Computer Assignment 2

CPE 261456 (Introduction to Computational Intelligence)

โดย

นายพีรณัฐ ธารทะเลทอง

รหัสนักศึกษา 550610530

เสนอ

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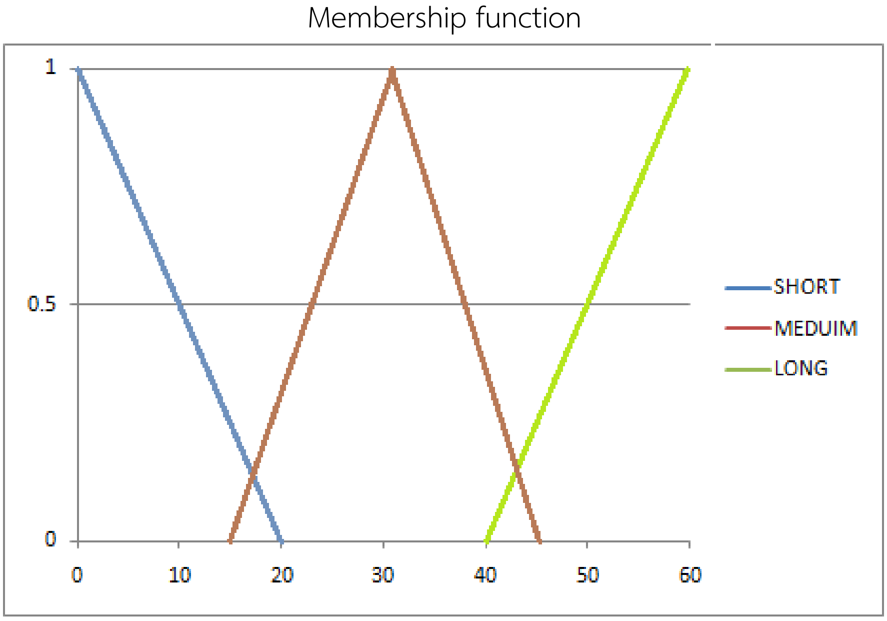
Steak Fuzzy Logic Simulator

เป็นระบบควบคุมความแรงของไฟในการย่างสเต็ก

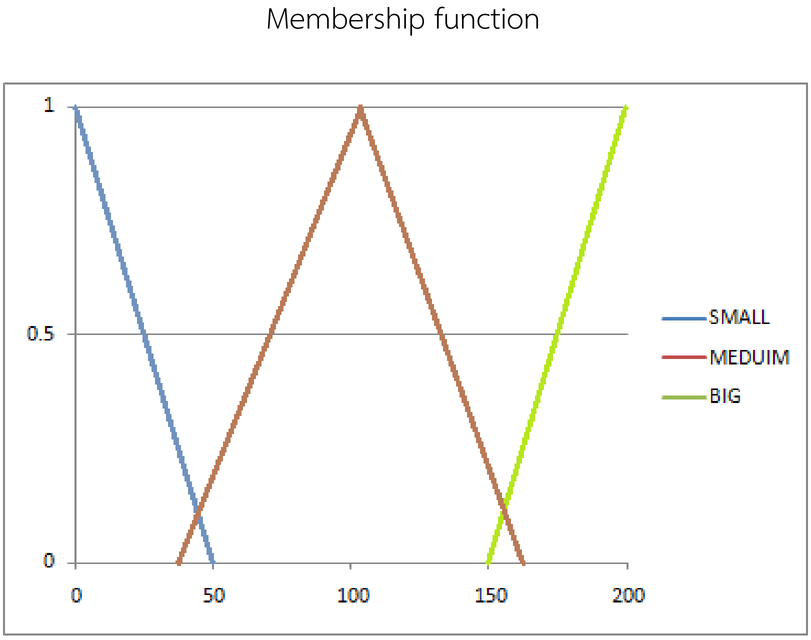
ลักษณะการทำงานของระบบ รวมถึง rules ที่ใช้

