Strain Visualization Microsensor based on Moiré Fringes

Team 9 (sddec20-9)
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Project Statement

Due to the large amount of large structure used, such as buildings and bridges, new ways of determining strain is needed. A possible solution for this problem is the development of strain visualization microsensor based on moire fringes.

Purpose

- Accurately indicates if the member of a structure is under too much strain
- Cheap for utilization in many places - less wiring and power needed
- Usable on large structures - buildings or bridges
- Easy to see if maintenance needs to be done on the structure
- Effective enough to prevent the collapse of a structure

Deliverables

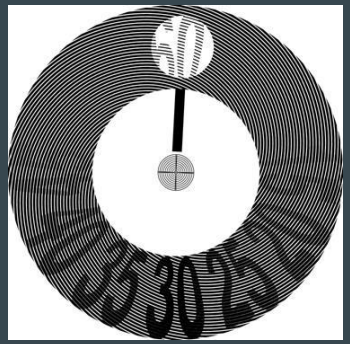
- MATLAB program simulation
  - Two gratings (patterns) - Number grating and line grating
  - Moire fringe pattern
  - Able to show strain level
- Last semester
  - Building the gratings with optical lithography but changed to MATLAB due to COVID

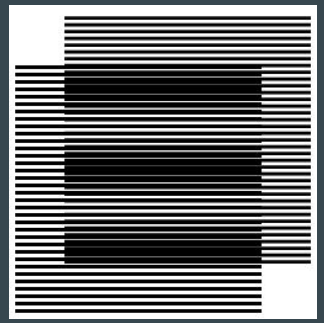
Benefits

- No electrical equipment to view moire fringe pattern
- Easy to read and understand
- Can be viewed in isolated environments
- Grating manufacturing cheaper

Moire Fringes

- Moire Fringes are patterns that can be produce when opaque patterns with transparent gaps are overlaid on a similar pattern that is displaced, rotated, or slightly pitched
- Moire Fringes can produce geometrical design that when added together create a new image
- Their application includes (airplane body inspection, measurement of shape and three-dimensional displacement, measure of strain on semiconductor devices)





Fabrication Process

We had planned to use optical lithography as our method of fabricating the moire fringe filter. Why?

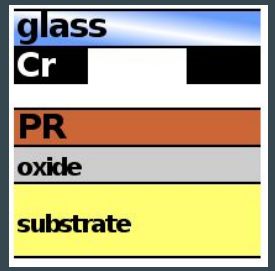
- A method that could create very small patterns (down to the micrometer)
- We needed two gratings to be produced inexpensively
- The process is relatively quick

Fabrication Process

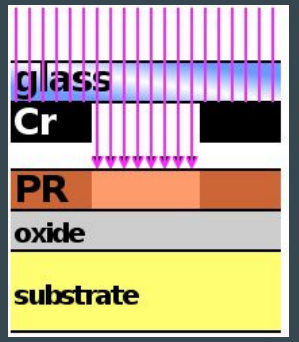
Steps the optical lithography process would follow

