Strain visualization microsensor based on Moire fringes

DESIGN DOCUMENT

Team 9

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Executive Summary

Development Standards & Practices Used

- Following all safety procedures
- Weekly meetings
- Document all processes

Summary of Requirements

- Measure the tensile and compressive strain
- Visible by the naked eye
- Use of Moire Fringes
- Create a strain visualization microsensor

Applicable Courses from Iowa State University Curriculum

- EE 224 and 324 - Signals and Systems I & II
- EE 531 - Micro and Nano Systems and Devices
- EE 532 - Microelectronics and Fabrication Techniques
- EE 538 - Optoelectronics Devices and Applications

New Skills/Knowledge acquired that was not taught in courses

Through the research and design of this project we have learned many new skills that we haven't yet covered in class. The first skill we learned was how to prototype new designs. We also learned how to work with a client to reach the desired outcome. Finally, we learned what moire fringes are and how they are used.

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List of figures/tables/symbols/definitions (This should be the similar to the project plan)

None

1 Introduction

1.1 Acknowledgement

Thank you to Dr. Long Que for his continued guidance throughout our project.

1.2 Problem and Project Statement

Due to the increased use of large structures, such as buildings and bridges, new ways of determining how much strain the structure is under needs to be developed and tested. A possible solution for this problem could be the development of a strain visualization microsensor based on moire fringes. This would make it easier to determine the compressive and tensile strain of a structure. This is because the moire fringe filter is readable by the naked eye and visible without the use of electrical equipment.

1.3 Operational Environment

This product, when completed, will be used throughout various environments. It will need to withstand heat, cold, wind, dust and other forces of nature.

1.4 Requirements

Our project must be able to measure the compressive and tensile strain of an object. It must also be readable by the naked eye and easily readable to anyone without circuitry or other complicated reading methods. Finally, we must be able to design and build our project within our budget of $50.

1.5 Intended Users and Uses

The intended user of our project is Dr. Long Que. The use of our project will help the user measure the compressive and tensile strain of a structure.

1.6 Assumptions and Limitations

Assumptions: Our microsensor will be able to measure the tensile and compressive strain of a structure with the use of moire fringes.

Limitations: Must be visible to the naked eye

1.7 Expected End Product and Deliverables

The end product will be a moire fringe filter that measures the compressive and tensile strain. The filter will be readable by the naked eye as well as by a micro sensor.

2. Specifications and Analysis

2.1 Proposed Approach

In an article we read, they described a strain visualization sticker using moire fringe patterns. This sticker would be attached to structures and would display the strain on the structure. The moire fringe sticker will also be readable by a microsensor. This microsensor will take in the nonelectrical quantity of the moire fringe filter and convert it into an electrical signal. The strain that is read off the filter could either be tensile and compressive strain.

The moire fringe sticker will only display images when strain is applied to the structure. When strain is applied the sticker will depict the distance the structure has moved. This distance corresponds to a specific amount of force on the structure.

Current Progress:

We have done large amounts of research over moire fringe filters and how they are used in determining the strain in buildings and structures. Through this we have determined we are going to use the moire fringe filter as a sticker. This means we will stick the filter on the structure and as force is applied different numbers will appear. We decided we would use numbers to depict the distance from the original structure to help determine the strain on the structure. We have also discussed with our advisor how we plan to fabricate the filter. We decided to use a process called optical lithography. This will allow us to make the filter in the lab next semester.

This semester we have also done research over microsensors and how they could be useful in determining the strain on the structure. He determined we would build a micro sensor to read the data off the moire fringe sticker. This would be helpful because if the sticker was in a remote area and it is hard to reach to view the filter. You should fly the microsensor there to view the filter or you could leave it there to view the filter.

The final thing we worked on this semester was planning how we will test the moire fringe filter as well as the micro sensor next semester. We decided to test

