

Measurement of Earthquakes

New Mexico

Supercomputing Challenge

Final Report

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Team #91

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Executive Summary

The destructive power of earthquakes is a very important subject to understand. The media refers to earthquakes with a rating based off of scientific analysis. It is vital to understanding and to safety there is a way to comprehend what is meant by all the different ratings and degrees of earthquake.

Within our project we have gone in depth into studying the different ways that earthquakes are measured. In this project we used statistics and computer programming to develop a model that helps in the understanding the relationship between the two major ways to measure earthquakes.

We study the importance of finding correlation between different scales. We have developed a computer program that models the problem we have set out to solve. This program is explained in detail and all the code is listed in the appendix.

Statement of Problem

Earthquakes are disastrous natural events that **occur** everywhere on Earth. They are caused by a release of energy on or in the Earth's crust. The amount of energy released is recorded with a scale of **dimensionless numbers**. This scale is called the **moment magnitude scale**. Scientists use this scale to rate the power of an earthquake. The rating is found using a logarithmic equation.

For centuries earthquakes have been a source of fear for humans everywhere. This fear is particularly found in major cities that are located along fault lines or the coast line. Cities along fault lines face minor earthquakes commonly. However, they also face the most intense earthquakes possible. When this happens, major destruction can result to structures. Coastal cities, regardless of their locations, face the threat of earthquake driven tsunamis. In the past decade major tsunamis that resulted from mid-ocean earthquakes had a huge impact on the media and earthquakes were again seen for their destructive power.

It is because of these dangers that our team sees the importance of understanding the force involved in earthquakes. Particularly, our team wants to know the relation of an earthquake's **magnitude** to an earthquake's **intensity**. With knowledge of this relationship, or lack of a relationship, we can better understand the damage done by earthquakes. Important questions come up from this problem. What role do structures play in the damage done by an earthquake? What happens as you move away from the **epicenter** of an earthquake? Does terrain

make a difference? We hope to help in the understanding of these questions through our research and experimentation.

Solving the Problem

Earthquakes are measured on many different scales that measure many different things. The scale most commonly referenced, however, is the moment magnitude scale. This scale measures the amount of energy released by an earthquake and then represents it on a dimensionless scale.

The value calculated by the moment magnitude scale is written as M_w , or mechanical work. M_w is a logarithmic function of M_o , or the magnitude of the seismic moment. M_o is recorded in either **dyne-centimeters** or in **Newton meters**. The seismic moment is calculated using a variety of variables including: **shear modulus, area of rupture**, and displacement caused by the seismic event. The full equation for finding the moment magnitude of an earthquake is:

$$M_w = \frac{2}{3}(\log_{10} M_o) - 6.067$$

Another scale used to measure earthquakes is the **Mercalli Intensity Scale**. This scale is different from the moment magnitude scale because instead of measuring the energy released, it is a measurement of the effects and damage done by an earthquake. The modified Mercalli

intensity scale, the version commonly accepted by geologists and seismologists, ranges from a degree of I to XII. The degrees are based off of whether an earthquake can be felt, how it is felt, and what damage is a result of the earthquake.

Because of the variables involved in the Mercalli intensity scale and its purpose, the scale can be recorded differently by different people, and any single earthquake can have many recorded intensities. For example, a person who is located very far from the epicenter of an earthquake might rate it very low on the scale. A person very near to the epicenter would probably record a much higher value for the intensity.

These facts themselves show the difficulties that might arise from trying to form a relation between an earthquake's intensity and an earthquake's moment magnitude. One of these difficulties, the fact that each event can have multiple intensities, is mostly erased by simply choosing a single constant intensity to use in a comparison. We decided on using the average reported intensity as provided by the **United States Geological Survey** (USGS). This also helps to fix the distance problem. The majority of people who report earthquake intensities will be near the epicenter. Thus, the average intensity is a good representation of the intensity at the center location of an earthquake.