Input

1. เวลา (Time) มี 3 ระดับคือ SHORT MEDIUM LONG

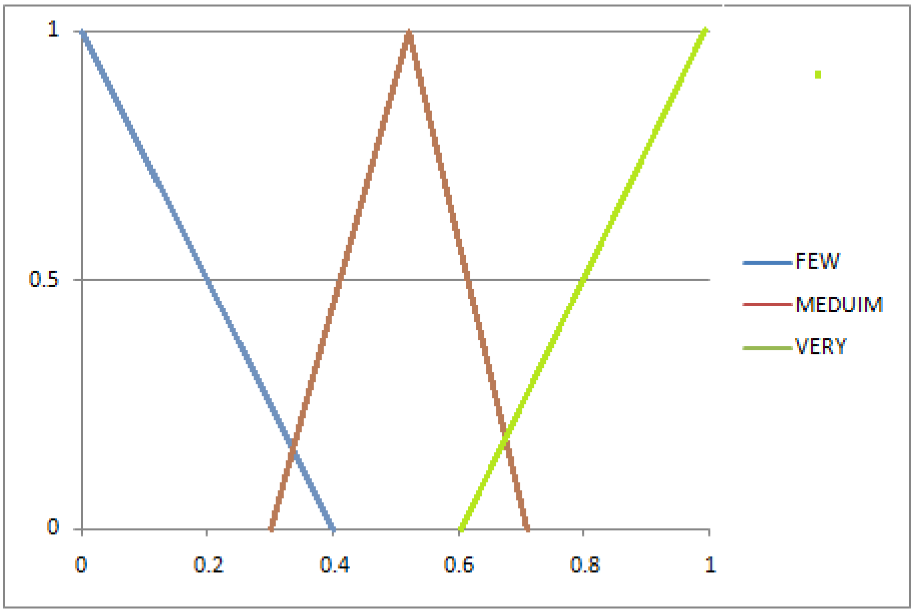


2. ขนาด (Size) มี 3 ระดับคือ SMALL MEDIUM BIG



3. ความแข็งของเนื้อ (Hardness) มี 3 ระดับคือFEW MEDIUM VERY

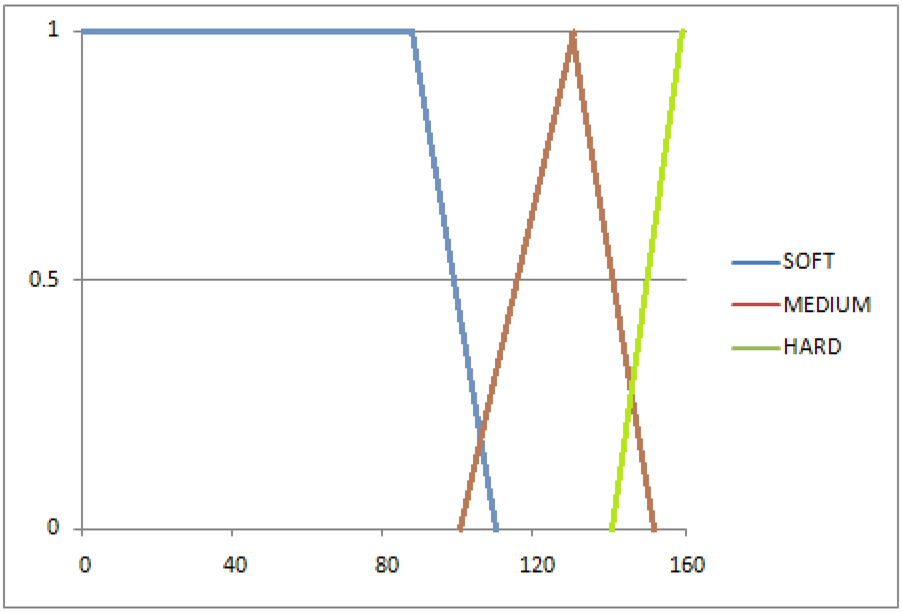
Membership function



Output

ความแรงของไฟที่จะใช้ย่างสเต็ก (Fire) มี 3 ระดับคือ SOFT MEDIUM HARD

Membership function



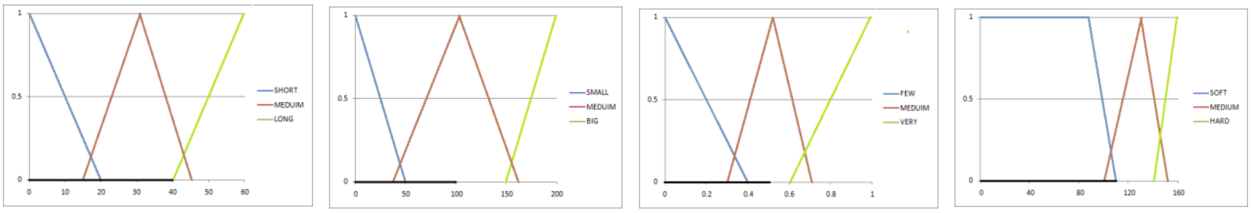
Rules

1. If Time is **SHORT** and Size is **SMALL** and Hardness is **FEW** then Fire is **SOFT**
2. If Time is **SHORT** and Size is **SMALL** and Hardness is **MEDIUM** then Fire is **SOFT**
3. If Time is **SHORT** and Size is **SMALL** and Hardness is **BIG** then Fire is **SOFT**
4. If Time is **SHORT** and Size is **MEDIUM** and Hardness is **FEW** then Fire is **HARD**
5. If Time is **SHORT** and Size is **MEDIUM** and Hardness is **MEDIUM** then Fire is **HARD**
6. If Time is **SHORT** and Size is **MEDIUM** and Hardness is **BIG** then Fire is **HARD**
7. If Time is **SHORT** and Size is **BIG** and Hardness is **FEW** then Fire is **HARD**
8. If Time is **SHORT** and Size is **BIG** and Hardness is **MEDIUM** then Fire is **HARD**
9. If Time is **SHORT** and Size is **BIG** and Hardness is **BIG** then Fire is **HARD**
10. If Time is **MEDIUM** and Size is **SMALL** and Hardness is **FEW** then Fire is **SOFT**
11. If Time is **MEDIUM** and Size is **SMALL** and Hardness is **MEDIUM** then Fire is **SOFT**
12. If Time is **MEDIUM** and Size is **SMALL** and Hardness is **BIG** then Fire is **SOFT**
13. If Time is **MEDIUM** and Size is **MEDIUM** and Hardness is **FEW** then Fire is **MEDIUM**
14. If Time is **MEDIUM** and Size is **MEDIUM** and Hardness is **MEDIUM** then Fire is **MEDIUM**
15. If Time is **MEDIUM** and Size is **MEDIUM** and Hardness is **BIG** then Fire is **MEDIUM**
16. If Time is **MEDIUM** and Size is **BIG** and Hardness is **FEW** then Fire is **HARD**
17. If Time is **MEDIUM** and Size is **BIG** and Hardness is **MEDIUM** then Fire is **HARD**
18. If Time is **MEDIUM** and Size is **BIG** and Hardness is **BIG** then Fire is **HARD**
19. If Time is **LONG** and Size is **SMALL** and Hardness is **FEW** then Fire is **SOFT**
20. If Time is **LONG** and Size is **SMALL** and Hardness is **MEDIUM** then Fire is **SOFT**
21. If Time is **LONG** and Size is **SMALL** and Hardness is **BIG** then Fire is **SOFT**
22. If Time is **LONG** and Size is **MEDIUM** and Hardness is **FEW** then Fire is **SOFT**
23. If Time is **LONG** and Size is **MEDIUM** and Hardness is **MEDIUM** then Fire is **SOFT**
24. If Time is **LONG** and Size is **MEDIUM** and Hardness is **BIG** then Fire is **SOFT**
25. If Time is **LONG** and Size is **BIG** and Hardness is **FEW** then Fire is **HARD**
26. If Time is **LONG** and Size is **BIG** and Hardness is **MEDIUM** then Fire is **HARD**
27. If Time is **LONG** and Size is **BIG** and Hardness is **BIG** then Fire is **HARD**

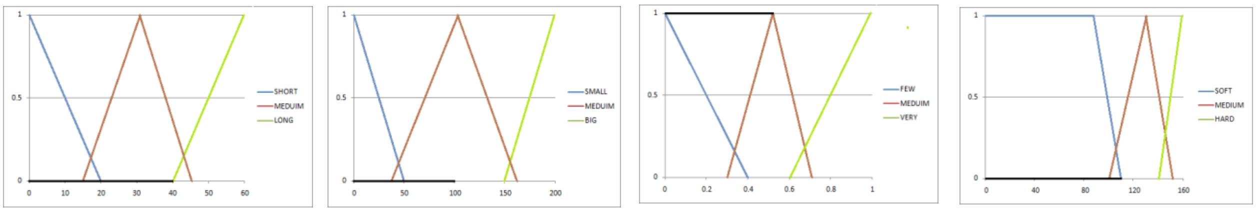
Simulation ของระบบ

สมมติให้ Input Time = 40, Size = 100, Hardness = 0.5

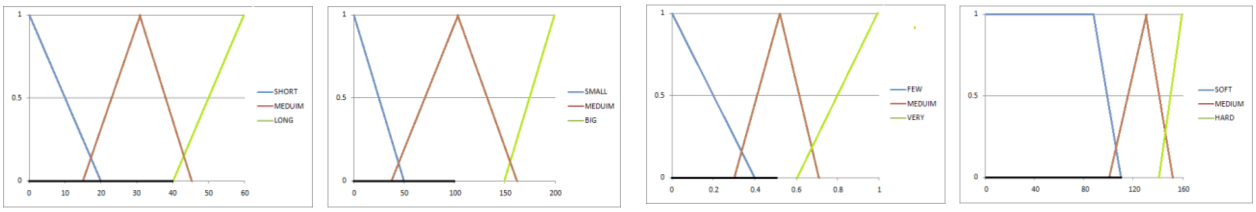
1. If Time is **SHORT** and Size is **SMALL** and Hardness is **FEW** then Fire is **SOFT**



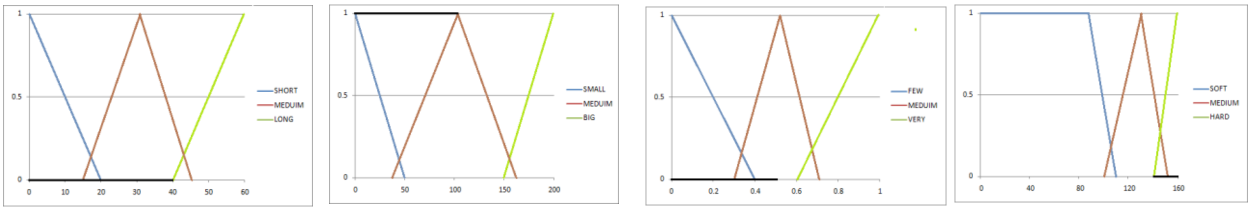
2. If Time is **SHORT** and Size is **SMALL** and Hardness is **MEDIUM** then Fire is **SOFT**



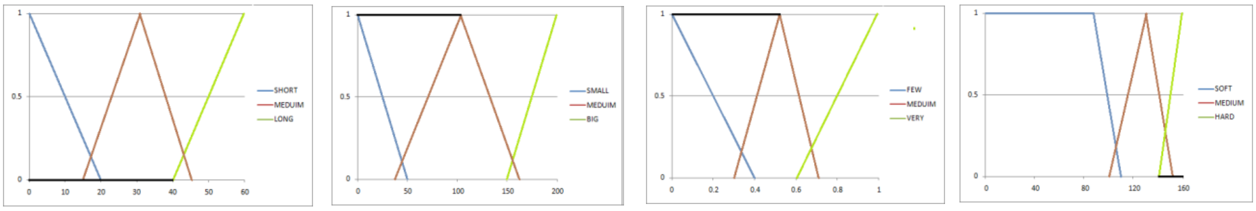
3. If Time is **SHORT** and Size is **SMALL** and Hardness is **BIG** then Fire is **SOFT**