Prepare wafer

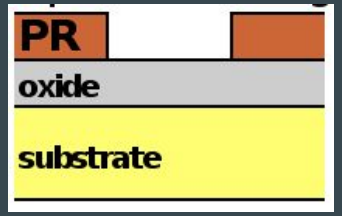
Apply photoresist



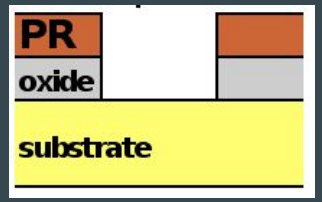
Apply photomask



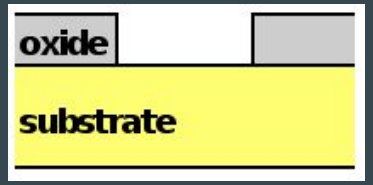
Expose UV light



Remove exposed photoresist

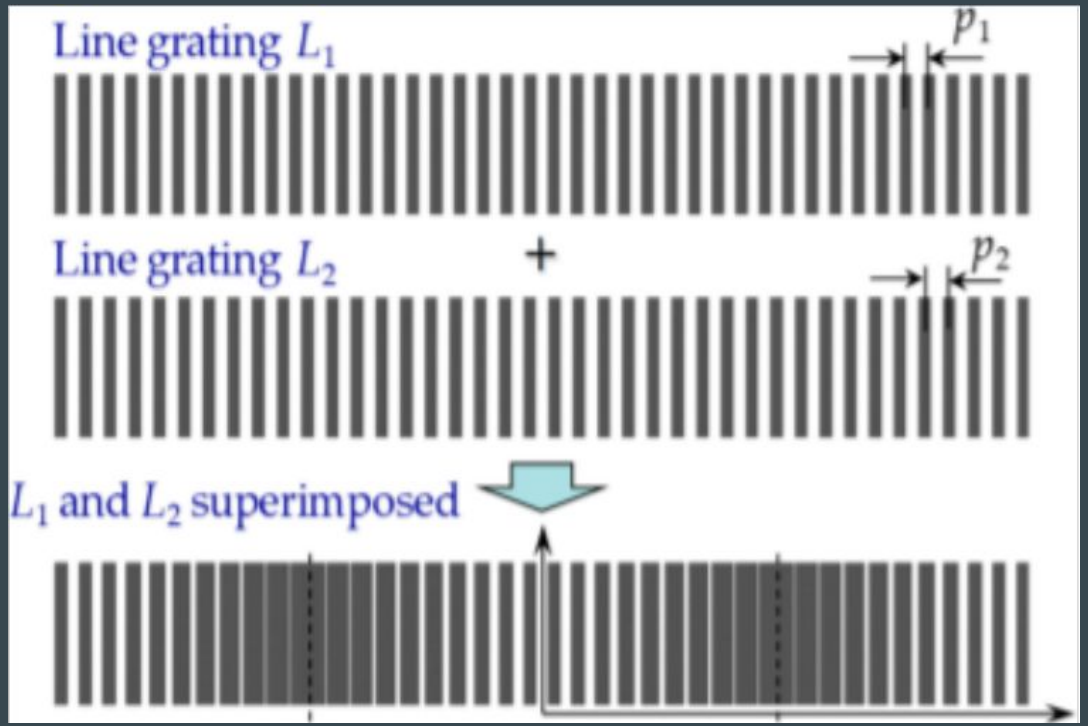


Etch exposed oxide layer

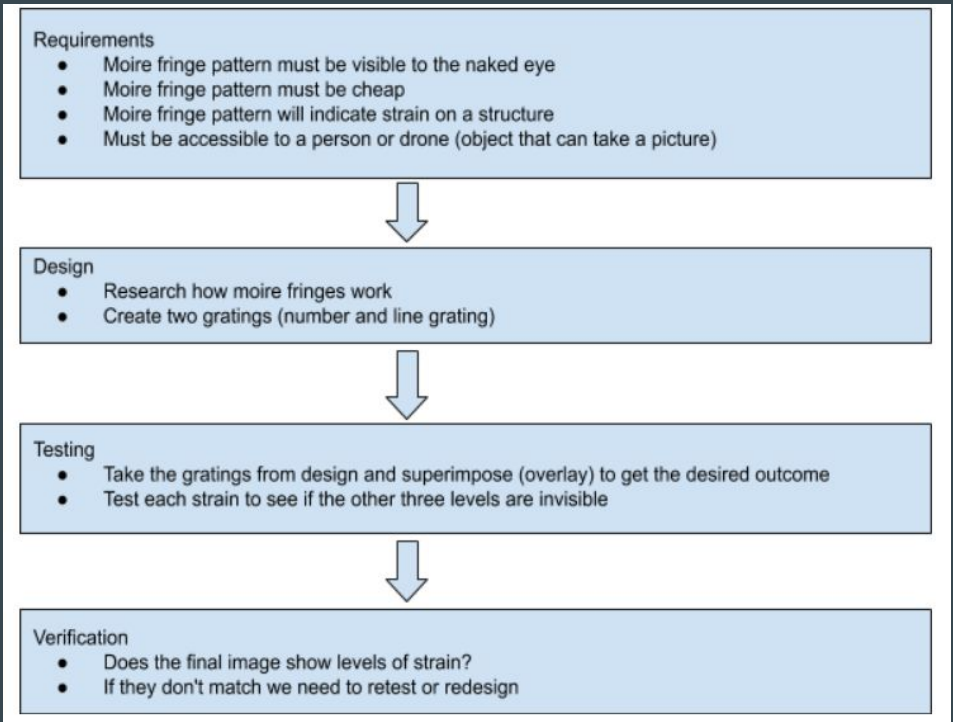


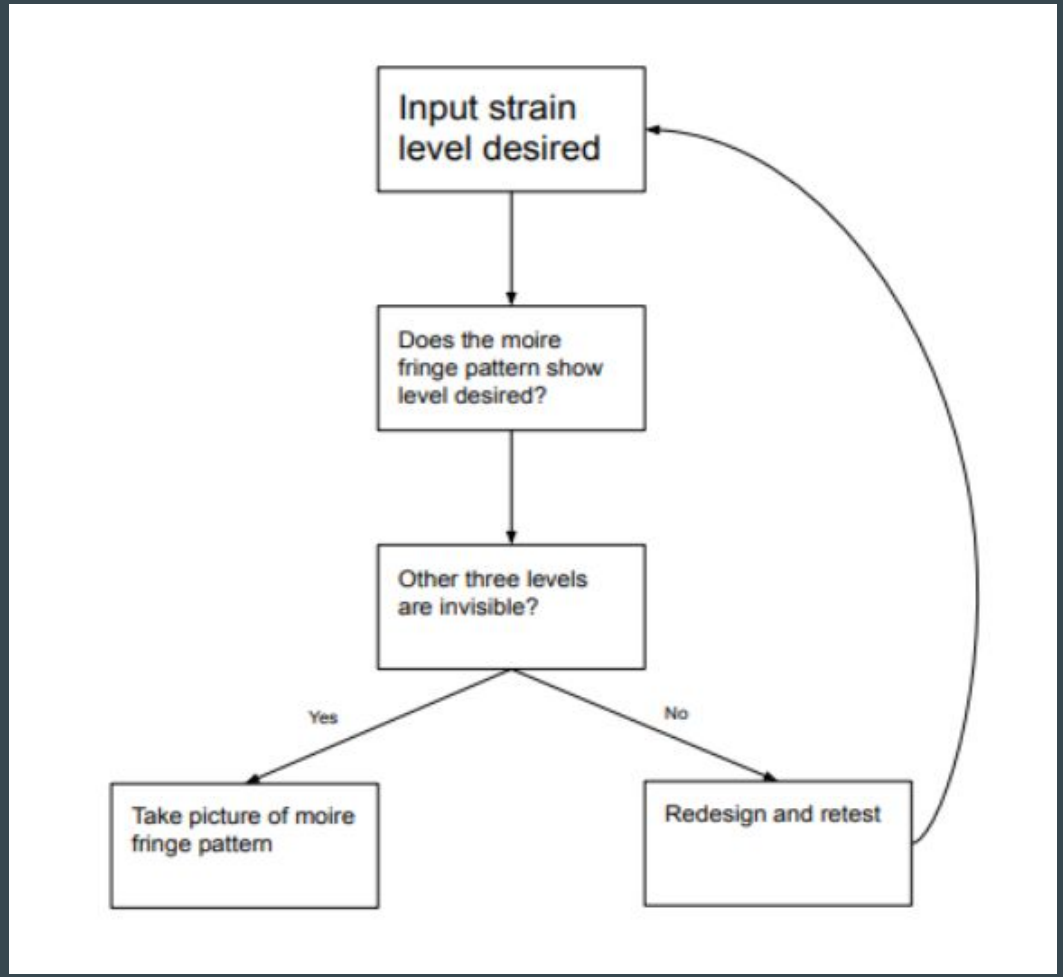
Remove remaining photoresist

Fabrication Result



