	21	Add guide system, or automated flipping mechanism with sensors
Digital image scanner based scanning of address on mail	improper orientation of envelope on scanning bed	Address illegibilty	Envelope may be displaced from scanning bed due to irregularities in the form/shape of envelope. Improper loading.	8	3	24	Clamp or suction mechanism, alignment rails
OCR by computer	Illegible address	Address unable to be detected. scanning halted.	Low contrast of text, illegible handwriting, orientation of envelope	6	5	30	Enhance software preprocessing to improve text contrast.
	Processor malfunction		Failure of computer, faulty connection to computer	9	2	18	Ensure reliable connections; use a higher-quality processor.
Validating address by comparison with database	False positives, False negatives in validation	Erroneous sorting	Robustness of address database may be insufficient. AI may not be trained sufficiently.	5	2	10	Dynamic database, Regular updation, user feedback

FMEA - CONCEPT 2

Process Step	Potential Failure Mode	Potential Failure Effect	Potential Causes	SEV	OCC	RPN	Action Recommended
Choice of sorting compartment based on destination	Incorrect choice of compartment	Erroneous sorting	Improper training of AI model.	7	4	28	Improve AI training; test against edge case.
	Inadequate number of choices for sorting mail	Inadequate sorting	Space constraints	8	4	32	Introduce more trays.
Orientation of sorting head to correct sorting compartment	Electro-mechanical failure	Erroneous sorting	Servo motor failure, faulty electrical wiring	8	2	16	Regular maintanence, fault detection mechanism
	Calibration of hardware	Mismatched orientation of intended compartment and actual compartment	Sorter gets shifted around without recalibration, accidental shifting.	8	3	24	Periodic calibration, real-time position feedback
Printing of authentication seal on mail	Illegibility of print	No legible proof of authentication	Printerhead malfunction, Printer ink not sufficient.	7	2	14	Add a low-ink detection mechanism; ensure the printer is well-calibrated and serviced periodically to avoid feed issues.
Ejecting the letter out to compartment	Electro-mechanical faliure	Mail gets jammed in the ejector.	Faulty mechanical components, roller, motor. Mail too thick to be rolled out.	8	2	16	Ensure chute is designed with adequate tolerances; implement sensors to detect and clear jams automatically.

THANK YOU