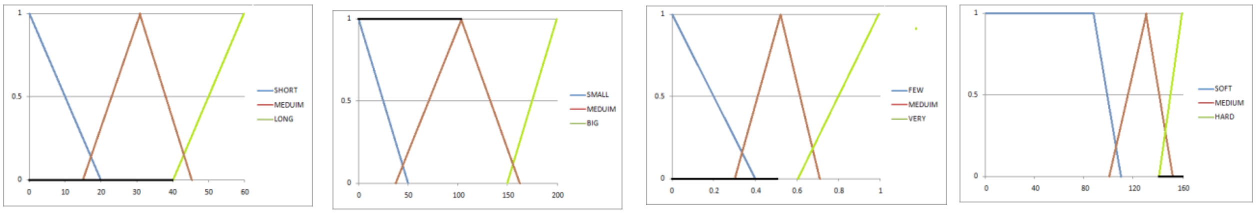
4. If Time is **SHORT** and Size is **MEDIUM** and Hardness is **FEW** then Fire is **HARD**



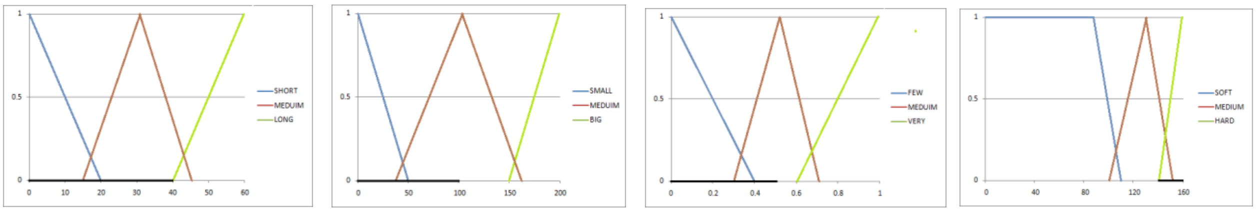
5. If Time is **SHORT** and Size is **MEDIUM** and Hardness is **MEDIUM** then Fire is **HARD**



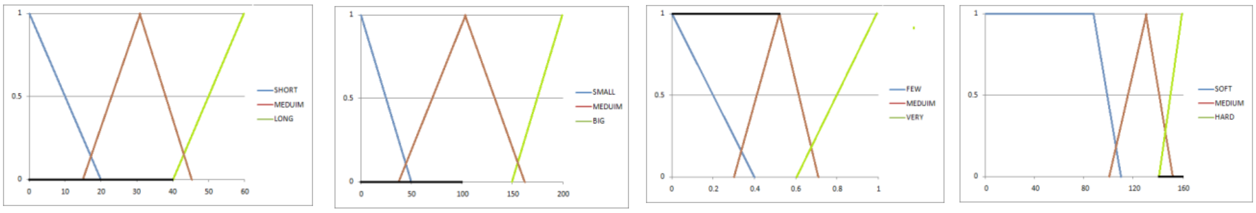
6. If Time is **SHORT** and Size is **MEDIUM** and Hardness is **BIG** then Fire is **HARD**



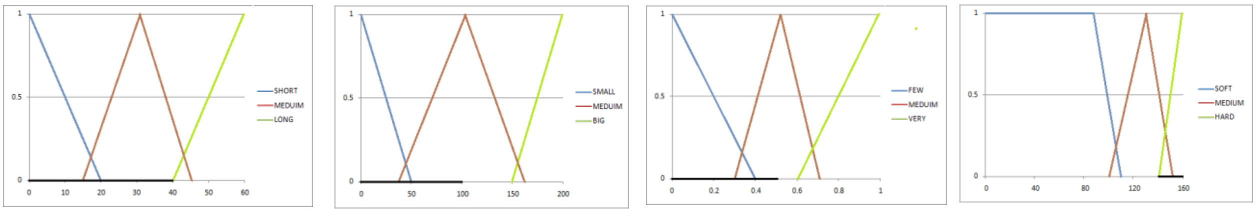
7. If Time is **SHORT** and Size is **BIG** and Hardness is **FEW** then Fire is **HARD**



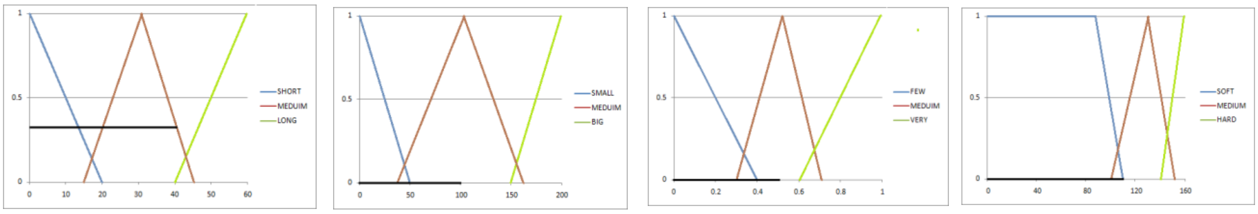
8. If Time is **SHORT** and Size is **BIG** and Hardness is **MEDIUM** then Fire is **HARD**



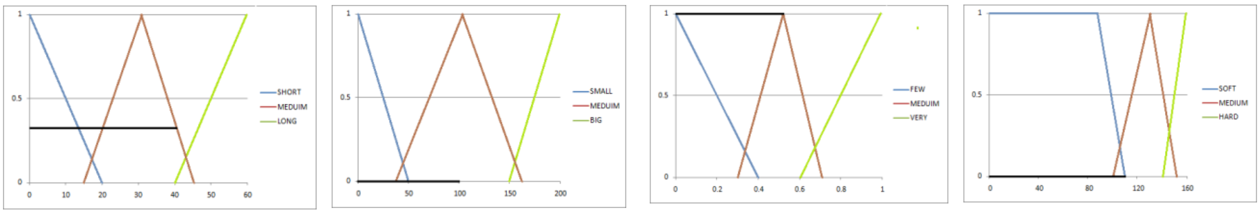
9. If Time is **SHORT** and Size is **BIG** and Hardness is **BIG** then Fire is **HARD**



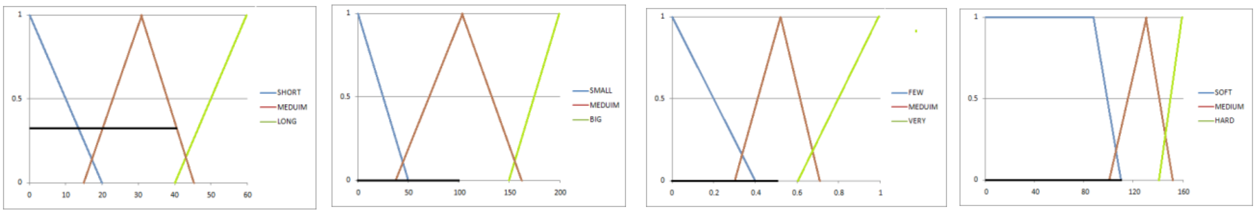
10. If Time is **MEDIUM** and Size is **SMALL** and Hardness is **FEW** then Fire is **SOFT**