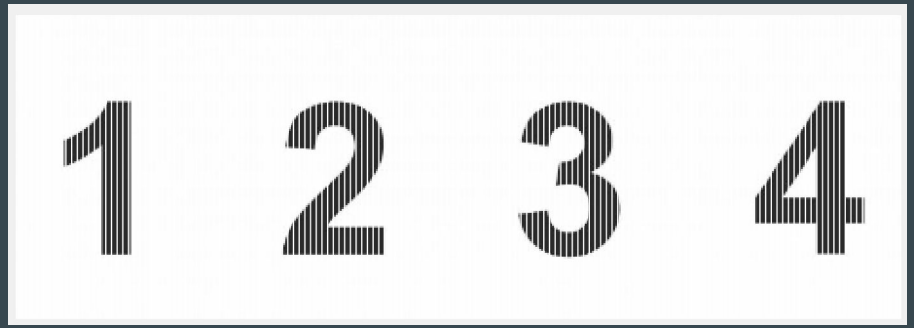
Development Process




Input strain level desired
Does the moire fringe pattern show level desired?
Other three levels are invisible?
Yes
No
Take picture of moire fringe pattern
Redesign and retest

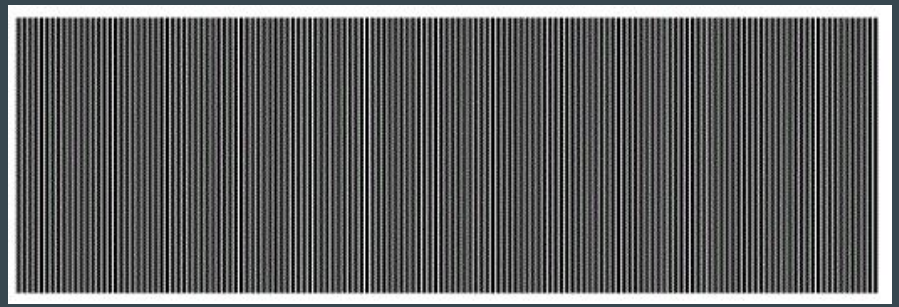
Number (Bottom) Grating

- Rectangular grating that goes on bottom and would stay in place
- Original image is four black numbers with white background