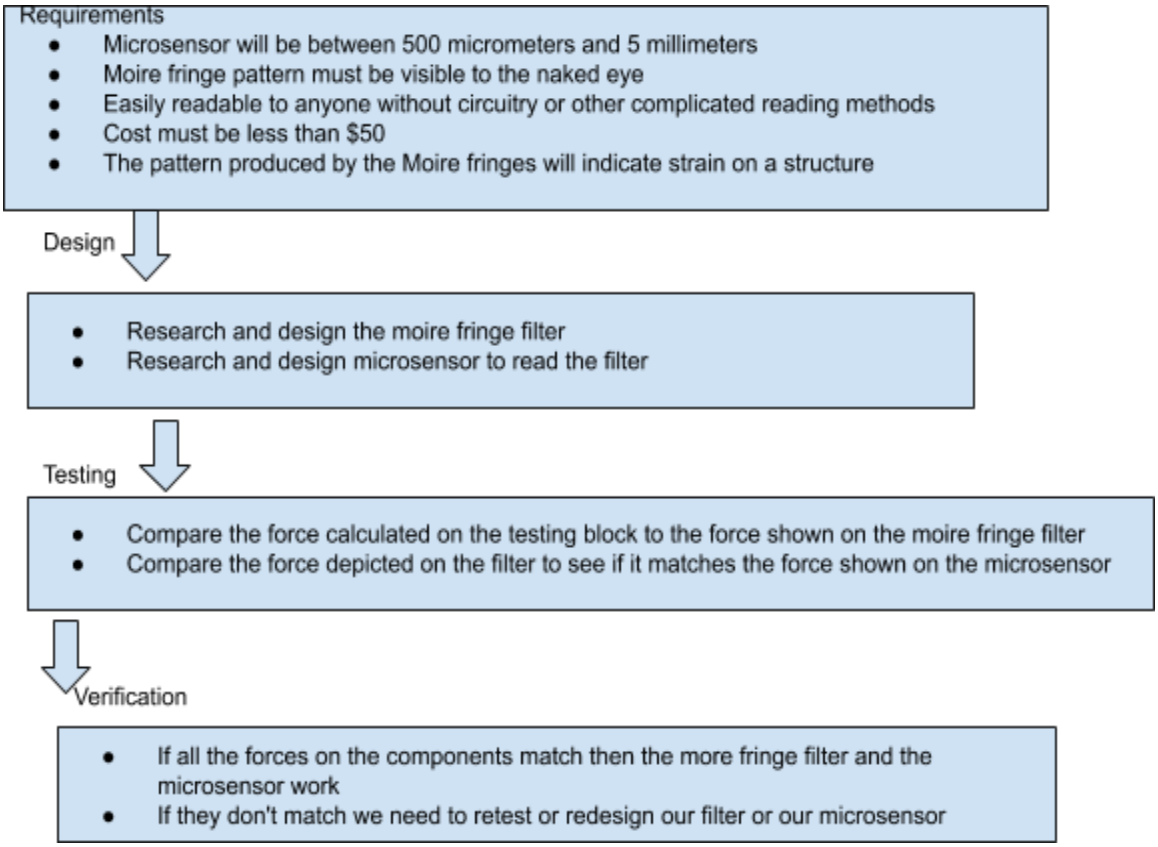
these components. We will attach the moire fringe filter to a testing block and apply force to the testing block. From here we will calculate the force applied and compare it to the moire fringe filter reading if they are the same it proves the moire fringe filter works. To test the microsensor we will use it to read the moire fringe pattern if both the microsensor and the moire fringe pattern match the microsensor works.

2.2 Design Analysis

Our group is still in the research phase of the process. We have looked at several articles given to us by our advisor over how moire fringes are used to measure strain and how we might implement it with structures. We are currently brainstorming designs of how we can apply what we have learned.