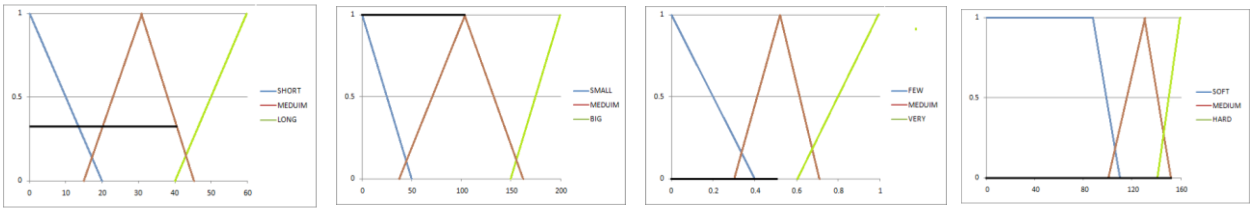
11. If Time is **MEDIUM** and Size is **SMALL** and Hardness is **MEDIUM** then Fire is **SOFT**



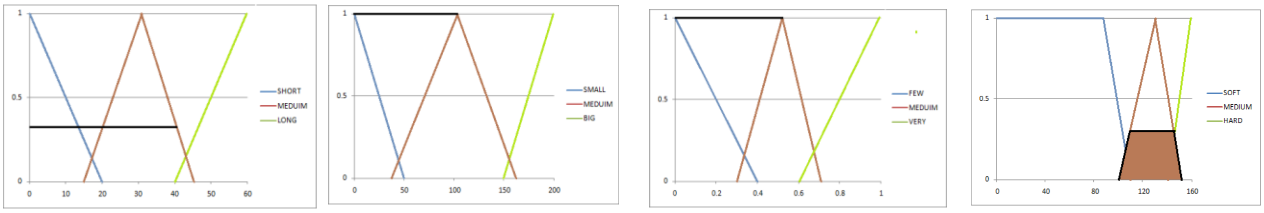
12. If Time is **MEDIUM** and Size is **SMALL** and Hardness is **BIG** then Fire is **SOFT**



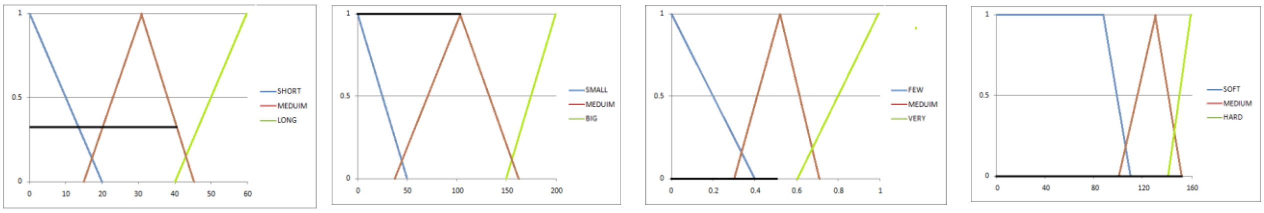
13. If Time is **MEDIUM** and Size is **MEDIUM** and Hardness is **FEW** then Fire is **MEDIUM**



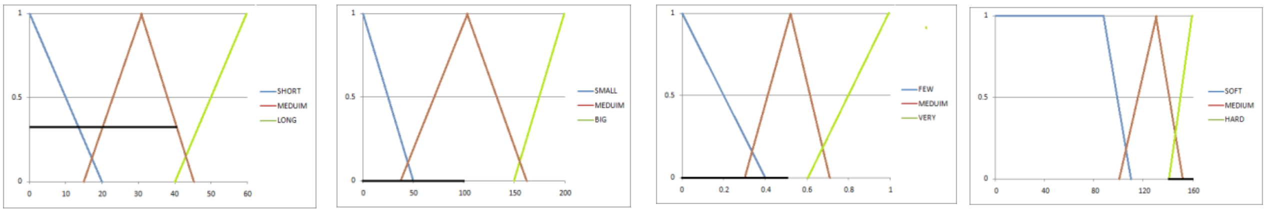
14. If Time is **MEDIUM** and Size is **MEDIUM** and Hardness is **MEDIUM** then Fire is **MEDIUM**



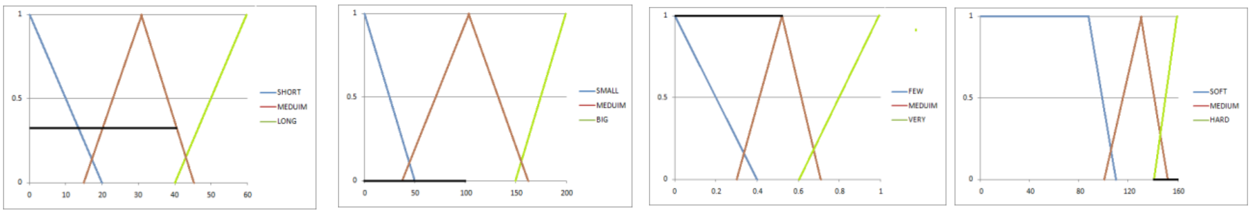
15. If Time is **MEDIUM** and Size is **MEDIUM** and Hardness is **BIG** then Fire is **MEDIUM**



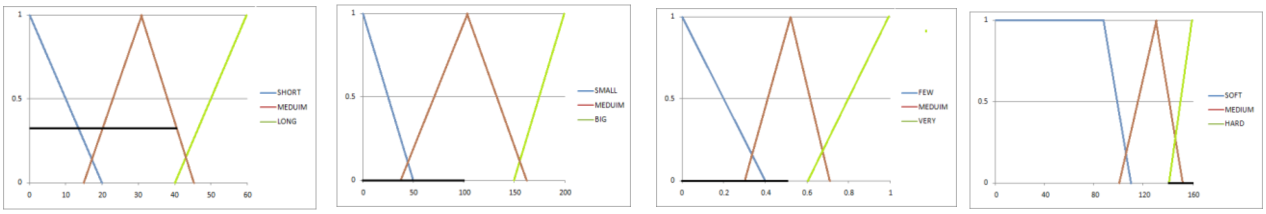
16. If Time is **MEDIUM** and Size is **BIG** and Hardness is **FEW** then Fire is **HARD**



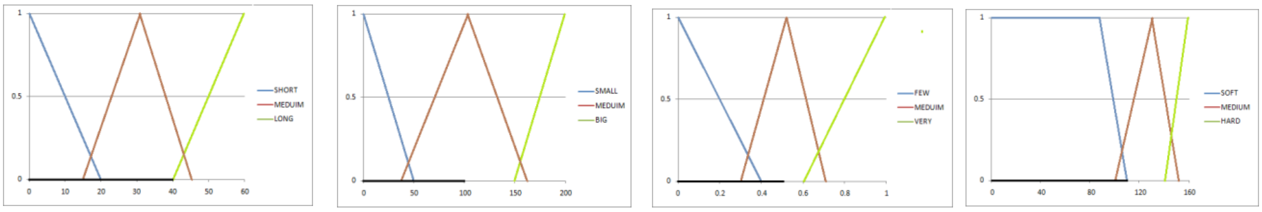
17. If Time is **MEDIUM** and Size is **BIG** and Hardness is **MEDIUM** then Fire is **HARD**



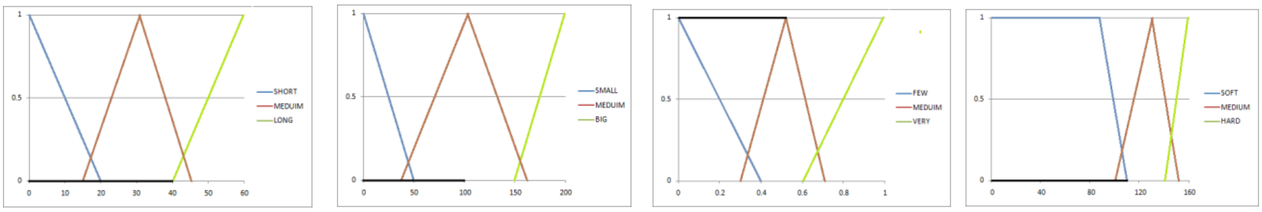
18. If Time is **MEDIUM** and Size is **BIG** and Hardness is **BIG** then Fire is **HARD**



