

INFO-6205

Fall 2023 Project

Fibonacci = Pythagoras

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Introduction:

Aim of the project:

- In this project we use the Fibonacci numbers video by mathologer as a base with the following goals in mind.
- We are to build a tree of Pythagorean triples. For example, 3, 4, 5 or 5, 12, 13..
- The next part would include building a (lazy) tree of Rational Number pairs as described in the video. Given a sequence of branches from the root of the tree {3,4,5}, you should be able to return either a Pythagorean triple or a pair of Rationonals.

Program:

1. Base code:

Here in the fibonacci number we make use of the notation using u and v as mentioned by the professor. Thus in each node of the tree we will have two variables u and v with the Fibonacci box given by: [v-u, u , v , v+u]

The base class for each node looks like this:

```
public class Node {  
  
    // Value of that particular node  
    public int v,u;  
    public int level;  
    // Three nodes representing the three branches of the tree  
    public Node left;  
    public Node mid;  
    public Node right;  
    // Supplier for lazy printing of node  
    private Supplier<String> rSupplier;  
    private Supplier<String> pSupplier;  
    // Functional interfaces for lazy evaluation  
    private Supplier<Double> aSupplier;  
    private Supplier<Double> bSupplier;
```

```

// Getter and setter methods

// Functional interfaces for lazy evaluation
public Node() {
    // Initialize lazy printing of rational and pythagorean
    rSupplier = () -> "("+(this.v - this.u)+"/ "+(this.v + this.u)+"," +u +"/"+v+"")";
    pSupplier = () -> "{"+(this.v*this.v) - (this.u*this.u))+"," +(2*this.u*this.v)+"," +(this.u*(this.v+this.u)
+this.v*(this.v-this.u))+"}";

    // Initialize lazy evaluation for a and b of rational
    aSupplier = () -> (v - u) / (double) (v + u);
    bSupplier = () -> u / (double) v;
}

// Getter for lazy-printed rational
public String getRationalLazy() {
    return rSupplier.get();
}

// Getter for lazy-evaluated rational
public double getRationalALazy() {
    return aSupplier.get();
}

// Getter for lazy-evaluated rational
public double getRationalBALazy() {
    return bSupplier.get();
}

// Getter for lazy-printed pythagorean
public String getPythagoreanLazy() {
    return pSupplier.get();
}
}

```

Here we make use of the supplier class for lazy evaluation of the Rational numbers and Pythagorean Triples.

Tree Traversal:

The goal of this is to traverse a tree given a array of string which represent a path on the tree and output the resultant Pythagorean triple or Rational numbers or Fibonacci box.

Code snippet:

```
public String pythagoreanTraversal(List<String> path){  
    if (path == null || path.size() <= 0 || path.size() > height) return "";  
  
    Node curNode = root;  
    String res = "";  
    for(String i : path){  
        if(i == "l") curNode = curNode.left;  
        else if (i == "m") curNode = curNode.mid;  
        else if (i == "r") curNode = curNode.right;  
    }  
  
    res = "["+((curNode.v*curNode.v) - (curNode.u*curNode.u))+","+(2*curNode.u*curNode.v)+","+(  
    (curNode.u*(curNode.v+curNode.u)+curNode.v*(curNode.v-curNode.u))+""]";  
  
    return res;  
}
```

Generate the values of Pythagorean/Rational tree values :

To output the values of the tree we make use of a BFS approach. Printing the values level by level.

Code Snippet:

```
public void pythagoreanBFS(Node tree){  
  
    res = "";  
    if(tree == null) return ;
```

```

List<Node> queue = new ArrayList<>();
queue.add(tree);
while(!queue.isEmpty()){
    Node temp = queue.remove(0);
    res = res + temp.getPythagoreanLazy()+", ";
    if(temp.getLeft() != null) {
        queue.add(temp.getLeft());
        queue.add(temp.getMid());
        queue.add(temp.getRight());
    }
}
}

```

2. Unit test:

We have added unit tests for testing the generation of the Fibonacci tree, Pythagorean Triples and Rational Number. We have also added the testing for Tree traversal given a path.

