Assignment 4

ME-291 Computer Aided Engineering
(Fall 2020)

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Classroom Document Reader

Traditional (face-to-face) teaching has been greatly impacted by the COVID-19 pandemic; as a result of which remote instruction, which used to be a rarity, has now taken center stage in universities and colleges all across the world. Habib University is no exception to this shift. For a STEM instructor like myself, one of the biggest hurdles with online teaching has been the ability to seamlessly make sketches, write notes, annotate, and point at written / drawn material the way I could during in-person classes. I have tried using a tablet via Zoom screen-share but there have been issues with delayed response (as most of you can probably attest to), pointing at something without scribbling on the screen, and compatibility with my computer that I run *Creo* on. A promising solution to this problem is to use a document reader, which is what you are required to design in this major assignment that counts for **10%** of your final grade. Design requirements of the reader follow.

Design a document reader in *Creo Assembly* that satisfies the following requirements:

- I should be able to write[1] on an A4 sized paper and the camera should be able to clearly capture the written material
- There should be sufficient light for me to write and the camera to discern the written material
- There should be no physical hindrances that make it difficult to write
- "Legs" of the stand should not appear in the frame of view
- There should be a smooth writing surface[2]
- It should be easy to position the paper in the camera's field of view
- The paper should not move as I write on it
- It should be easy to change papers
- The assembly should be easy, relatively quick (matter of weeks), and economical to manufacture and should use parts that are available locally in Pakistan
- The reader should be portable, that is, if needed, it could be transported in a car
- The camera used should be easily available (e.g. cellphone or a webcam)
- The camera should be able to be connected to a laptop so that it could be used with *Panopto*
- Bonus feature if possible: the camera should be able to be swiveled to show my face

Treat the afore-listed requirements as your *need statement*. Then, use the design process to:

(1) *Define* the problem[3]. This requires you to clearly state the *objectives* (at least 4, try not to go beyond 6) of what you are designing and identify *constraints* (at least 3, try not to go beyond 6) that act as limits to your design's attributes or behaviors. Next,

   a. Rank the objectives in order of their importance. Use a *pairwise comparison chart* (PCC) to help you with this. An example of a PCC is provided at the end (*Figure 1*) in which a design team has ranked its objectives for a surgical stabilization device project. You can use the same scoring method. The objective with the highest score is the most important and the one with the lowest score is the least important. Come up with at least four objectives that address all the design requirements.

[1] "Writing" includes drawing, annotating, and scribbling etc. as well.
[2] You can assume that the reader will be placed on a desk. Your design can use the desktop as the writing surface.
[3] A good description of this stage that I recently came across read, "The idea is to translate a client's wishes into a set of specifications that state in engineering terms how the design is to function or behave. These are benchmarks against which we can measure a design's performance."

b. Establish *metrics*[4] that will be used to gauge the performance of your designs, e.g. if one of your objectives is to allow for portability, then your metric could be weight in N or the volume in m^3, or you could come up with a combined metric that accounts for both weight and volume, like *Combined Portability Metric = weight* volume¸* which would have the units of $N.m^3$. The metric scores should then be scaled such that a larger value signifies better compliance with a design objective compared to a smaller value. Moreover, for comparison across different metrics, scale all metric scores from 0 to 100. So, in the foregoing example if we have two document reader designs, one weighing 10 N and one 15 N, the former is better as it is lighter and thus more portable. It should therefore have a larger value for the portability metric. I will, therefore, give it a score of 100 as it is the most portable design.[5] Next, I will calculate how much less (in %) portable is the other design. That comes out to be 50% as shown below.

$$\text{Scaled metric value for design X} =$$

$$\frac{\text{Metric value for desgn X} - \text{Metric value for best performing design for "portability" objective}}{\text{Metric value for best performing design for "portability" objective}}$$

$$= \frac{15\text{ N} - 10\text{ N}}{10\text{ N}} * 100 = 50\%$$

Thus 50 is the scaled portability metric score for the 15 N design. Similarly, you can come up with metrics and scaled metric scores for all of your objectives. If measurable, quantitative metrics are not possible for some objectives, you can resort to using qualitative metrics where you define a scoring scheme between 0 and 100, e.g. if an objective is: easy writing access, you can use a scale similar to the one shown below to assign metric values for each design.

No hand access	0 points
Very high / consistent hinderance	25 points
Hinderance only during drawing	50 points
Slight hinderance	75 points
Hinderance-free hand access	100 points

(2) *Synthesize* two different design schemes based on the problem definition. Make preliminary models of your designs. These can be made in *Creo* as part or assembly files. Alternatively, you can make hand sketches that provide all important design details, e.g. *Figure 2* but neater.