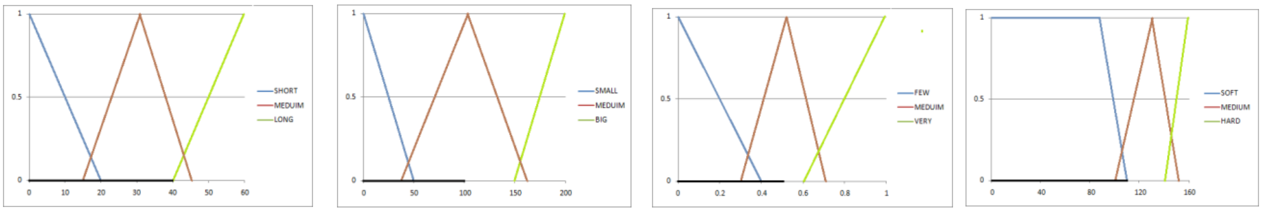
19. If Time is **LONG** and Size is **SMALL** and Hardness is **FEW** then Fire is **SOFT**



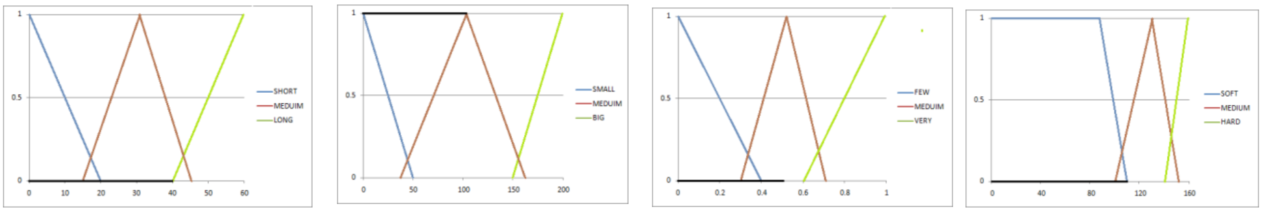
20. If Time is **LONG** and Size is **SMALL** and Hardness is **MEDIUM** then Fire is **SOFT**



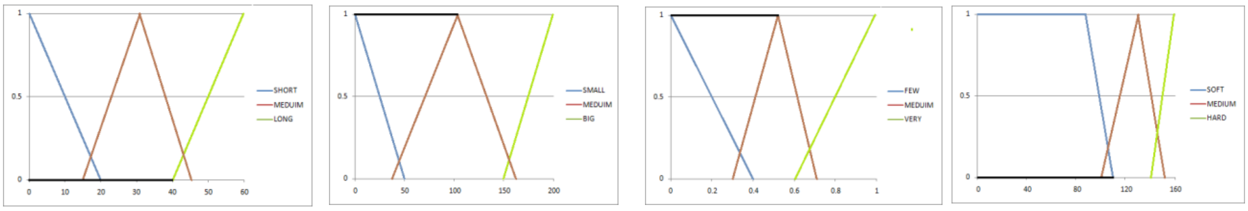
21. If Time is **LONG** and Size is **SMALL** and Hardness is **BIG** then Fire is **SOFT**



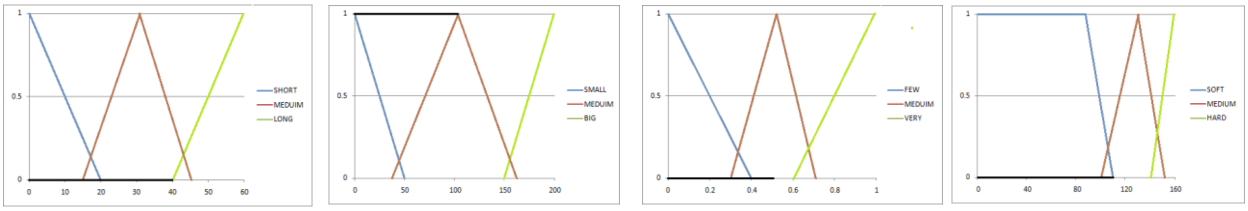
22. If Time is **LONG** and Size is **MEDIUM** and Hardness is **FEW** then Fire is **SOFT**



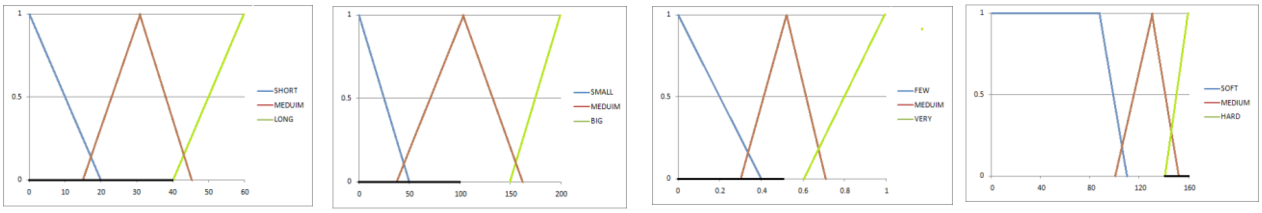
23. If Time is **LONG** and Size is **MEDIUM** and Hardness is **MEDIUM** then Fire is **SOFT**



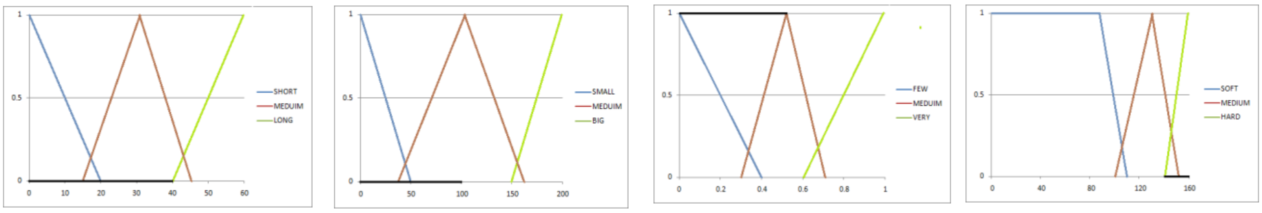
24. If Time is **LONG** and Size is **MEDIUM** and Hardness is **BIG** then Fire is **SOFT**



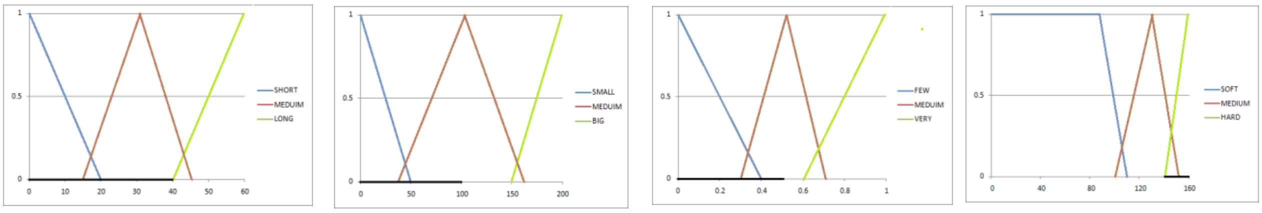
25. If Time is **LONG** and Size is **BIG** and Hardness is **FEW** then Fire is **HARD**