Fibonacci Test File:

```

@Test
public void baseCase0(){

    FibonacciSquares test = new FibonacciSquares();
    test.generateSquares(0);
    String exp = "[1,1,2,3], ";
    assertEquals(exp,test.treeBFS());
    System.out.println("Expected: "+exp+"\nRecieved:"+test.treeBFS());
}

@Test
public void baseCaseN(){

    FibonacciSquares test = new FibonacciSquares();

```

```

    test.generateSquares(3);

    String exp = "[1,1,2,3], [3,1,4,5], [3,2,5,7], [1,2,3,5], [5,1,6,7], [5,4,9,13], [3,4,7,11], [7,2,9,11],
[7,5,12,17], [3,5,8,13], [5,2,7,9], [5,3,8,11], [1,3,4,7], [7,1,8,9], [7,6,13,19], [5,6,11,17], [13,4,17,21],
[13,9,22,31], [5,9,14,23], [11,4,15,19], [11,7,18,25], [3,7,10,17], [11,2,13,15], [11,9,20,29], [7,9,16,25],
[17,5,22,27], [17,12,29,41], [7,12,19,31], [13,5,18,23], [13,8,21,29], [3,8,11,19], [9,2,11,13], [9,7,16,23],
[5,7,12,19], [11,3,14,17], [11,8,19,27], [5,8,13,21], [7,3,10,13], [7,4,11,15], [1,4,5,9], ";

    assertEquals(exp,test.treeBFS());

    System.out.println("Expected: "+exp+"\nRecieved:"+test.treeBFS());

}

```

Pythagorean Triples:

```

@Test
public void baseCase0(){

    PythagoreanTriples t = new PythagoreanTriples();
    String genRes = t.generateTriples(0);
    String exp = "{3,4,5}, ";
    assertEquals(genRes, exp);

}

@Test
public void baseCaseN(){

    PythagoreanTriples t = new PythagoreanTriples();
    String genRes = t.generateTriples(3);
    String exp = "{3,4,5}, {15,8,17}, {21,20,29}, {5,12,13}, {35,12,37}, {65,72,97}, {33,56,65}, {77,36,85},
{119,120,169}, {39,80,89}, {45,28,53}, {55,48,73}, {7,24,25}, {63,16,65}, {133,156,205}, {85,132,157},
{273,136,305}, {403,396,565}, {115,252,277}, {209,120,241}, {275,252,373}, {51,140,149}, {165,52,173},
{319,360,481}, {175,288,337}, {459,220,509}, {697,696,985}, {217,456,505}, {299,180,349},
{377,336,505}, {57,176,185}, {117,44,125}, {207,224,305}, {95,168,193}, {187,84,205}, {297,304,425},
{105,208,233}, {91,60,109}, {105,88,137}, {9,40,41}, ";
    assertEquals(genRes, exp);

}

```

Rational Numbers:

```
@Test
public void baseCase0(){

    RationalPairs p = new RationalPairs();
    String genRes = (p.generatePairs(0));
    String exp = "(1/3, 1/2), ";

    assertEquals(genRes, exp);
}

@Test
public void baseCase1(){

    RationalPairs p = new RationalPairs();
    String genRes = (p.generatePairs(3));
    String exp = "(1/3, 1/2), (3/5, 1/4), (3/7, 2/5), (1/5, 2/3), (5/7, 1/6), (5/13, 4/9), (3/11, 4/7), (7/11, 2/9),
(7/17, 5/12), (3/13, 5/8), (5/9, 2/7), (5/11, 3/8), (1/7, 3/4), (7/9, 1/8), (7/19, 6/13), (5/17, 6/11), (13/21, 4/17),
(13/31, 9/22), (5/23, 9/14), (11/19, 4/15), (11/25, 7/18), (3/17, 7/10), (11/15, 2/13), (11/29, 9/20), (7/25,
9/16), (17/27, 5/22), (17/41, 12/29), (7/31, 12/19), (13/23, 5/18), (13/29, 8/21), (3/19, 8/11), (9/13, 2/11),
(9/23, 7/16), (5/19, 7/12), (11/17, 3/14), (11/27, 8/19), (5/21, 8/13), (7/13, 3/10), (7/15, 4/11), (1/9, 4/5), ";

    assertEquals(genRes, exp);
}
```