(3) Evaluate the schemes based on (1) their adherence to the design objectives, as quantified by their respective scaled metric scores, and (2) whether they comply with the design constraints. Make a *decision matrix* like the one shown in *Table 1* for your evaluation and provide a verdict about which design is superior. Use *Table 1* as a template. Note that while using the decision matrix approach, the scaled metric scores are “weighted” based on the PCC scores that represent the relative importance of various objectives. Refer to for *Table 1* implementation steps.

(4) Select the winning design from step-3 and make a detailed *assembly* model of it in *Creo*.

Note that this is a partial implementation of the design process and does not use the complete iterative design model.

To get you started, I have made a rough sketch of one potential document reader design (see *Figure 2*). Just look at it for reference, not for guidance as it might not be a good design in terms of meeting the design requirements. In fact, taking the sketch too seriously might bias your independent concept generation process vis-à-vis the *means* of

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[4] Metrics can be thought of as rulers to gauge the extent to which a design objective is achieved.
[5] The point to note from this step is that the better performing design for the objective under consideration will have a metric score equal to 100. So, for each objective one design will have a score of 100 and the other one < 100.

meeting the design objectives and honoring the constraints. Therefore, just look at *Figure 2*, and erase it from your memory. Let your creativity flow independent of any implied solution that might've been suggested in the figure.[6]

To help you with selecting a camera and the height of your design, I have taken pictures of an A4 sheet of paper from my phone and webcam at three different heights (see *Table 2*). Hint 1: You can make a "field of view cone or prism" using information from the pictures. You are welcome to use your own cameras for reference. Hint 2: You can try to find CAD files for different cameras on the internet.

Reporting

Provide a mini report that has the following elements:

(1) Problem definition
    a. List of objectives
    b. List of constraints
(2) Pairwise comparison chart
(3) Pictures / sketches of both the design schemes. Make sure that the pictures convey all important aspects of the designs including a few important dimensions (they can be approximate).
    a. If using *Creo*: Provide 2-3 pictures of each design. Use features like annotations, rendering, colors, exploded views, picture backgrounds, and sections to generate elucidatory graphics. Trust your judgement to: (1) select the most revealing views of your design and (2) not overcrowd the pictures with unnecessary information that does not add any illustrative value.
(4) List of metrics with brief descriptions (1-2 lines, each) and units
(5) Table with metric scores (both unscaled and scaled) for all objectives
(6) Decision making matrix
(7) 3-4 pictures of the detailed assembly design for the winning design. Follow guidelines listed in point-3(a) while generating the graphics.

The report does not have to be too wordy. You can (and should try to) convey all the required information in the form of tables and graphics with descriptive captions.

At the top of the report state the following:

- Design Project Title
- Design Project Statement: A 1-2 sentence statement of what is being designed.
- Designer: Your name, major, and classification (junior or senior)
- Client: Who is your client?
- Users: Who will benefit from using your design (your target market)?

In addition to the report:

- Provide *Creo* assembly file for the winning design. Name it as <your initials>.asm
- DO NOT provide additional *Creo* files, but have your part files of the preliminary design saved in case you used *Creo.* They might be requested for grading later on.

[6] A popular saying among engineering design circles is, "don't marry your first design idea."

Tables and Figures

A *pairwise comparison chart* created by one of the student teams to compare objectives for the microlaryngeal stabilization device. An entry "1" indicates the objective in that row is more important than that of the column in which it is entered. It shows that the reduction of the surgeon's tremor is the most important objective for this project

Goals	Reduce Tremor	Sturdy	Safe	Inexpensive	Easily Used	Score
Reduce Tremor	••••	1	1	1	1	4
Sturdy	0	••••	0	1	0	1
Safe	0	1	••••	1	1	3
Inexpensive	0	0	0	••••	0	0
Easily Used	0	1	0	1	••••	2

Figure 1: Sample pairwise comparison chart (PCC). Copied from Engineering Design by Dym and Little.

Constraints		**Design 1**	**Design 2**
1. Cannot obstruct the writer's hand		Satisfied	Not satisfied
2. Constraint # 2		Satisfied	Satisfied
3. Constraint # 3		Satisfied	Satisfied
Total Score:		**3 constraints satisfied**	**2 constraints satisfied**
Design Objectives (most to least important)	**PCC Scores**	**Metric Scores (Scaled between 0 and 100)** Note: No contribution of the PCC scores	
1. Portability	4	100	50
2. Objective # 2	3	100	40
3. Objective # 3	2	100	20
4. Objective # 4	1	10	100
Design Objectives (most to least important)	**Scaled PCC Scores**[7]	**Metric Scores (Scaled between 0 and 100)** Note: The PCC scores are also factored in by multiplying the scaled metric scores with their respective *scaled* PCC scores	
1. Portability	$\left(\frac{4}{4+3+2+1}\right)=0.4$	$100*0.4=40$	$50*0.4=20$
2. Objective # 2	$\left(\frac{3}{4+3+2+1}\right)=0.3$	$100*0.3=30$	$40*0.3=12$
3. Objective # 3	$\left(\frac{2}{4+3+2+1}\right)=0.2$	$100*0.2=20$	$20*0.2=4$
4. Objective # 4	$\left(\frac{1}{4+3+2+1}\right)=0.1$	$10*0.1=1$	$100*0.1=10$
Total Score:		**91**	**46**
Verdict: **Design 1 is superior because is satisfies all the constraints and has a higher (91 vs 46) total score of scaled metrics after PCC scores have been factored in.**			