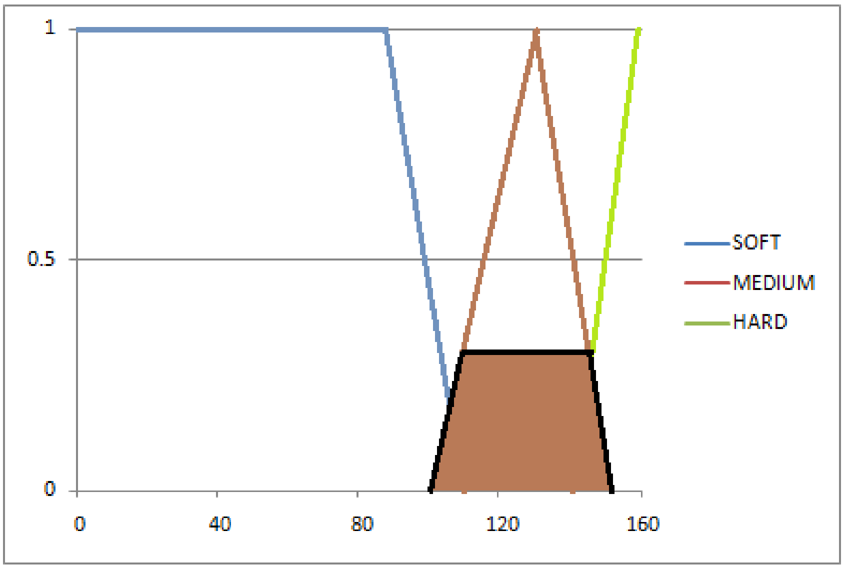
26. If Time is **LONG** and Size is **BIG** and Hardness is **MEDIUM** then Fire is **HARD**



27. If Time is **LONG** and Size is **BIG** and Hardness is **BIG** then Fire is **HARD**



Output ที่ได้



จากนั้นทำ defuzzification โดยการหา centroid

ซึ่งได้ค่าความแรงของไฟ = 124.99999999999984 °c

การทดลอง

ให้ Input Time = 20, Size = 190, Hardness = 0.9

Output fire = 151.81632653061232 °c

ให้ Input Time = 40, Size = 100, Hardness = 0.5

Output fire = 124.99999999999984 °c

ให้ Input Time = 41, Size = 150, Hardness = 0.5

Output fire = 95.14259453781511 °c

วิเคราะห์ผลการทดลอง

จากการทดลองโดยการปรับค่า เวลาที่จะใช้ (Time), ขนาดของเนื้อ(Size), ความแข็งของเนื้อ (Hardness) คำตอบที่ได้นั้นเป็นไปตามกฎที่ได้ตั้งไว้ข้างต้น ซึ่งกฎนี้สามารถปรับเปลี่ยนได้ตามความเหมาะสม