Tree Traversal :

```
@Test
public void baseCase0(){

    Traversal t = new Traversal(4);
    List<String> path = new ArrayList<>();
    path.add("l");
    path.add("m");
```

```
String rec = t.getNode(path);
String exp = "[13,9,4,5]";

assertEquals(exp, rec);

}

@Test
public void baseCase1(){

    Traversal t = new Traversal(4);
    List<String> path = new ArrayList<>();
    path.add("l");
    path.add("m");
    path.add("r");
    String rec = t.getNode(path);
    String exp = "[23,14,9,5];

    assertEquals(exp, rec);

}

@Test
public void errorCase0(){

    // Length of path > Height of generated tree
    Traversal t = new Traversal(4);
    List<String> path = new ArrayList<>();
    path.add("l");
    path.add("m");
    path.add("r");
    path.add("l");
    path.add("m");
    path.add("r");
    String rec = t.getNode(path);
    String exp = "";

}
```

```
        assertEquals(exp, rec);

    }

@Test
public void pythagoreanTraversalErrorTest(){

    // Length of path > Height of generated tree
    Traversal t = new Traversal(4);
    List<String> path = new ArrayList<>();
    path.add("l");
    path.add("m");
    path.add("r");
    path.add("l");
    path.add("m");
    path.add("r");
    String rec = t.pythagoreanTraversal(path);
    String exp = "";

    assertEquals(exp, rec);

}

@Test
public void pythagoreanTraversalTest0(){

    Traversal t = new Traversal(4);
    List<String> path = new ArrayList<>();
    path.add("l");
    path.add("m");
    String rec = t.pythagoreanTraversal(path);
    String exp = "[65,72,97]";

    assertEquals(exp, rec);
```

```
}

@Test
public void rationalTraversalErrorTest(){

    // Length of path > Height of generated tree
    Traversal t = new Traversal(4);
    List<String> path = new ArrayList<>();
    path.add("l");
    path.add("m");
    path.add("r");
    path.add("l");
    path.add("m");
    path.add("r");
    String rec = t.rationalTraversal(path);
    String exp = "";

    assertEquals(exp, rec);

}

@Test
public void rationalTraversalTest0(){

    Traversal t = new Traversal(4);
    List<String> path = new ArrayList<>();
    path.add("l");
    path.add("m");
    String rec = t.rationalTraversal(path);
    String exp = "(5/13, 4/9)";

    assertEquals(exp, rec);

}
```

3.Output:

Output generated for 6 levels:

FibonacciSquares:

[1,1,2,3], [3,1,4,5], [3,2,5,7], [1,2,3,5], [5,1,6,7], [5,4,9,13], [3,4,7,11], [7,2,9,11], [7,5,12,17], [3,5,8,13], [5,2,7,9], [5,3,8,11], [1,3,4,7], [7,1,8,9],
[7,6,13,19], [5,6,11,17], [13,4,17,21], [13,9,22,31], [5,9,14,23], [11,4,15,19], [11,7,18,25], [3,7,10,17], [11,2,13,15], [11,9,20,29], [7,9,16,25], [17,5,22,27],
[17,12,29,41], [7,12,19,31], [13,5,18,23], [13,8,21,29], [3,8,11,19], [9,2,11,13], [9,7,16,23], [5,7,12,19], [11,3,14,17], [11,8,19,27], [5,8,13,21], [7,3,10,13],
[7,4,11,15], [1,4,5,9], [9,1,10,11], [9,8,17,25], [7,8,15,23], [19,6,25,31], [19,13,32,45], [7,13,20,33], [17,6,23,29], [17,11,28,39], [5,11,16,27], [21,4,25,29],
[21,17,38,55], [13,17,30,47], [31,9,40,49], [31,22,53,75], [13,22,35,57], [23,9,32,41], [23,14,37,51], [5,14,19,33], [19,4,23,27], [19,15,34,49], [11,15,26,41],
[25,7,32,39], [25,18,43,61], [11,18,29,47], [17,7,24,31], [17,10,27,37], [3,10,13,23], [15,2,17,19], [15,13,28,41], [11,13,24,37], [29,9,38,47], [29,20,49,69],
[11,20,31,51], [25,9,34,43], [25,16,41,57], [7,16,23,39], [27,5,32,37], [27,22,49,71], [17,22,39,61], [41,12,53,65], [41,29,70,99], [17,29,46,75],
[31,12,43,55], [31,19,50,69], [7,19,26,45], [23,5,28,33], [23,18,41,59], [13,18,31,49], [29,8,37,45], [29,21,50,71], [13,21,34,55], [19,8,27,35], [19,11,30,41],
[3,11,14,25], [13,2,15,17], [13,11,24,35], [9,11,20,31], [23,7,30,37], [23,16,39,55], [9,16,25,41], [19,7,26,33], [19,12,31,43], [5,12,17,29], [17,3,20,23],
[17,14,31,45], [11,14,25,39], [27,8,35,43], [27,19,46,65], [11,19,30,49], [21,8,29,37], [21,13,34,47], [5,13,18,31], [13,3,16,19], [13,10,23,33], [7,10,17,27],
[15,4,19,23], [15,11,26,37], [7,11,18,29], [9,4,13,17], [9,5,14,19], [1,5,6,11], [11,1,12,13], [11,10,21,31], [9,10,19,29], [25,8,33,41], [25,17,42,59], [9,17,26,43],
[23,8,31,39], [23,15,38,53], [7,15,22,37], [31,6,37,43], [31,25,56,81], [19,25,44,69], [45,13,58,71], [45,32,77,109], [19,32,51,83], [33,13,46,59],
[33,20,53,73], [7,20,27,47], [29,6,35,41], [29,23,52,75], [17,23,40,63], [39,11,50,61], [39,28,67,95], [17,28,45,73], [27,11,38,49], [27,16,43,59],
[5,16,21,37], [29,4,33,37], [29,25,54,79], [21,25,46,71], [55,17,72,89], [55,38,93,131], [21,38,59,97], [47,17,64,81], [47,30,77,107], [13,30,43,73],
[49,9,58,67], [49,40,89,129], [31,40,71,111], [75,22,97,119], [75,53,128,181], [31,53,84,137], [57,22,79,101], [57,35,92,127], [13,35,48,83], [41,9,50,59],
[41,32,73,105], [23,32,55,87], [51,14,65,79], [51,37,88,125], [23,37,60,97], [33,14,47,61], [33,19,52,71], [5,19,24,43], [27,4,31,35], [27,23,50,73],
[19,23,42,65], [49,15,64,79], [49,34,83,117], [19,34,53,87], [41,15,56,71], [41,26,67,93], [11,26,37,63], [39,7,46,53], [39,32,71,103], [25,32,57,89],
[61,18,79,97], [61,43,104,147], [25,43,68,111], [47,18,65,83], [47,29,76,105], [11,29,40,69], [31,7,38,45], [31,24,55,79], [17,24,41,65], [37,10,47,57],
[37,27,64,91], [17,27,44,71], [23,10,33,43], [23,13,36,49], [3,13,16,29], [19,2,21,23], [19,17,36,53], [15,17,32,49], [41,13,54,67], [41,28,69,97],
[15,28,43,71], [37,13,50,63], [37,24,61,85], [11,24,35,59], [47,9,56,65], [47,38,85,123], [29,38,67,105], [69,20,89,109], [69,49,118,167], [29,49,78,127],
[51,20,71,91], [51,31,82,113], [11,31,42,73], [43,9,52,61], [43,34,77,111], [25,34,59,93], [57,16,73,89], [57,41,98,139], [25,41,66,107], [39,16,55,71],
[39,23,62,85], [7,23,30,53], [37,5,42,47], [37,32,69,101], [27,32,59,91], [71,22,93,115], [71,49,120,169], [27,49,76,125], [61,22,83,105], [61,39,100,139],
[17,39,56,95], [65,12,77,89], [65,53,118,171], [41,53,94,147], [99,29,128,157], [99,70,169,239], [41,70,111,181], [75,29,104,133], [75,46,121,167],
[17,46,63,109], [55,12,67,79], [55,43,98,141], [31,43,74,117], [69,19,88,107], [69,50,119,169], [31,50,81,131], [45,19,64,83], [45,26,71,97], [7,26,33,59],
[33,5,38,43], [33,28,61,89], [23,28,51,79], [59,18,77,95], [59,41,100,141], [23,41,64,105], [49,18,67,85], [49,31,80,111], [13,31,44,75], [45,8,53,61],
[45,37,82,119], [29,37,66,103], [71,21,92,113], [71,50,121,171], [29,50,79,129], [55,21,76,97], [55,34,89,123], [13,34,47,81], [35,8,43,51], [35,27,62,89],
[19,27,46,73], [41,11,52,63], [41,30,71,101], [19,30,49,79], [25,11,36,47], [25,14,39,53], [3,14,17,31], [17,2,19,21], [17,15,32,47], [13,15,28,43], [35,11,46,57],
[35,24,59,83], [13,24,37,61], [31,11,42,53], [31,20,51,71], [9,20,29,49], [37,7,44,51], [37,30,67,97], [23,30,53,83], [55,16,71,87], [55,39,94,133],
[23,39,62,101], [41,16,57,73], [41,25,66,91], [9,25,34,59], [33,7,40,47], [33,26,59,85], [19,26,45,71], [43,12,55,67], [43,31,74,105], [19,31,50,81],
[29,12,41,53], [29,17,46,63], [5,17,22,39], [23,3,26,29], [23,20,43,63], [17,20,37,57], [45,14,59,73], [45,31,76,107], [17,31,48,79], [39,14,53,67],
[39,25,64,89], [11,25,36,61], [43,8,51,59], [43,35,78,113], [27,35,62,97], [65,19,84,103], [65,46,111,157], [27,46,73,119], [49,19,68,87], [49,30,79,109],
[11,30,41,71], [37,8,45,53], [37,29,66,95], [21,29,50,79], [47,13,60,73], [47,34,81,115], [21,34,55,89], [31,13,44,57], [31,18,49,67], [5,18,23,41],
[19,3,22,25], [19,16,35,51], [13,16,29,45], [33,10,43,53], [33,23,56,79], [13,23,36,59], [27,10,37,47], [27,17,44,61], [7,17,24,41], [23,4,27,31],
[23,19,42,61], [15,19,34,53], [37,11,48,59], [37,26,63,89], [15,26,41,67], [29,11,40,51], [29,18,47,65], [7,18,25,43], [17,4,21,25], [17,13,30,43],
[9,13,22,35], [19,5,24,29], [19,14,33,47], [9,14,23,37], [11,5,16,21], [11,6,17,23], [1,6,7,13], [13,1,14,15], [13,12,25,37], [11,12,23,35], [31,10,41,51],
[31,21,52,73], [11,21,32,53], [29,10,39,49], [29,19,48,67], [9,19,28,47], [41,8,49,57], [41,33,74,107], [25,33,58,91], [59,17,76,93], [59,42,101,143],
[25,42,67,109], [43,17,60,77], [43,26,69,95], [9,26,35,61], [39,8,47,55], [39,31,70,101], [23,31,54,85], [53,15,68,83], [53,38,91,129], [23,38,61,99],
[37,15,52,67], [37,22,59,81], [7,22,29,51], [43,6,49,55], [43,37,80,117], [31,37,68,105], [81,25,106,131], [81,56,137,193], [31,56,87,143], [69,25,94,119]