- Vertical white lines go across image with intervals of certain distance (pitch)



Line (Top) Grating

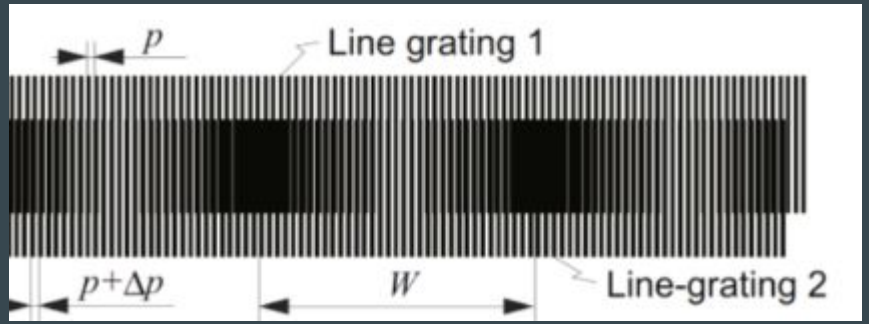
- Rectangular grating that is on top and slides across the bottom
- Original image is a plain white background
- Vertical black lines go across the image with a different pitch



How we designed the patterns

- In the code, we keep the thickness of the lines same
- Bottom grating and top grating pitch are different