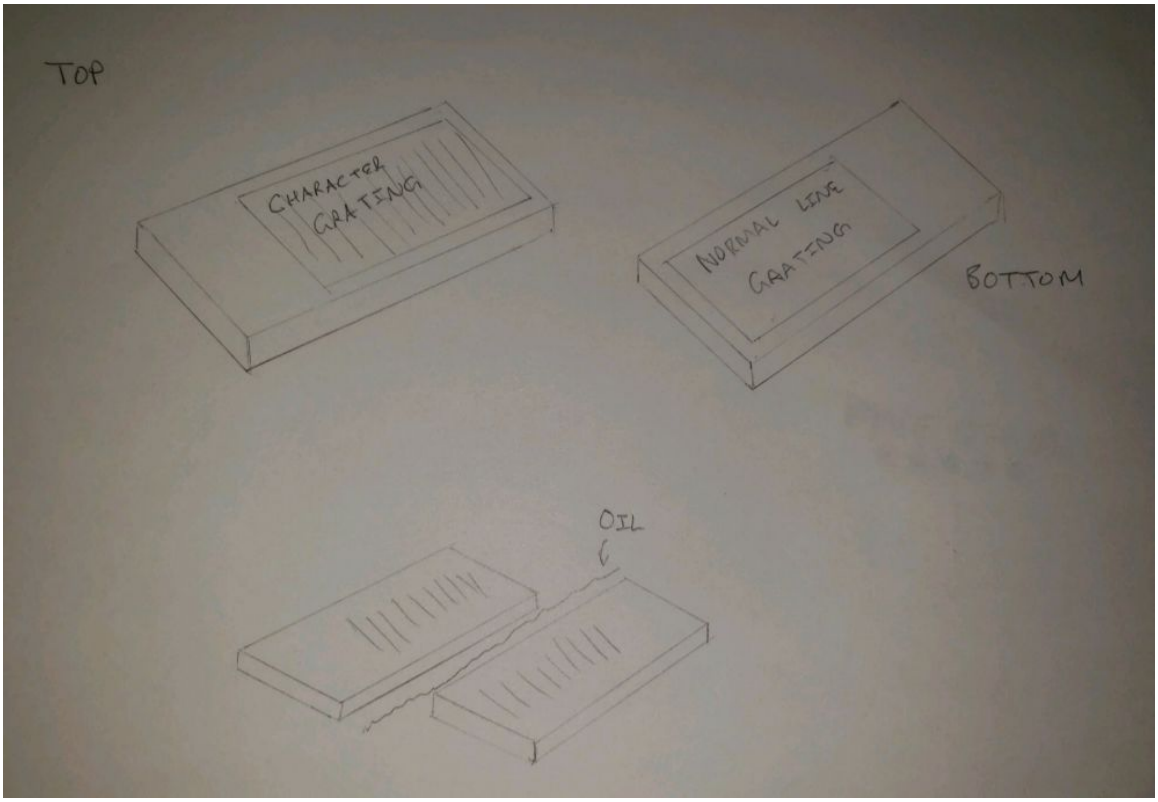
Through the research and the brainstorming process we decided we would design a moire fringe pattern that will depict numbers 1-5 these numbers will correspond to a distance that the object is displaced. For our microsensor we are still brainstorming, but as of now we are planning on making a microsensor that Our microsensor will take in an image of our moire fringe pattern and then detect two physical changes about the image the brightness of the pixel and the change in pixel position.

2.3 Development Process



Our group is using the waterfall development process. This means we are taking the steps of our project one at a time to each step depending on the one previous to it. The first step is look at the requirements of the project and start to do research over the ways we can meet the requirements. Through the research we can start to design how we will build the microsensor as well as the moire fringe filter. When we finish designing these components we will start to build and test them. If the tests are successful we have completed our project, if the tests are unsuccessful we will need to go back into the process and redesign and retest until we get the result we wanted.

2.4 Conceptual Sketch



3. Statement of Work

3.1 Previous Work And Literature

In our research of Moire Fringes we have found several examples of similar techniques of using Moire Fringes to test the strain on structures. One example our technical advisor Long Que gave us showed the research group using stickers with the Moire Fringe pattern that displayed different patterns when the structure experienced different amounts of strain. They then used a camera with a telescope lens connected to a computer to get a measurement of the strain. Our project differs from this because instead of using a camera with a telescope lens connected to a computer to read the data we plan to make the sticker visible to the naked eye. This would allow the user to either go out and record the strain or use a drone with a camera to record the strain on the object if the location is in a remote area.

3.2 Technology Considerations

The primary strengths of our project is the capability to see the strain with the naked eye. This will allow the user to determine the strain without any access to electrical equipment. This will make the process of finding the strain easier and less expensive than previous

methods. Another advantage of our product is the ability to find the strain from a distance with a drone. This will help the user because if the structure is located in a remote or hard to reach location instead of having to find a way to reach the area they can fly a drone in and take a picture of the strain.

One possible weakness of our product is instead of a machine reading the strain the sticker will display a number that correlates to the amount strain on the structure. This will lead to a higher degree of error due to the visible numbers being an estimate rather than an exact number. One way we can limit this error is through adding symbols or smaller increments between numbers.

3.3 Task Decomposition

We have separated our project into two sections. Two people will be working with the microsensor and two other members will work with the Moire Fringes. The group working on the microsensor will need to determine how we test the moire fringe pattern and how we plan to implement the microsensor. The group that will work with the Moire Fringe pattern will need to design and build the filter. This will include picking how they want to display the strain as well as any redesigns that need to be made.

After figuring out how to solve those problems we will share with the other group in our team and confirm if the solution is suitable.

3.4 Possible Risks And Risk Management

There are several possible details that could potentially slow our progress. One of those is the recent outbreak break of COVID-19 which has caused our group to work from home. This will prevent us from meeting in person, which will hurt communication. We also will not be able to meet with our advisor, Dr. Long Que. This is a big hindrance as communication is slowed down and significantly more difficult. Another way it hurts our progress is that without access to labs we will be unable to build or test or project until next semester. One other detail that has slowed us down is the limited knowledge of the topic. Our group has never worked with Moire Fringes which has caused our group to spend a lot of time researching the topic so we can better understand what's going on.