[69,44,113,157], [19,44,63,107], [71,13,84,97], [71,58,129,187], [45,58,103,161], [109,32,141,173], [109,77,186,263], [45,77,122,199], [83,32,115,147],
[83,51,134,185], [19,51,70,121], [59,13,72,85], [59,46,105,151], [33,46,79,125], [73,20,93,113], [73,53,126,179], [33,53,86,139], [47,20,67,87],
[47,27,74,101], [7,27,34,61], [41,6,47,53], [41,35,76,111], [29,35,64,99], [75,23,98,121], [75,52,127,179], [29,52,81,133], [63,23,86,109], [63,40,103,143],
[17,40,57,97], [61,11,72,83], [61,50,111,161], [39,50,89,139], [95,28,123,151], [95,67,162,229], [39,67,106,173], [73,28,101,129], [73,45,118,163],
[17,45,62,107], [49,11,60,71], [49,38,87,125], [27,38,65,103], [59,16,75,91], [59,43,102,145], [27,43,70,113], [37,16,53,69], [37,21,58,79], [5,21,26,47],
[37,4,41,45], [37,33,70,103], [29,33,62,95], [79,25,104,129], [79,54,133,187], [29,54,83,137], [71,25,96,121], [71,46,117,163], [21,46,67,113],
[89,17,106,123], [89,72,161,233], [55,72,127,199], [131,38,169,207], [131,93,224,317], [55,93,148,241], [97,38,135,173], [97,59,156,215], [21,59,80,139],
[81,17,98,115], [81,64,145,209], [47,64,111,175], [107,30,137,167], [107,77,184,261], [47,77,124,201], [73,30,103,133], [73,43,116,159], [13,43,56,99],
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[37,14,51,65], [37,23,60,83], [9,23,32,55], [21,5,26,31], [21,16,37,53], [11,16,27,43], [23,6,29,35], [23,17,40,57], [11,17,28,45], [13,6,19,25], [13,7,20,27],
[1,7,8,15].

Pythagorean Triples for 6 levels:

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{407,624,745}, {1363,684,1525}, {2001,1960,2801}, {561,1240,1361}, {1075,612,1237}, {1425,1312,1937}, {273,736,785}, {999,320,1049}, {1917,2156,2885}, {1037,1716,2005}, {2665,1272,2953}, {4059,4060,5741}, {1275,2668,2957}, {1705,1032,1993}, {2139,1900,2861}, {315,988,1037}, {759,280,809}, {1357,1476,2005}, {637,1116,1285}, {1305,592,1433}, {2059,2100,2941}, {715,1428,1597}, {665,432,793}, {779,660,1021}, {75,308,317}, {221,60,229}, {455,528,697}, {279,440,521}, {851,420,949}, {1265,1248,1777}, {369,800,881}, {627,364,725}, {817,744,1105}, {145,408,433}, {391,120,409}, {765,868,1157}, {429,700,821}, {1161,560,1289}, {1755,1748,2477}, {539,1140,1261}, {777,464,905}, {987,884,1325}, {155,468,493}, {247,96,265}, {429,460,629}, {189,340,389}, {345,152,377}, {555,572,797}, {203,396,445}, {153,104,185}, {171,140,221}, {11,60,61}, {143,24,145}, {341,420,541}, {261,380,461}, {1025,528,1153}, {1475,1428,2053}, {387,884,965}, {897,496,1025}, {1219,1140,1669}, {259,660,709}, {1333,444,1405}, 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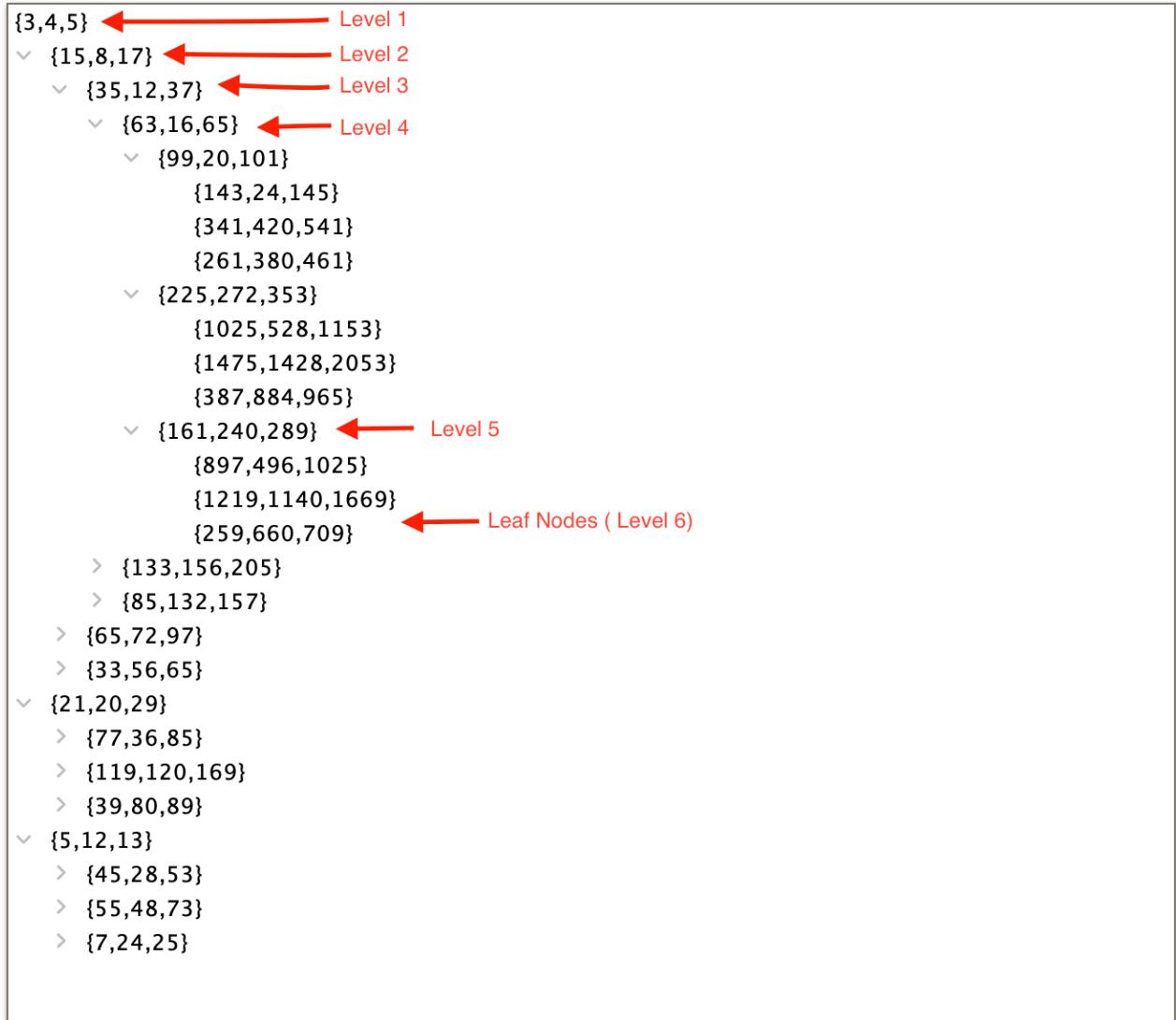
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Tree Visualization:

Collapsed view of a 6 layer tree



Pythagorean Triple Tree (n = 6)