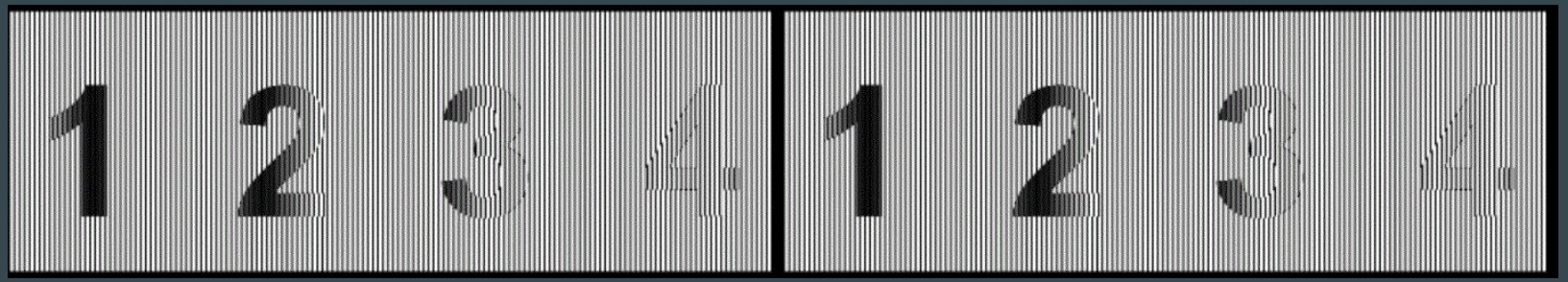
$$W = \frac{(p + \Delta p)}{\Delta p} * p$$ p is the pitch (distance between lines + thickness of line)



How we designed the patterns

- Selection of distance was based on formula below
- W value decided by length of image 467 used 934
- P value was selected by us to be 5.25 (4 + 1.25)
- By calculation p + Δp is 5.3096 (4.0596 + 1.25) - 467
- Used 5.279677 (4.029677 + 1.25) - 934

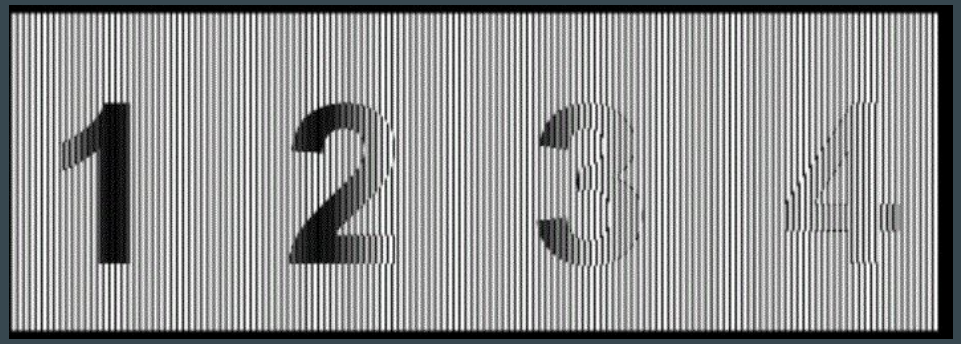
$$W = \frac{(p + \Delta p)}{\Delta p} * p$$ p is the pitch (distance between lines + thickness of line)

