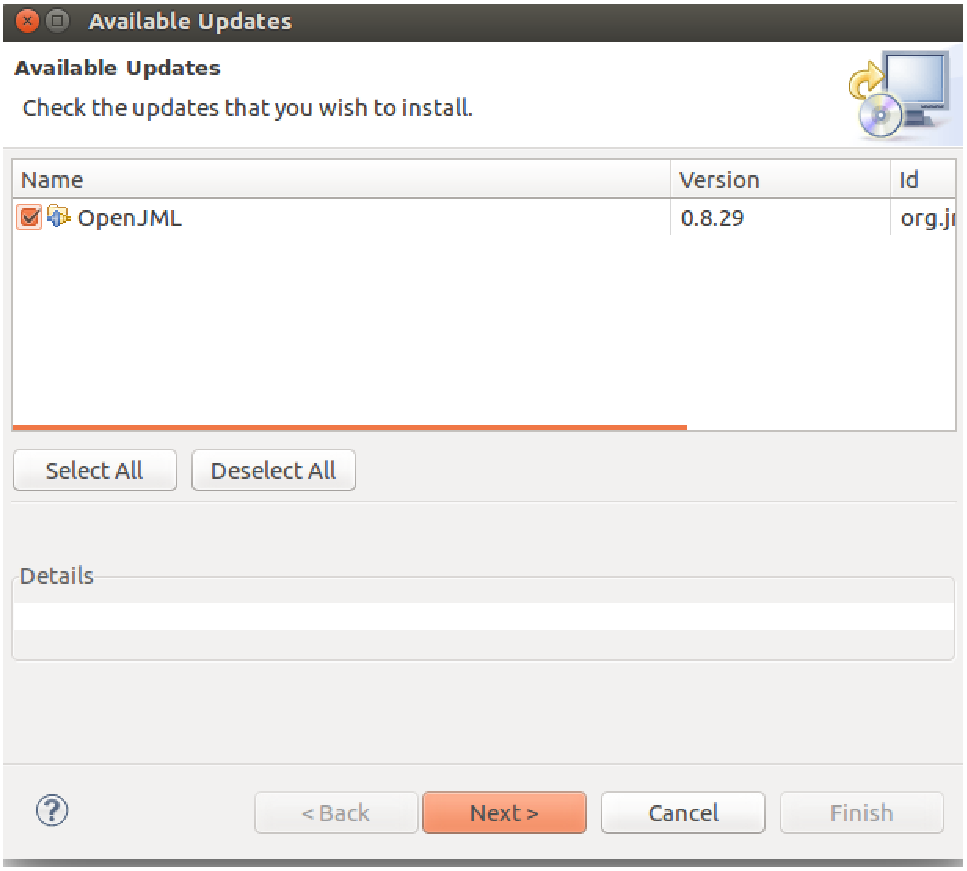
26/04/2018

OpenJML RAC Update



Available Updates

Check the updates that you wish to install.

Name	Version	Id
☑ OpenJML	0.8.29	org.jı

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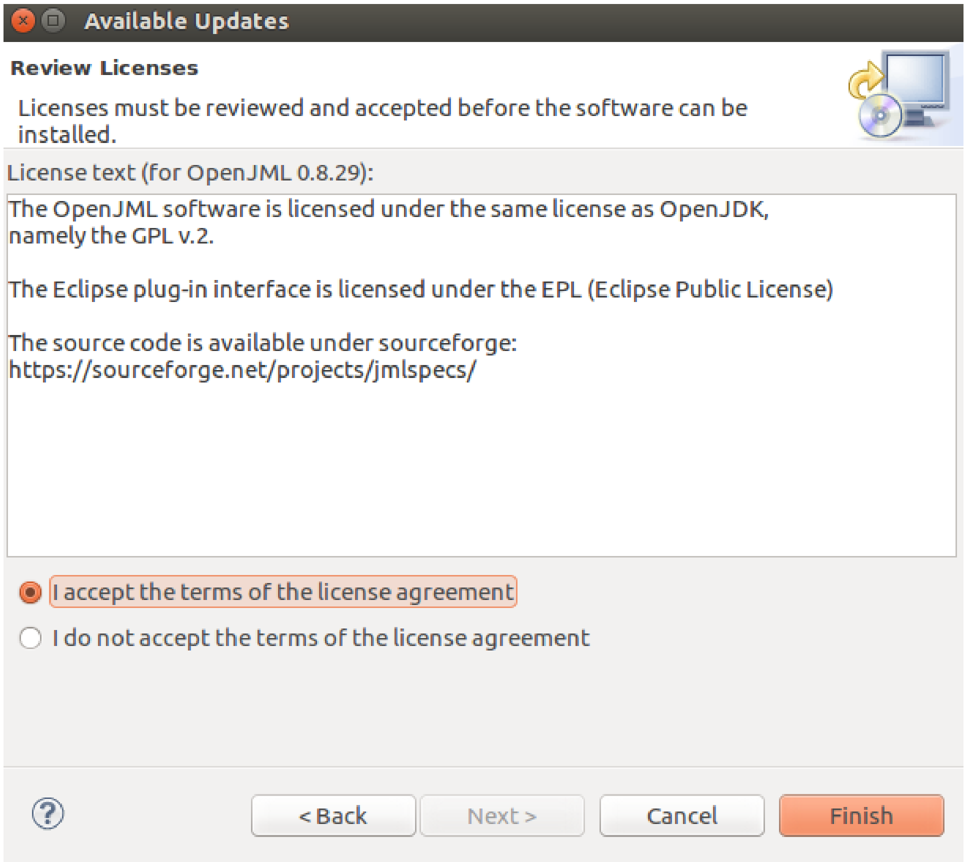