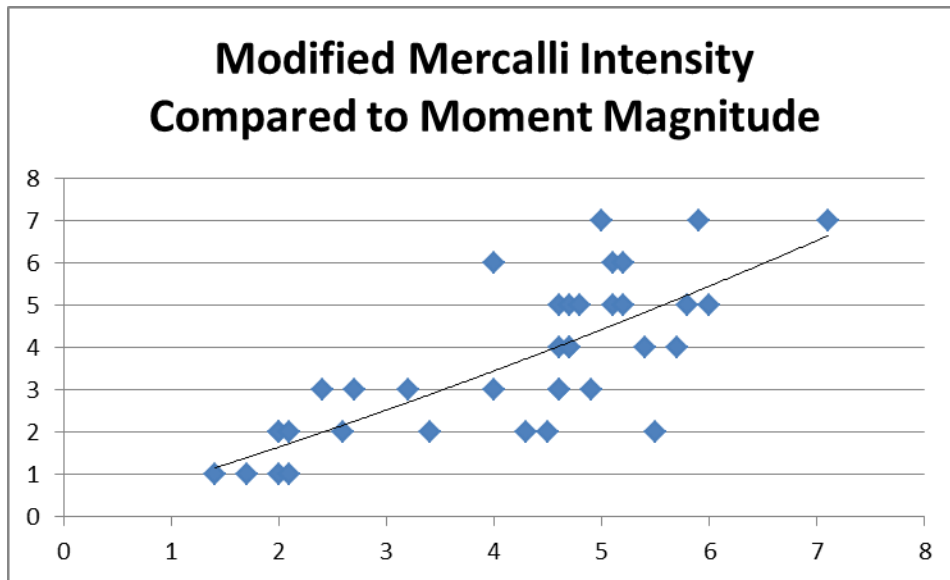
We created a table of many earthquakes comparing their moment magnitudes and the average reported Mercalli intensity. We were able to plot this data on a scatter plot and calculate an equation to represent the relation that we observed. We used the moment magnitude as the domain so that we could attempt to derive the intensity from an input of a magnitude. The equation that we found to represent this relation was:

$$f(mm) = 0.0255mm^2 + 0.7466mmi + 0.0583$$

**where mmi = modified Mercalli Intensity and
mm = moment magnitude**

**Modified Mercalli Intensity Compared to Moment
Magnitude**

Moment Magnitude	Modified Mercalli Intensity
1.4	1
1.7	1
2	1
2	2
2	2
2.1	1
2.1	2
2.4	3
2.6	2
2.7	3
3.2	3
3.4	2
4	3
4	6
4.3	2
4.5	2
4.6	5
4.6	4
4.6	3
4.6	3
4.7	4
4.7	5
4.7	4
4.8	5
4.9	3
5	7
5.1	6
5.1	5
5.2	6
5.2	5
5.4	4
5.5	2
5.7	4
5.8	5
5.9	7
6	5
7.1	7



At this point we had a relationship that we could work with and we planned to utilize a computer resource to help implement this relationship. We chose to create a program using the **Java Programming Language** that could help to model this equation.

Our team wanted the program to be user friendly, so that it could be used by anyone. This became one of the major goals of the development of the program. In order to achieve this goal, we knew that our program would need a working **Graphic User Interface** (GUI). This meant the addition of buttons and controls that would allow the user to easily get the desired result from our program.

In order to create this program with a GUI we utilized many built in Java classes from the **Java Foundation Classes** (JFC). We used **Swing**, a toolkit for creating portable, cross platform GUIs. We also used imported layouts to allow for the adjustability of the program. These steps allow for the user to successfully operate the program with ease. Below is some of the code that we used to create this easy to use GUI.

```

import javax.swing.*;

public class Primary {
    public static void main(String[] args){

        //// creating the window ////
        gui window = new gui();

        //// setting the window properties ////
        window.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        window.setSize(400,600);
        window.setVisible(true);

    }
}

import java.awt.*;
import java.awt.event.*;
import javax.swing.*;

public class gui extends JFrame{

    //// declaring components ////
    private JButton startButton;
    private JTextField momentMagnitudeField;
    private JComboBox timerField;

{More shown in Appendix: Code}

```

The functionality of our program is based off of the object-oriented nature of Java programming. There are three classes in the final program. The first class, Primary, sets up the window using an object of the second class, gui. The final class, CreateFile, is used to create and save text files with the data that is calculated within the program.

Our finished program utilized the equation we found earlier to calculate intensity based off of an input of a magnitude. This allows a user to predict roughly what damage could be done by an earthquake, or how severely it could be felt. Based off of those results, they could determine many useful things.

Results of our Study

We have successfully shown a relationship between the intensity of an earthquake and the magnitude of the energy that it releases. We learned about the ways that earthquakes are measured. There is the Moment Magnitude Scale and the Modified Mercalli Intensity scale. The scales tell different things. The Moment magnitude measures the energy of an earthquake while the Mercalli measures the observed effects of the earthquake. We created a Java program that allows you to quickly use the relationship between these two scales. We discovered through our research that there are many factors involved in determining the intensity of an earthquake. These include the distance from which the intensity is recorded to the epicenter of the earthquake, the terrain of the area that is affected by the earthquake, the types of structures in the area, and the person who reports the intensity.

From this project we have had the original achievements of developing a computer program and understanding the correlation of the damage done by an earthquake and the technical interpretation of its physical properties.

Conclusion

From this project, we conclude that there is a relation between magnitude and intensity. This is not a perfect relationship, as many factors can show a lack of correlation between the sets of data. However, this relationship is still apparent and important. Understanding what the different numbers on the different scales mean is vital to understanding exactly what happened to an area that is affected by an earthquake. Using this knowledge helps to create a broad understanding of what happens within an earthquake.