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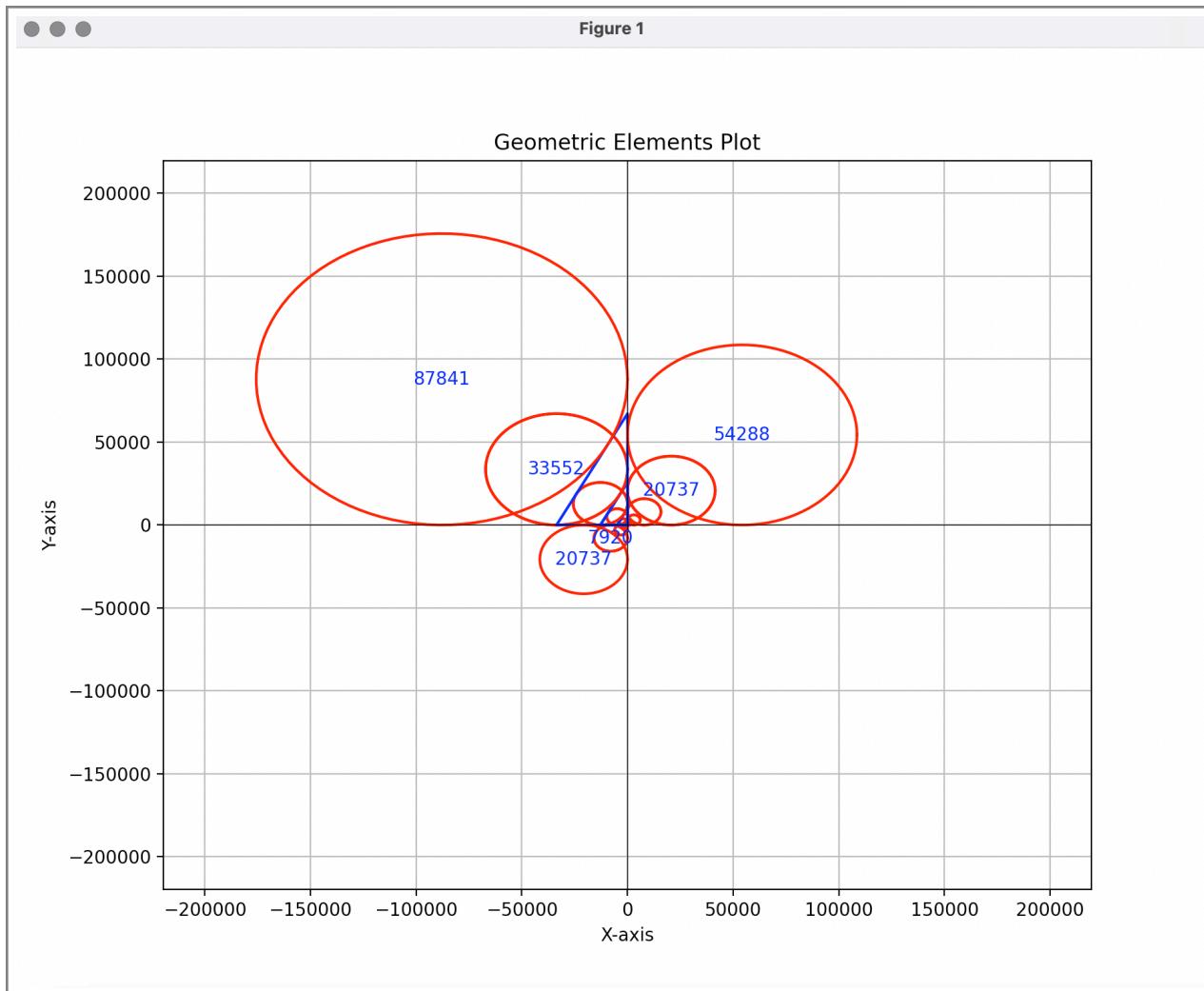
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(17/79, 31/48)
 - ▽ (11/39, 14/25)
 - (39/67, 14/53)
(39/89, 25/64)
(11/61, 25/36)
 - ▽ (11/27, 8/19)
 - ▽ (27/43, 8/35)
 - (43/59, 8/51)
(43/113, 35/78)
(27/97, 35/62)
 - ▽ (27/65, 19/46)
 - (65/103, 19/84)
(65/157, 46/111)
(27/119, 46/73)
 - ▽ (11/49, 19/30)
 - (49/87, 19/68)
(49/109, 30/79)
(11/71, 30/41)
 - ▽ (5/21, 8/13)
 - ▽ (21/37, 8/29)
 - (37/53, 8/45)
(37/95, 29/66)
(21/79, 29/50)
 - ▽ (21/47, 13/34)
 - (47/73, 13/60)
(47/115, 34/81)
(21/89, 34/55)
 - ▽ (5/31, 13/18)
 - (31/57, 13/44)
(31/67, 18/49)