Table 1: Decision making matrix template.

[7] $\text{Scaled PCC Score for Objective X} = \frac{\text{PCC Score for Objective X}}{\text{Sum of PCC Scores for All Objectives}}$

It is technically wrong to add weights to subjective measures of importance like the PCC rankings, but for the purposes of this assignment we are ignoring the technical error.

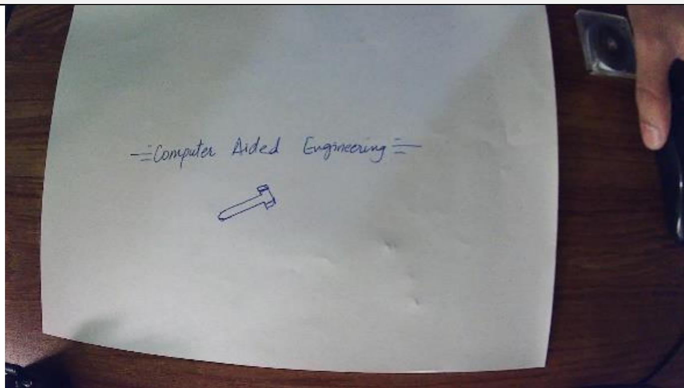
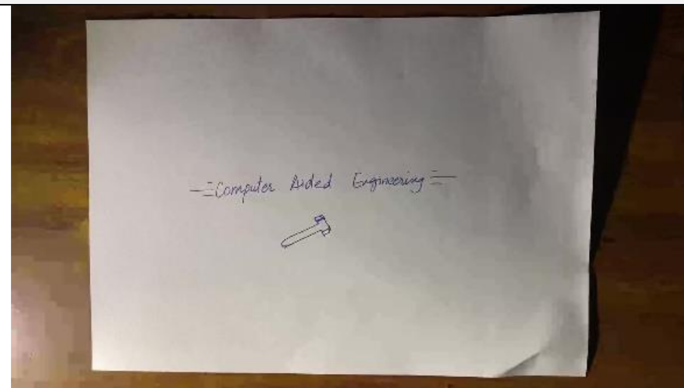
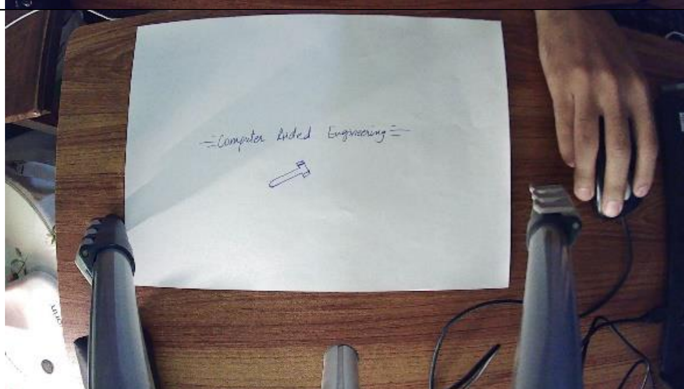
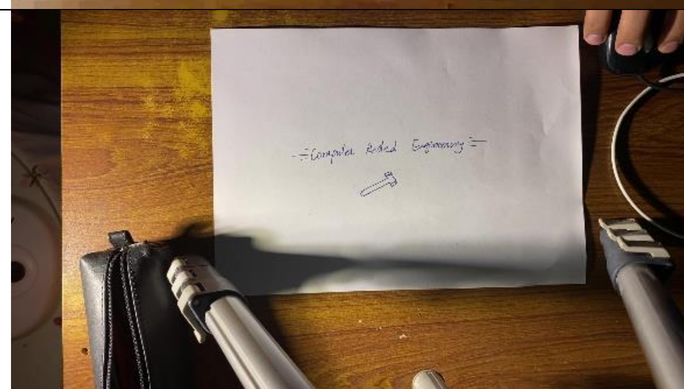
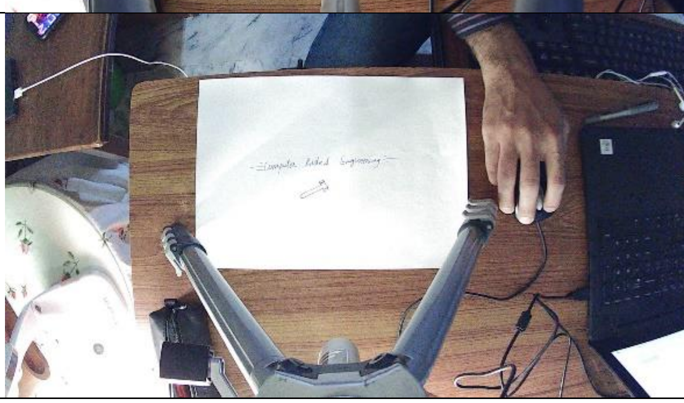
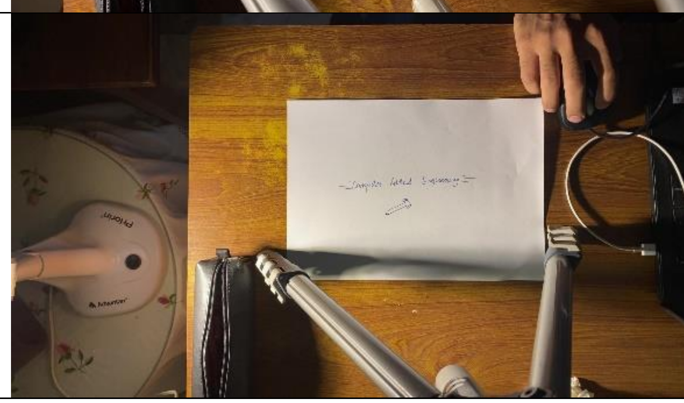
Height from Paper (cm)	Webcam	Cellphone Camera
25		
37		
55		