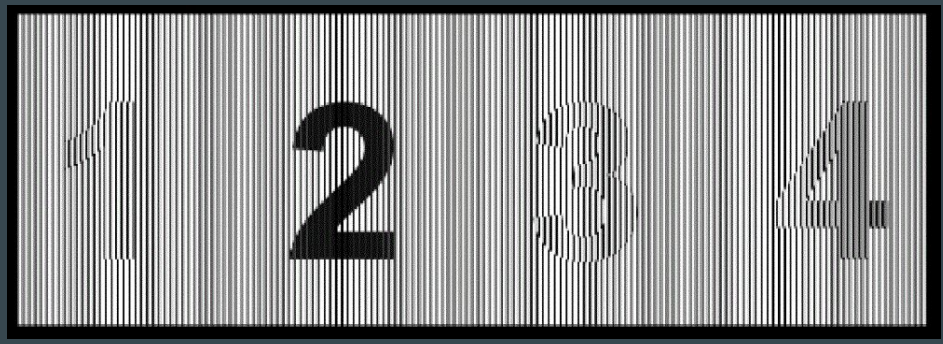


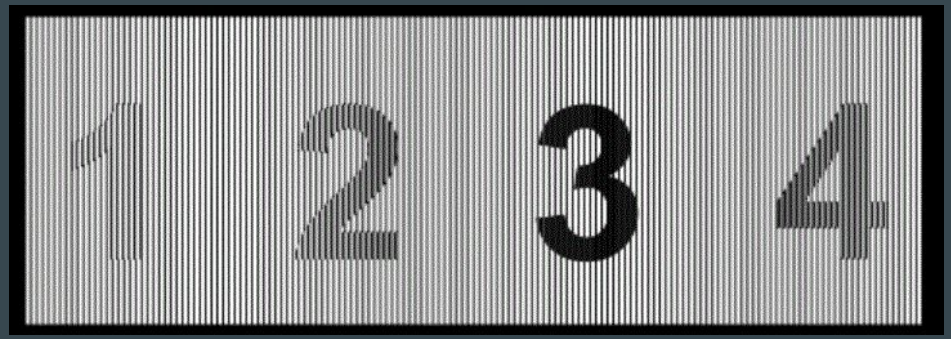
How the Moire Fringe pattern works

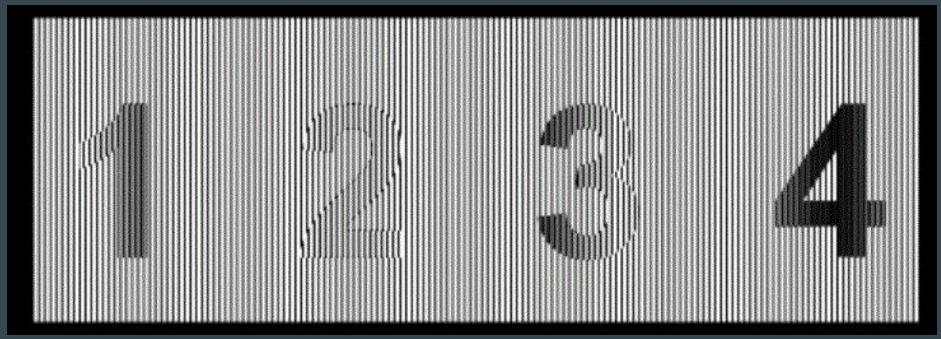
- The number grating is on the bottom - not moving
- The line grating is the on the top and slides across - moving
- As the structure experiences strain the patterns will shift past each other revealing a new level of strain
- Each number represents a different level of strain experienced for example level 1: is the resting state, level 2: under minor strain applied, level 3 moderate strain applied, level 4 extreme strain applied.