3.5 Project Proposed Milestones and Evaluation Criteria

Some key milestones that we have achieved right now

- We brainstormed different ideas to build this project
- Met with Dr. Long Que to determine that we were going in the right direction
- Wrote the first version of the design document

Some key milestones we want to achieve by the end of the semester

- A plan on testing the sensor for next semester
- A final sketch or drawing for when we build it next semester

Possible testing method

- Build a small structure on which we would attach the microsensor to measure the levels of strain that the structure has upon it and see the changes with moire fringe patterns - structure could be a small bridge

3.6 Project Tracking Procedures

As of now we have been using a progress document with all the required tasks and when they are supposed to be finished by. This has helped us keep on track and to make sure everyone knows what they must complete by what time. Our group has decided to use this method for this semester as well as next semester to make sure we are all focused.

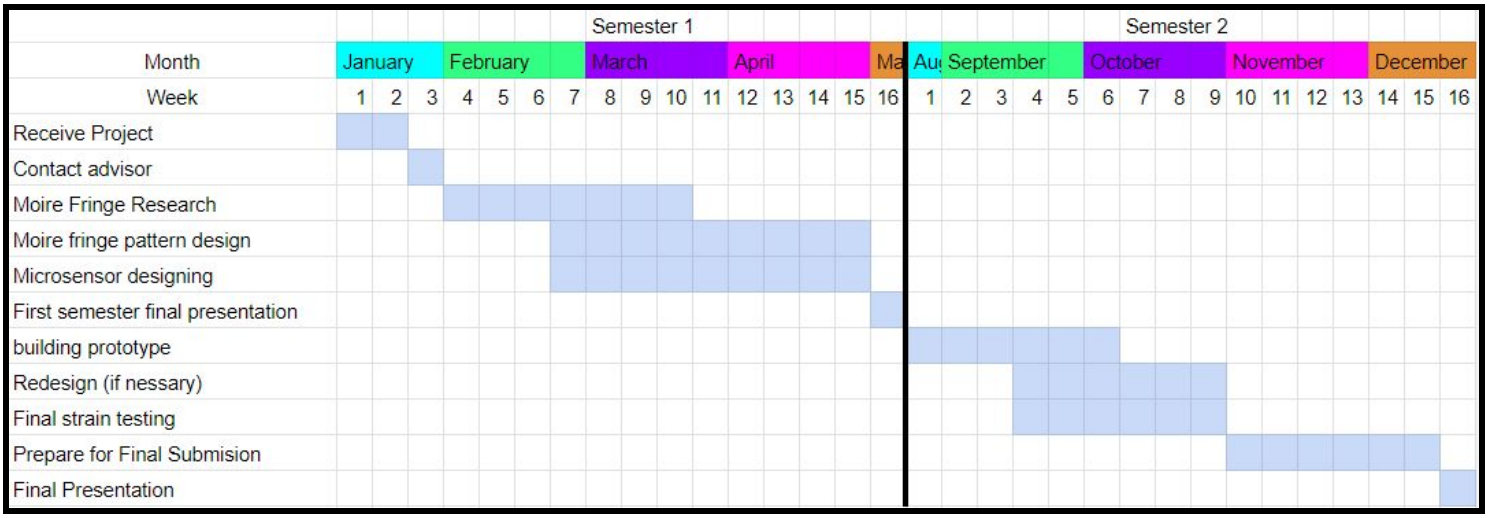
3.7 Expected Results and Validation

The desired outcome is to build a microsensor that will measure the compressive and tensile strain upon a structure and visualize it with a Moire Fringe pattern. It should be visible to the naked eye. The pattern should have symbols or letters that would be easy to understand.

The desired outcome of this product is to create a Moire Fringe sticker capable of being observed with the naked eye. We will confirm the product works by adding a set amount of strain to a structure with a moire Fringe sticker to see if the sticker depicts the correct level of strain as the strain on the structure changes. If it accomplishes this task multiple times in a row it will show that this product can work consistently.

4. Project Timeline, Estimated Resources, and Challenges

4.1 Project Timeline



4.2 Feasibility Assessment

As of now we are still on track to finishing our project next semester. If you look at the project timeline we have finished all the way up to the first semester final presentation. Next semester we will start to build the microsensor prototype. This semester we spent our time planning and designing for next semester. Next semester we will start the building and testing of the moire fringe filter as well as the microsensor. The pattern will be readable by our microsensor and will tell the amount of strain on the structure. A couple challenges we see in the future is finding a structure to test this on and getting the microsensor to be able to read the Moire Fringe pattern. If we keep up the work we should be able to finish this at the end of next semester.