Code (https://github.com/porpeeranut/Computational_Intelligence_Assignment2)

```
//          Main.java

import java.util.ArrayList;
import java.util.HashMap;


public class Main {


        public static void main(String[] args) {
                HashMap<Enum, Graph> mfTime = new HashMap<Enum, Graph>();
                mfTime.put(TimeLevel.SHORT, new Graph(0, 20));
                mfTime.put(TimeLevel.MEDIUM, new Graph(15, 45));
                mfTime.put(TimeLevel.LONG, new Graph(40, 60));

                HashMap<Enum, Graph> mfSize = new HashMap<Enum, Graph>();
                mfSize.put(SizeLevel.SMALL, new Graph(0, 50));
                mfSize.put(SizeLevel.MEDIUM, new Graph(40, 160));
                mfSize.put(SizeLevel.BIG, new Graph(150, 200));

                HashMap<Enum, Graph> mfHardness = new HashMap<Enum, Graph>();
                mfHardness.put(HardnessLevel.FEW, new Graph(0, 0.4));
                mfHardness.put(HardnessLevel.MEDIUM, new Graph(0.3, 0.7));
                mfHardness.put(HardnessLevel.VERY, new Graph(0.6, 1));

                HashMap<Enum, Graph> mfFire = new HashMap<Enum, Graph>();
                mfFire.put(FireLevel.SOFT, new Graph(90, 110));
                mfFire.put(FireLevel.MEDIUM, new Graph(100, 150));
                mfFire.put(FireLevel.HARD, new Graph(140, 160));



                HashMap<Fuzzy, Data> input = new HashMap<Fuzzy, Data>() ;
                input.put(Fuzzy.TIME, new Data(mfTime, new Range(0, 60, 1)));
                input.put(Fuzzy.SIZE, new Data(mfSize, new Range(0, 200, 1)));
                input.put(Fuzzy.HARDNESS, new Data(mfHardness, new Range(0, 1, 0.05)));

                HashMap<Fuzzy, Data> output = new HashMap<Fuzzy, Data>();
                output.put(Fuzzy.FIRE, new Data(mfFire, new Range(0, 160, 1)));

                ArrayList<Rule> rules = new ArrayList<Rule>();
                /*addRule(TimeLevel.SHORT, SizeLevel.SMALL, HardnessLevel.FEW, FireLevel.SOFT, rules);
```

```
addRule(TimeLevel.SHORT, SizeLevel.SMALL, HardnessLevel.MEDIUM, FireLevel.MEDIUM, rules);
addRule(TimeLevel.SHORT, SizeLevel.SMALL, HardnessLevel.VERY, FireLevel.MEDIUM, rules);
addRule(TimeLevel.SHORT, SizeLevel.MEDIUM, HardnessLevel.FEW, FireLevel.MEDIUM, rules);
addRule(TimeLevel.SHORT, SizeLevel.MEDIUM, HardnessLevel.MEDIUM, FireLevel.HARD, rules);
addRule(TimeLevel.SHORT, SizeLevel.MEDIUM, HardnessLevel.VERY, FireLevel.HARD, rules);
addRule(TimeLevel.SHORT, SizeLevel.BIG, HardnessLevel.FEW, FireLevel.MEDIUM, rules);
addRule(TimeLevel.SHORT, SizeLevel.BIG, HardnessLevel.MEDIUM, FireLevel.HARD, rules);
addRule(TimeLevel.SHORT, SizeLevel.BIG, HardnessLevel.VERY, FireLevel.HARD, rules);

addRule(TimeLevel.MEDIUM, SizeLevel.SMALL, HardnessLevel.FEW, FireLevel.SOFT, rules);
addRule(TimeLevel.MEDIUM, SizeLevel.SMALL, HardnessLevel.MEDIUM, FireLevel.SOFT, rules);
addRule(TimeLevel.MEDIUM, SizeLevel.SMALL, HardnessLevel.VERY, FireLevel.MEDIUM, rules);
addRule(TimeLevel.MEDIUM, SizeLevel.MEDIUM, HardnessLevel.FEW, FireLevel.SOFT, rules);
addRule(TimeLevel.MEDIUM, SizeLevel.MEDIUM, HardnessLevel.MEDIUM, FireLevel.MEDIUM, rules);
addRule(TimeLevel.MEDIUM, SizeLevel.MEDIUM, HardnessLevel.VERY, FireLevel.HARD, rules);
addRule(TimeLevel.MEDIUM, SizeLevel.BIG, HardnessLevel.FEW, FireLevel.MEDIUM, rules);
addRule(TimeLevel.MEDIUM, SizeLevel.BIG, HardnessLevel.MEDIUM, FireLevel.HARD, rules);
addRule(TimeLevel.MEDIUM, SizeLevel.BIG, HardnessLevel.VERY, FireLevel.HARD, rules);

addRule(TimeLevel.LONG, SizeLevel.SMALL, HardnessLevel.FEW, FireLevel.SOFT, rules);
addRule(TimeLevel.LONG, SizeLevel.SMALL, HardnessLevel.MEDIUM, FireLevel.SOFT, rules);
addRule(TimeLevel.LONG, SizeLevel.SMALL, HardnessLevel.VERY, FireLevel.MEDIUM, rules);
addRule(TimeLevel.LONG, SizeLevel.MEDIUM, HardnessLevel.FEW, FireLevel.SOFT, rules);
addRule(TimeLevel.LONG, SizeLevel.MEDIUM, HardnessLevel.MEDIUM, FireLevel.SOFT, rules);
addRule(TimeLevel.LONG, SizeLevel.MEDIUM, HardnessLevel.VERY, FireLevel.MEDIUM, rules);
addRule(TimeLevel.LONG, SizeLevel.BIG, HardnessLevel.FEW, FireLevel.MEDIUM, rules);
addRule(TimeLevel.LONG, SizeLevel.BIG, HardnessLevel.MEDIUM, FireLevel.MEDIUM, rules);
addRule(TimeLevel.LONG, SizeLevel.BIG, HardnessLevel.VERY, FireLevel.HARD, rules);*/

addRule(TimeLevel.SHORT, SizeLevel.SMALL, HardnessLevel.FEW, FireLevel.SOFT, rules);
addRule(TimeLevel.SHORT, SizeLevel.SMALL, HardnessLevel.MEDIUM, FireLevel.SOFT, rules);
addRule(TimeLevel.SHORT, SizeLevel.SMALL, HardnessLevel.VERY, FireLevel.SOFT, rules);
addRule(TimeLevel.SHORT, SizeLevel.MEDIUM, HardnessLevel.FEW, FireLevel.HARD, rules);
addRule(TimeLevel.SHORT, SizeLevel.MEDIUM, HardnessLevel.MEDIUM, FireLevel.HARD, rules);
addRule(TimeLevel.SHORT, SizeLevel.MEDIUM, HardnessLevel.VERY, FireLevel.HARD, rules);
addRule(TimeLevel.SHORT, SizeLevel.BIG, HardnessLevel.FEW, FireLevel.HARD, rules);
addRule(TimeLevel.SHORT, SizeLevel.BIG, HardnessLevel.MEDIUM, FireLevel.HARD, rules);
addRule(TimeLevel.SHORT, SizeLevel.BIG, HardnessLevel.VERY, FireLevel.HARD, rules);

addRule(TimeLevel.MEDIUM, SizeLevel.SMALL, HardnessLevel.FEW, FireLevel.SOFT, rules);
```

```
        addRule(TimeLevel.MEDIUM, SizeLevel.SMALL, HardnessLevel.MEDIUM, FireLevel.SOFT, rules);
        addRule(TimeLevel.MEDIUM, SizeLevel.SMALL, HardnessLevel.VERY, FireLevel.SOFT, rules);
        addRule(TimeLevel.MEDIUM, SizeLevel.MEDIUM, HardnessLevel.FEW, FireLevel.MEDIUM, rules);
        addRule(TimeLevel.MEDIUM, SizeLevel.MEDIUM, HardnessLevel.MEDIUM, FireLevel.MEDIUM, rules);
        addRule(TimeLevel.MEDIUM, SizeLevel.MEDIUM, HardnessLevel.VERY, FireLevel.MEDIUM, rules);
        addRule(TimeLevel.MEDIUM, SizeLevel.BIG, HardnessLevel.FEW, FireLevel.HARD, rules);
        addRule(TimeLevel.MEDIUM, SizeLevel.BIG, HardnessLevel.MEDIUM, FireLevel.HARD, rules);
        addRule(TimeLevel.MEDIUM, SizeLevel.BIG, HardnessLevel.VERY, FireLevel.HARD, rules);

        addRule(TimeLevel.LONG, SizeLevel.SMALL, HardnessLevel.FEW, FireLevel.SOFT, rules);
        addRule(TimeLevel.LONG, SizeLevel.SMALL, HardnessLevel.MEDIUM, FireLevel.SOFT, rules);
        addRule(TimeLevel.LONG, SizeLevel.SMALL, HardnessLevel.VERY, FireLevel.SOFT, rules);
        addRule(TimeLevel.LONG, SizeLevel.MEDIUM, HardnessLevel.FEW, FireLevel.SOFT, rules);
        addRule(TimeLevel.LONG, SizeLevel.MEDIUM, HardnessLevel.MEDIUM, FireLevel.SOFT, rules);
        addRule(TimeLevel.LONG, SizeLevel.MEDIUM, HardnessLevel.VERY, FireLevel.SOFT, rules);
        addRule(TimeLevel.LONG, SizeLevel.BIG, HardnessLevel.FEW, FireLevel.HARD, rules);
        addRule(TimeLevel.LONG, SizeLevel.BIG, HardnessLevel.MEDIUM, FireLevel.HARD, rules);
        addRule(TimeLevel.LONG, SizeLevel.BIG, HardnessLevel.VERY, FireLevel.HARD, rules);



        SteakFuzzyLogic steakFuzzy = new SteakFuzzyLogic(input, output, rules);
        //System.out.println(steakFuzzy.defuz(20, 190, 0.9)+" °c\n"); //> 150
        //System.out.println(steakFuzzy.defuz(40, 100, 0.5)+" °c\n"); //>124
        System.out.println(steakFuzzy.defuz(41, 150, 0.9)+" °c\n"); //>95
    }

    static void addRule(TimeLevel tLevel, SizeLevel sLevel, HardnessLevel hLevel, FireLevel fLevel, ArrayList<Rule>
rules) {
        ArrayList<RuleData> ifRule = new ArrayList<RuleData>();
        ifRule.add(new RuleData(Fuzzy.TIME, tLevel));
        ifRule.add(new RuleData(Fuzzy.SIZE, sLevel));
        ifRule.add(new RuleData(Fuzzy.HARDNESS, hLevel));

        RuleData thenRule = new RuleData(Fuzzy.FIRE, fLevel);
        rules.add(new Rule(ifRule, thenRule));
    }
}
```

```
//    SteakFuzzyLogic.java
import java.util.ArrayList;
import java.util.HashMap;
import java.util.Map.Entry;

public class SteakFuzzyLogic {

    HashMap<Fuzzy, Data> input;
    HashMap<Fuzzy, Data> output;
    ArrayList<Rule> rules;
    double maxFireSoft = 0;
    double maxFireMed = 0;
    double maxFireHard = 0;

    public SteakFuzzyLogic(HashMap<Fuzzy, Data> input, HashMap<Fuzzy, Data> output, ArrayList<Rule> rules) {
        this.input = input;
        this.output = output;
        this.rules = rules;
    }

    double defuz(double time, double size, double hardness) {
        maxFireSoft = 0;
        maxFireMed = 0;
        maxFireHard = 0;
        int r = 1;
        boolean debug = false;
        for(Rule rule : rules) {
            double minInRule = 1;
            if (debug) {
                System.out.print ("#"+r+" ");
            }
            for(RuleData ruleData : rule.ifRule) {
                //    ifRule.add(new RuleData(Fuzzy.TIME, TimeLevel.SHORT));
                //    input.put(Fuzzy.TIME, new Data(mfTime, new Range(0, 60, 1)));
                double tmp = 0;
                if (ruleData.fuzzy == Fuzzy.TIME) {
                    if (ruleData.level == TimeLevel.SHORT) {
                        tmp =
input.get(Fuzzy.TIME).mf.get(TimeLevel.SHORT).getFuzzyValDown(time);
                        if (debug) {
                            System.out.print ("SHORT->"+tmp);
                        }