Testing

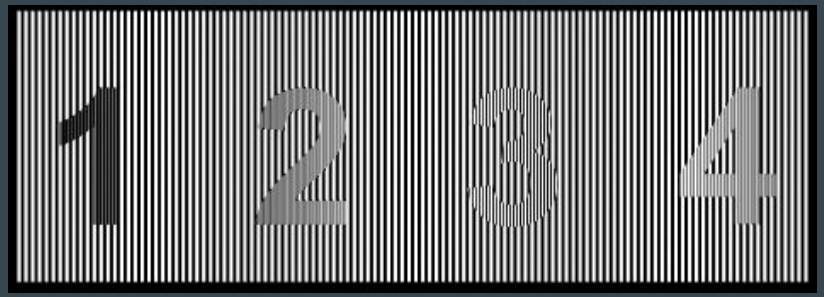


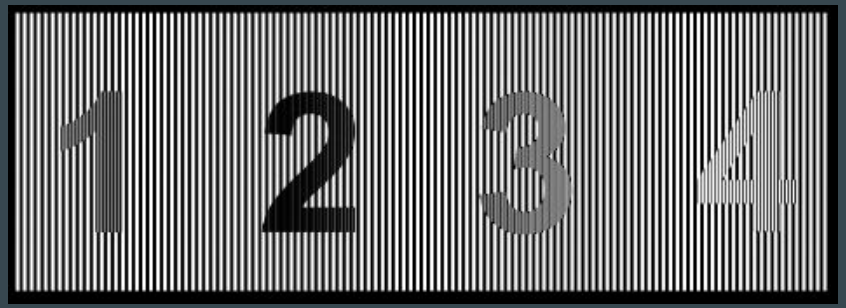


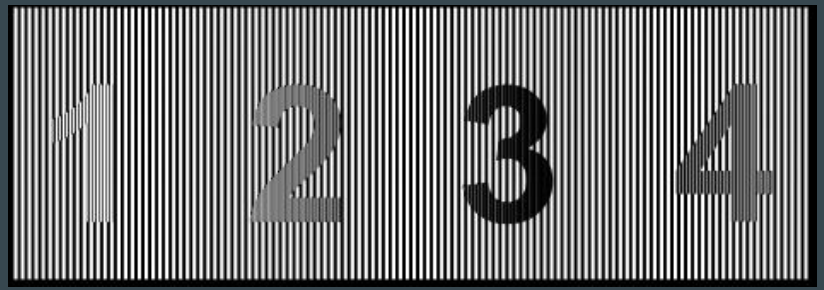


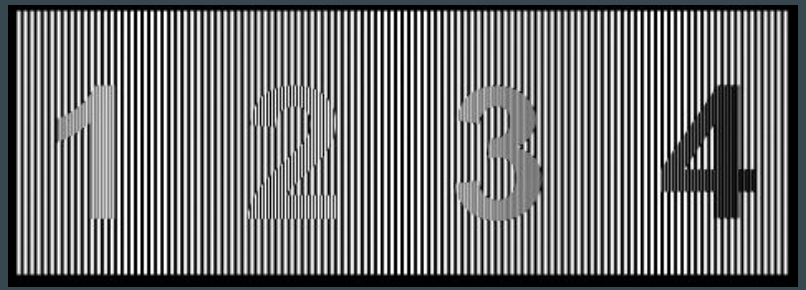


Testing

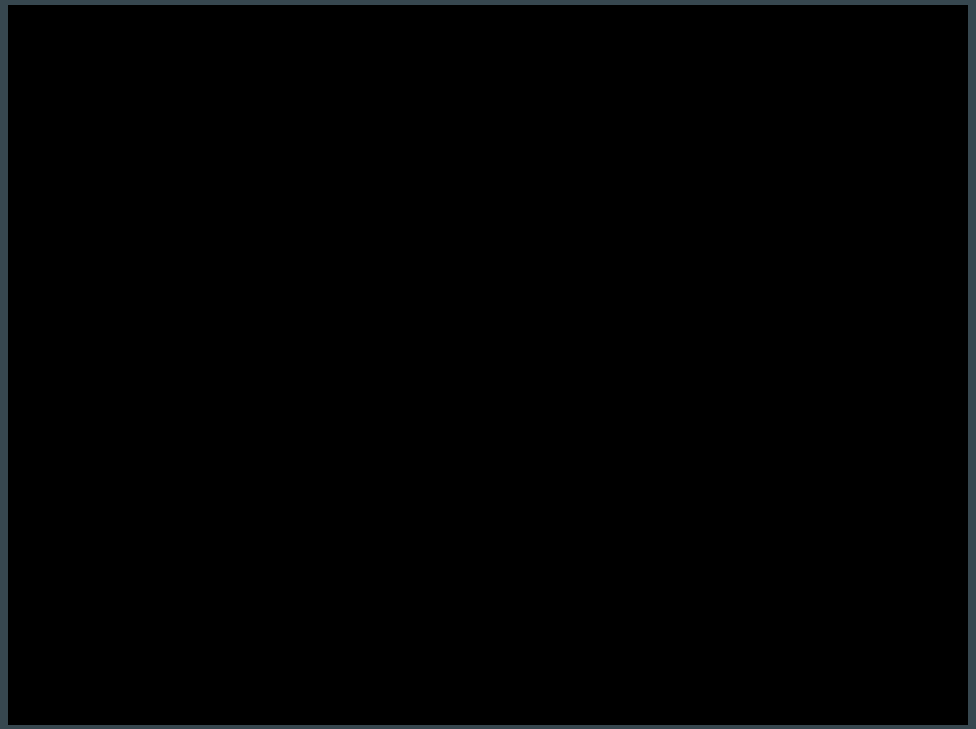






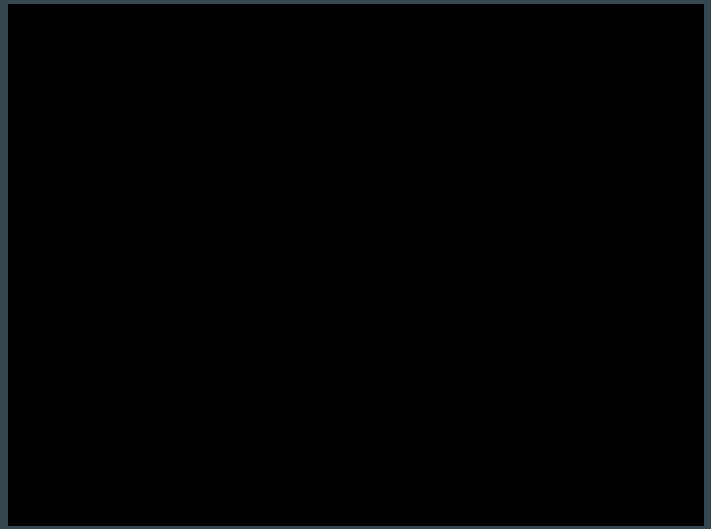


Demo Code



Why we choose these values

- We chose four levels because we wanted a resting state, minor strain, moderate strain and extreme strain/possible collapse
- It could be chosen to be any number, letter or symbol
- Our code can allow a different scale if desired (ex. 1-3 or A-D)



Challenges

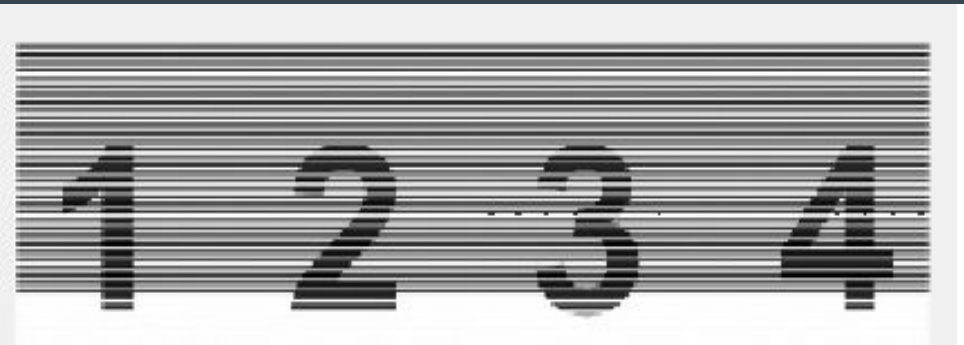
- Coding challenges
  - Finding a function in MATLAB that would save the images without distorting the pattern
  - Finding a geometrical pattern that would produce the moire fringe effect