4.3 Personnel Effort Requirements

Task	Description	Estimated Hours
Moire Fringe Research	Researching moire fringe patterns and how they work Finding articles and videos to get a complete understanding How we can implement this in our project	30
Microsensor Designing	Picking what sensor we want to use and how we will implement	20
Moire Fringe Designing	Picking a way to display strain on the sticker.	20
Building the moire fringe filter	Building the moire fringe filter for testing	40
Testing	Make sure the project is usable	30

4.4 Other Resource Requirements

We need to build the microsensor as well as the moire fringe filter next semester. We will also need to build a structure as a testing block to test the moire fringe filter as well as the microsensor. To build the microsensor next semester we will work with Dr. Que, so we have yet to determine what materials we will exactly need.

4.5 Financial Requirements

We will need to purchase the materials to build the microsensor and the moire fringe filter. Our budget to build these components is $50.

5. Testing and Implementation

1. For our project we will need to do a functional and nonfunctional requirements and an integrity test
2. We will need to test the Moire Fringe Filter and the microsensor
3. Test case 1: The Moire fringe filter matches the force applied on the testing block.

   Test case 2: The Moire fringe filter doesn't match the force applied on the testing block.
4. Test case 1: The Moire Fringe filter works

Test case 2: the Moire Fringe filter doesn't work.

5. Testing procedure; Attach the moire fringe-based sensor onto the testing block, Apply force to the testing block: compressive and tensile forces, Record the strain shown on the Moire Fringe-based sensor, Calculate the strain by the applied force on the block, Compare the strains to see if they match.
6. Evaluate the results
7. Redesign or retest if the Moire Fringe filter doesn't work
8. If remade redo the tests
9. Document and publish the results

5.1 Interface Specifications

We will need to do some hardware interfacing with the Moire Fringe pattern and the microsensor. We will need to make sure they are communicating with each other and that the moire fringe pattern is properly lined up. We haven't been able to do any testing since we switched to online classes before we started building our Moire Fringe filter or our microsensor.

5.2 Hardware and software

We haven't used any software yet, but we may need some with the microsensor we are building. For hardware we are using a testing block (to apply force to), moire fringe pattern (displays the force), microsensor(reads the moire fringe filter) and vice (to apply force).

5.3 Functional Testing

For functional testing we need to make sure the results of the Moire Fringe filter matches the force applied to the testing block. We also need to compare the readings of the Moire fringe filter to the microsensor to make sure those match as well.

5.4 Non-Functional Testing

For non-functional testing we need to make sure the microsensor can read the microsensor. We also need to make sure the moire fringe pattern moves equally to the testing block. If they don't move together the correct reading won't be visible.

5.5 Process

We have not done any actual testing as of now, as we are unable to access the lab, but this is the procedure we have planned. Testing procedure; Attach the moire fringe-based sensor onto the testing block, Apply force to the testing block: compressive and tensile forces, Record the strain shown on the Moire Fringe-based sensor, Calculate the strain by the applied force on the block, Compare the strains to see if they match.

5.6 Results

As of right now we haven't done any testing due to the rest of the semester being online. We have had some failures with making our moire fringe filter. originally we were going to use pictures and symbols to display the strain, but we realized this would be more difficult than just displacing the numerical value of how much the object has moved. We have had success in getting the final moire fringe filter planned for building next semester.

6. Closing Material

6.1 Conclusion

So far this semester we have done large amounts of research over moire fringe filters and how they are used in determining the strain in buildings and structures. Through this we have determined we are going to use the moire fringe filter as a sticker. This means we will stick the filter on the structure and as force is applied different numbers will appear. We decided we would use numbers to depict the distance from the original structure to help determine the strain on the structure. We have also discussed with our advisor how we plan to fabricate the filter. We decided to use a process called optical lithography. This will allow us to make the filter in the lab next semester.

This semester we have also done research over microsensors and how they could be useful in determining the strain on the structure. He determined we would build a micro sensor to read the data off the moire fringe sticker. This would be helpful because if the sticker was in a remote area and it is hard to reach to view the filter. You should fly the microsensor there to view the filter or you could leave it there to view the filter.

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6.2 References

Moiré pattern. (2020, April 16). Retrieved April 27, 2020, from https://en.wikipedia.org/wiki/Moir%C3%A9_pattern

Takaki, T, et al. "Strain Visualization Sticker Using Moiré Fringe for Remote Sensing." Bridge Maintenance, Safety, Management, Resilience and Sustainability Bridge Maintenance, Safety and Management, 2012, pp. 2212–2217., doi:10.1201/b12352-330.

6.3 Appendices

N/A