                    } else if (ruleData.level == TimeLevel.MEDIUM) {
                        tmp =
input.get(Fuzzy.TIME).mf.get(TimeLevel.MEDIUM).getFuzzyValTriangle(time);
                        if (debug) {
                            System.out.print ("MED->"+tmp);
                        }
                    } else if (ruleData.level == TimeLevel.LONG) {
                        tmp =
input.get(Fuzzy.TIME).mf.get(TimeLevel.LONG).getFuzzyValUp(time);
                        if (debug) {
                            System.out.print ("LONG->"+tmp);
                        }
                    }
                } else if (ruleData.fuzzy == Fuzzy.SIZE) {
                    if (ruleData.level == SizeLevel.SMALL) {
                        tmp =
input.get(Fuzzy.SIZE).mf.get(SizeLevel.SMALL).getFuzzyValDown(size);
                        if (debug) {
                            System.out.print (" SMALL->"+tmp);
                        }
                    } else if (ruleData.level == SizeLevel.MEDIUM) {
                        tmp =
input.get(Fuzzy.SIZE).mf.get(SizeLevel.MEDIUM).getFuzzyValTriangle(size);
                        if (debug) {
                            System.out.print (" MED->"+tmp);
                        }
                    } else if (ruleData.level == SizeLevel.BIG) {
                        tmp =
input.get(Fuzzy.SIZE).mf.get(SizeLevel.BIG).getFuzzyValUp(size);
                        if (debug) {
                            System.out.print (" BIG->"+tmp);
                        }
                    }
                } else if (ruleData.fuzzy == Fuzzy.HARDNESS) {
                    if (ruleData.level == HardnessLevel.FEW) {
                        tmp =
input.get(Fuzzy.HARDNESS).mf.get(HardnessLevel.FEW).getFuzzyValDown(hardness);
                        if (debug) {
                            System.out.print (" FEW->"+tmp);
                        }
                    } else if (ruleData.level == HardnessLevel.MEDIUM) {
                        tmp =
input.get(Fuzzy.HARDNESS).mf.get(HardnessLevel.MEDIUM).getFuzzyValTriangle(hardness);
                        if (debug) {
                            System.out.print (" MED->"+tmp);
                        }
                    } else if (ruleData.level == HardnessLevel.VERY) {
                        tmp =
input.get(Fuzzy.HARDNESS).mf.get(HardnessLevel.VERY).getFuzzyValUp(hardness);
                        if (debug) {
                            System.out.print (" VERY->"+tmp);
                        }
                    }
                }
                /*for (int i = 0;i < tmp * 100.0;i++) {
                    System.out.print("*");
                }
                System.out.println("*");*/


                if (minInRule > tmp && tmp >= 0)
                    minInRule = tmp;
            }

            if (rule.thenRule.level == FireLevel.SOFT) {
                if (debug) {
                    System.out.println(" soft = "+minInRule);
                }
                if (maxFireSoft < minInRule)
                    maxFireSoft = minInRule;
            } else if (rule.thenRule.level == FireLevel.MEDIUM) {
                if (debug) {
                    System.out.println(" med = "+minInRule);
                }
                if (maxFireMed < minInRule)
                    maxFireMed = minInRule;
            } else if (rule.thenRule.level == FireLevel.HARD) {
                if (debug) {
                        System.out.println(" heig = "+minInRule);
                }
                if (maxFireHard < minInRule)
                        maxFireHard = minInRule;
        }
        r++;
}
if (debug) {
        System.out.println(maxFireSoft);
        System.out.println(maxFireMed);
        System.out.println(maxFireHard);
}

double start = output.get(Fuzzy.FIRE).range.start;
double end = output.get(Fuzzy.FIRE).range.end;
double step = output.get(Fuzzy.FIRE).range.step;
double startSoft = output.get(Fuzzy.FIRE).mf.get(FireLevel.SOFT).x_start;
double endSoft = output.get(Fuzzy.FIRE).mf.get(FireLevel.SOFT).x_end;
double startMed = output.get(Fuzzy.FIRE).mf.get(FireLevel.MEDIUM).x_start;
double endMed = output.get(Fuzzy.FIRE).mf.get(FireLevel.MEDIUM).x_end;
double startHard = output.get(Fuzzy.FIRE).mf.get(FireLevel.HARD).x_start;
double endHard = output.get(Fuzzy.FIRE).mf.get(FireLevel.HARD).x_end;

double sum1 = 0;
double sum2 = 0;
for (double x = start;x <= end;x += step) {
        double ySoft = 0;
        double yMed = 0;
        double yHard = 0;
        if (x <= endSoft) {
                ySoft = output.get(Fuzzy.FIRE).mf.get(FireLevel.SOFT).getFuzzyValDown(x);
                if (ySoft > maxFireSoft)
                        ySoft = maxFireSoft;
        }
        if (x >= startMed && x <= endMed) {
                yMed = output.get(Fuzzy.FIRE).mf.get(FireLevel.MEDIUM).getFuzzyValTriangle(x);
                if (yMed > maxFireMed)
                        yMed = maxFireMed;
        }
        if (x >= startHard) {
                yHard = output.get(Fuzzy.FIRE).mf.get(FireLevel.HARD).getFuzzyValUp(x);
                if (yHard > maxFireHard)
                    yHard = maxFireHard;
            }

            double max = max(ySoft, yMed, yHard);
            /*for (int i = 0;i < max * 100.0;i++) {
                System.out.print(" ");
            }
            System.out.println("*");*/
            sum1 += max*x;
            sum2 += max;
        }
        if (sum2 == 0)
            sum2 = 1;
        return sum1/sum2;
    }

    double max(double ySoft, double yMed, double yHard) {
        if (ySoft > yMed) {
            if (ySoft > yHard)
                return ySoft;
            else
                return yHard;
        } else {
            if (yMed > yHard)
                return yMed;
            else
                return yHard;
        }
    }
}
```

```
//          Graph.java
import java.util.ArrayList;
import java.util.Map.Entry;
public class Graph {
        public double x_start;
        public double x_end;
        public Graph(double x_start, double x_end) {
                this.x_start = x_start;
                this.x_end = x_end;
        }
        double getFuzzyValDown(double x) {
                double m = (1/(x_start-x_end));
                double c = -m*x_end;
                double y = m*x + c;
                return (y > 1) ? 1 : (y < 0) ? 0 : y;
        }
        double getFuzzyValTriangle(double x) {
                double center = x_start+(x_end-x_start)/2.0;
                if (x < center) {
                        double x_end = center;
                        double m = (-1/(x_start-x_end));
                        double c = -m*x_start;
                        double y = m*x + c;
                        return (y > 1) ? 1 : (y < 0) ? 0 : y;
                } else {
                        double x_start = center;
                        double m = (1/(x_start-x_end));
                        double c = -m*x_end;
                        double y = m*x + c;
                        return (y > 1) ? 1 : (y < 0) ? 0 : y;
                }
        }
        double getFuzzyValUp(double x) {
                double m = (-1/(x_start-x_end));
                double c = -m*x_start;
                double y = m*x + c;

                return (y > 1) ? 1 : (y < 0) ? 0 : y;
        }
}
```

```java
//          Data.java
import java.util.HashMap;


public class Data {

        Enum fuzzy;
        public HashMap<Enum, Graph> mf;
        public Range range;

        public Data(HashMap<Enum, Graph> mf, Range range) {
                //this.fuzzy = fuzzy;
                this.mf = mf;
                this.range = range;
        }
}

//          TimeLevel.java
public enum TimeLevel {
        SHORT, MEDIUM, LONG
}

//          SizeLevel.java
public enum SizeLevel {
        SMALL, MEDIUM, BIG
}

//          HardnessLevel.java
public enum HardnessLevel {
        FEW, MEDIUM, VERY
}

//          FireLevel.java
public enum FireLevel {
        SOFT, MEDIUM, HARD
}

//          Fuzzy.java
public enum Fuzzy {
        TIME, SIZE, HARDNESS, FIRE
}
```

```
//      Range.java
public class Range {

        double start;
        double end;
        double step;

        public Range(double start, double end, double step) {
                this.start = start;
                this.end = end;
                this.step = step;
        }
}
```

```
//      Rule.java
import java.util.ArrayList;
import java.util.Map.Entry;

public class Rule {

        public ArrayList<RuleData> ifRule;
        public RuleData thenRule;

        public Rule(ArrayList<RuleData> ifRule, RuleData thenRule) {
                this.ifRule = ifRule;
                this.thenRule = thenRule;
        }
}
```

```
//      RuleData.java
RuleDatapublic class RuleData {

        public Enum fuzzy;
        public Enum level;

        public RuleData(Enum fuzzy, Enum level) {
                this.fuzzy = fuzzy;
                this.level = level;
        }
}
```