  - Lack of knowledge in coding
- Weren't able to meet in person to work with each other
- The change in deliverables due to the switch to an online format
  - Switching from building a physical product to an online simulation

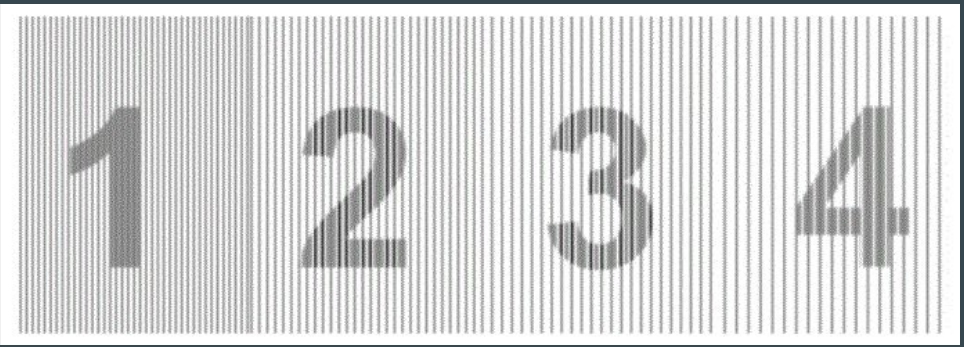
Intended Users

- Our intended users would be civil engineers, maintenance technicians, building developers. Any industry that is responsible for maintenance or quality control

Failed designs

- First try using a horizontal line pattern
  - We planned to shift the patterns together horizontally meaning we needed the pattern to be vertical vs horizontal
- Second try unable to get moire fringe effect due to wrong MATLAB function
  - We used the multiply function that would combine the images instead of superimposing them correctly





Thank You!