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Glossary

- **Area of rupture:** Occurs along the geologic fault where the earthquake occurs.
Recorded in cm^2
- **Dimensionless number:** A number not associated with a dimension; does not measure a specific quantity but instead represents size as relative to what is being assessed.
- **Dyne-centimeters:** 10 micro newtons per centimeter.
- **Epicenter:** The point that all seismic waves emit from in an earthquake.
- **Graphic User Interface:** In computer science, the part of a computer program where the user can see and interact with visual parts.
- **Intensity:** A broad term describing the effect of energy.
- **Java Foundation Classes:** A graphical framework made up of many classes and packages that was created to allow for ease in creating GUIs with java.
- **Java Programming Language:** A programming language developed by James Gosling.
- **Magnitude:** A scalar quantity; the scalar portion of a vector.
- **Mercalli Intensity Scale:** A scale used to measure the intensity of earthquakes
- **moment magnitude scale:** A scale used to measure the energy output of earthquakes.

- **Newton meters:** A unit of torque resulting from applying 1 Newton of force to a 1 meter long arm.
- **Shear modulus:** The ratio of shear stress to shear strain.
- **Swing:** In Java programming, the classes from the JFC that include many GUI components.
- **United States Geological Survey:** Scientific agency of the US government dealing with the geology of the nation and the world.

Appendix: Code

```
import javax.swing.*;

public class Primary {
    public static void main(String[] args){

        //// creating the window ////
        gui window = new gui();

        //// setting the window properties ////
        window.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        window.setSize(400,600);
        window.setVisible(true);

    }
}

import java.awt.*;
import java.awt.event.*;
import javax.swing.*;

public class gui extends JFrame{

    //// declaring components ////
    private JButton startButton;
    private JTextField momentMagnitudeField;
    private JComboBox timerField;

    //// creating the arrays for the timer field////
    private String[] elementsForTimerField = {"Choose the number of times to run the
program", "1", "10", "20", "30", "40", "50", "100",};

    //// setting variable to decide final run time ////

    private int chosenRunTime;

    //// constructor for the window ////
    public gui(){
        super("Moment Magnitude to Mercalli");

        //// sets the layout to flow layout ////
        setLayout(new FlowLayout());

        //// creating some of the components ////
        startButton = new JButton("Start");
        momentMagnitudeField = new JTextField("Enter the recorded moment magnitude");
        timerField = new JComboBox(elementsForTimerField);

        //// making the text field able to be edited ////
        momentMagnitudeField.setEditable(true);

        //// adding components ////
        add(startButton);
        add(timerField);
    }
}
```

```

add(momentMagnitudeField);

//// listening to the start button ////
startButton.addActionListener(

    //// anonymous class thing ////
    new ActionListener(){
        public void actionPerformed(ActionEvent event){

            //// trying and catching ////
            try{
                CreateFile g = new CreateFile();
                double i =
Double.parseDouble(momentMagnitudeField.getText());
                System.out.println(i);
                int x = (int) Math.round((0.0551*(i*i) +
(0.5553*i) + 0.4474);
                System.out.println(x);
                g.openFile();
                for(int counter = chosenRunTime;counter >=
1;counter = counter - 1){
                    g.addData(Double.parseDouble(momentMagnitudeField.getText()),x);
                }
                g.closeFile();
            }catch(Exception error){
                JOptionPane.showMessageDialog(null, "Error!
You either did not choose the number of times to run the program, \nor you did not input a
positive value greater than zero for the moment magnitude." + "\n" + error);
            }
        }
    });
//// item listener for the timer field ////
timerField.addItemListener(

    new ItemListener(){

        public void itemStateChanged(ItemEvent event){

            //// switch statement to se chosen run time ////
            switch (timerField.getSelectedIndex()){
                case 0:
                    chosenRunTime = 0;
                    break;
                case 1:
                    chosenRunTime = 1;
                    break;
                case 2:
                    chosenRunTime = 10;
                    break;
                case 3:
                    chosenRunTime = 20;
                    break;
                case 4:
                    chosenRunTime = 30;
                    break;
                case 5:
                    chosenRunTime = 40;
                    break;
            }
        }
    }
);

```

```

        case 6:
            chosenRunTime = 50;
            break;
        case 7:
            chosenRunTime = 100;
            break;
    }
    });
}

import java.io.*;
import java.lang.*;
import java.util.*;
import javax.swing.JOptionPane;

public class CreateFile {
    private Formatter formVar;

    public void openFile(){
        try{
            formVar = new Formatter("Statistics.txt");
            System.out.println("File created");
        }
        catch(Exception e){
            JOptionPane.showMessageDialog(null, "There was an error with file
creation!");
        }
    }

    public void addData(double mm, int mmi){
        formVar.format("%i%i", mm, mmi);
    }

    public void closeFile(){
        formVar.close();
    }
}

```