Table 2: Photographs of an A4 paper taken from different heights using a webcam and a cellphone camera.

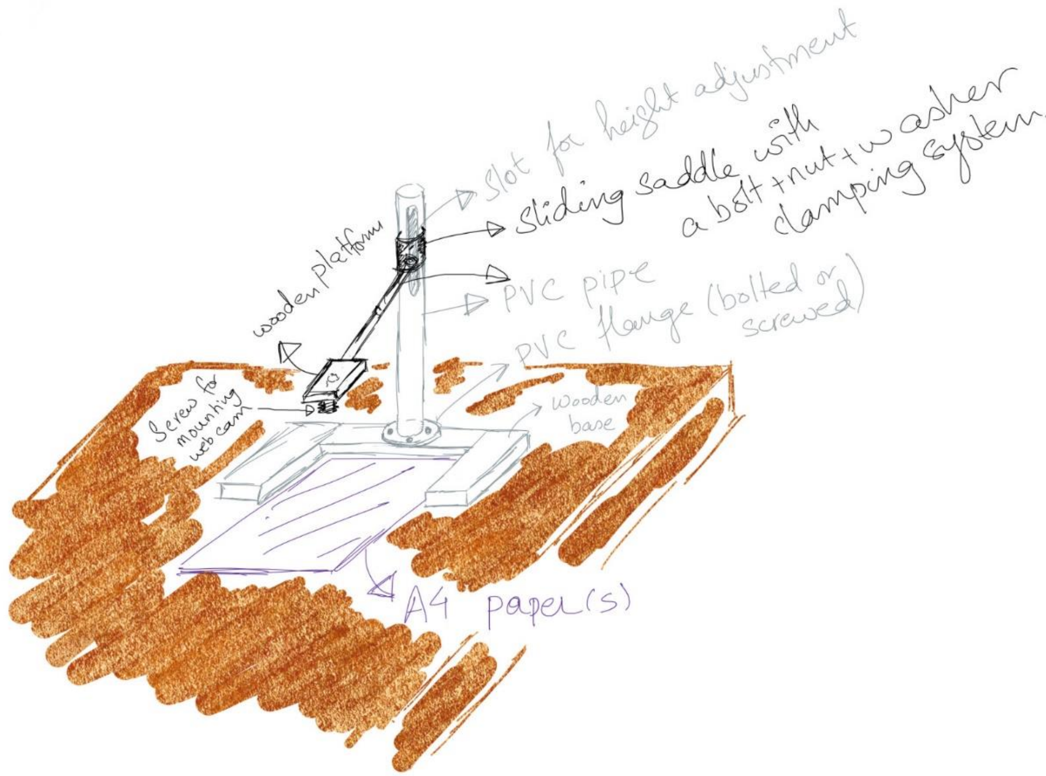


Figure 2: Sample document reader design.