-
- (5/41, 18/23)
- ▽ (1/7, 3/4)
 - ▽ (7/13, 3/10)
 - ▽ (13/19, 3/16)
 - (19/25, 3/22)
 - (19/51, 16/35)
 - (13/45, 16/29)
 - ▽ (13/33, 10/23)
 - (33/53, 10/43)
 - (33/79, 23/56)
 - (13/59, 23/36)
 - ▽ (7/27, 10/17)
 - (27/47, 10/37)
 - (27/61, 17/44)
 - (7/41, 17/24)
 - ▽ (7/15, 4/11)
 - ▽ (15/23, 4/19)
 - (23/31, 4/27)
 - (23/61, 19/42)
 - (15/53, 19/34)
 - ▽ (15/37, 11/26)
 - (37/59, 11/48)
 - (37/89, 26/63)
 - (15/67, 26/41)
 - ▽ (7/29, 11/18)
 - (29/51, 11/40)
 - (29/65, 18/47)
 - (7/43, 18/25)
 - ▽ (1/9, 4/5)
 - ▽ (9/17, 4/13)
 - (17/25, 4/21)
 - (17/43, 13/30)
 - (9/35, 13/22)
 - ▽ (9/19, 5/14)
 - (19/29, 5/24)
 - (19/47, 14/33)
 - (9/37, 14/23)
 - ▽ (1/11, 5/6)
 - (11/21, 5/16)
 - (11/23, 6/17)
 - (1/13, 6/7)

Collapsed View:

- | | |
|---|----------------|
| | (1/3, 1/2) |
| ▽ | (3/5, 1/4) |
| ▽ | (5/7, 1/6) |
| ▽ | (7/9, 1/8) |
| ▽ | (9/11, 1/10) |
| | (11/13, 1/12) |
| | (11/31, 10/21) |
| | (9/29, 10/19) |
| > | (9/25, 8/17) |
| > | (7/23, 8/15) |
| > | (7/19, 6/13) |
| > | (5/17, 6/11) |
| > | (5/13, 4/9) |
| > | (3/11, 4/7) |
| > | (3/7, 2/5) |
| > | (1/5, 2/3) |

Exocircle Visualisation:



Bonus Task:

Induction Proof :

To be proven:

$$F_n * F_{n+2} + F_{n+1} * F_{n+3} = F_{2n+4}$$

Step 1:

Consider n = 2

$$\begin{aligned} F_2 * F_4 + F_3 * F_5 \\ = 2 * 5 + 3 * 8 \\ = 34 = F_8 \end{aligned}$$

Hence the equation to be proven holds true for our base case n = 2

Step 2:

Consider for some value n the equation holds true
Thus we can write it as:

$$F_n * F_{n+2} + F_{n+1} * F_{n+3} = F_{2n+4} \quad \text{----- Eq 1}$$

To prove the equation we must show that if for some value of n the equation holds true then it holds true for n+1

Step 3:

The equation for n+1 :

$$F_{n+1} * F_{n+3} + F_{n+2} * F_{n+4} = F_{2n+6} \quad \text{----- Eq 2}$$

For any given value of n in the fibonacci series we know that :

$$F_n = F_{n-2} + F_{n-1} \quad \text{----- Eq 3}$$

$$F_n^2 + 2 * F_n * F_{n+1} + 2 * F_{n+1}^2 = F_{2n+4} \quad \text{----- Eq 4 **}$$

Using this in equation 2 LHS

$$\begin{aligned} & F_{n+1} * (F_{n+1} + F_{n+2}) + F_{n+2} * (F_{n+2} + F_{n+3}) \\ &= F_{n+1}^2 + F_{n+1} * F_{n+2} + F_{n+2}^2 + F_{n+2} * F_{n+3} \\ &= F_{n+1}^2 + F_{n+1} * F_{n+2} + F_{n+2}^2 + F_{n+2} * (F_{n+1} + F_{n+2}) \\ &= F_{n+1}^2 + 2 * F_{n+1} * F_{n+2} + 2 * F_{n+2}^2 \\ &= F_{2n+6} \end{aligned}$$

Induction:

Thus by induction we can prove that if Equation 1 holds true for some value of n then it is also true for n+1.

Given that this Equation holds true for n = 2 as shown in Step 1 we can also state that this holds true for all values of n > 2.

This has been proven in the publication **Fibonacci Meets Pythagoras. (Link provided by the mathologer) | [Link](#) (the equation had to be modified as our values for n begin from 0 while author uses 1)