Review Licenses

Licenses must be reviewed and accepted before the software can be installed.

License text (for OpenJML 0.8.29):

The OpenJML software is licensed under the same license as OpenJDK,
namely the GPL v.2.

The Eclipse plug-in interface is licensed under the EPL (Eclipse Public License)

The source code is available under sourceforge:
https://sourceforge.net/projects/jmlspecs/

● I accept the terms of the license agreement

○ I do not accept the terms of the license agreement

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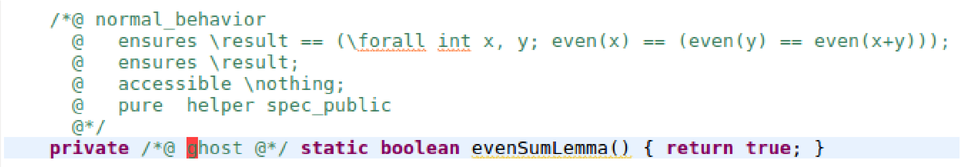
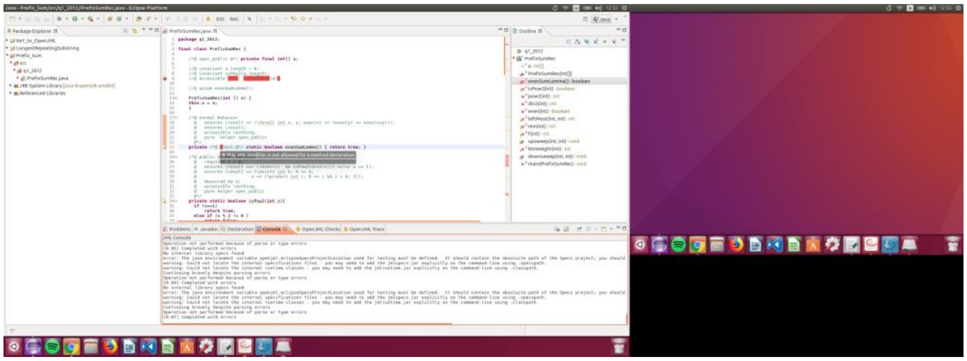
Note: the ability to use ghost methods would allow the use of Lemmas as done in KeY and Why3



```
    /*@ normal_behavior
      @   ensures \result == (\forall int x, y; even(x) == (even(y) == even(x+y)));
      @   ensures \result;
      @   accessible \nothing;
      @   pure  helper spec_public
      @*/
    private /*@ ghost @*/ static boolean evenSumLemma() { return true; }
```

Returns error: This JML modifier is not allowed for method declarations



This JML modifier is not allowed for a method declaration

```
JML Console
Operation not performed because of parse or type errors
[0.05] Completed with errors
No internal library specs found
error: The java environment variable openjml.eclipseSpecsProjectLocation used for testing must be defined.  It should contain the absolute path of the Specs project; you should
warning: Could not locate the internal specifications files - you may need to add the jmlspecs.jar explicitly on the command-line using -specspath.
warning: Could not locate the internal runtime classes - you may need to add the jmlruntime.jar explicitly on the command-line using -classpath.
Continuing bravely despite parsing errors
Operation not performed because of parse or type errors
[0.04] Completed with errors
No internal library specs found
error: The java environment variable openjml.eclipseSpecsProjectLocation used for testing must be defined.  It should contain the absolute path of the Specs project; you should
warning: Could not locate the internal specifications files - you may need to add the jmlspecs.jar explicitly on the command-line using -specspath.
warning: Could not locate the internal runtime classes - you may need to add the jmlruntime.jar explicitly on the command-line using -classpath.
Continuing bravely despite parsing errors
Operation not performed because of parse or type errors
[0.07] Completed with errors
```

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PrefixSumArray

Type-Checking

13:37: Partially converted KeY to OpenJML

- Multiple //@ not working so replaced with //@//**
- \singleton
- \infinite_union

RAC

15:36 – RAC performed

- Blue Icon:
  - Runtime assertion checking is not implemented for this type or number of declarations in a qualified expression.
  - Counterexample: No proof information available
- No Errors found

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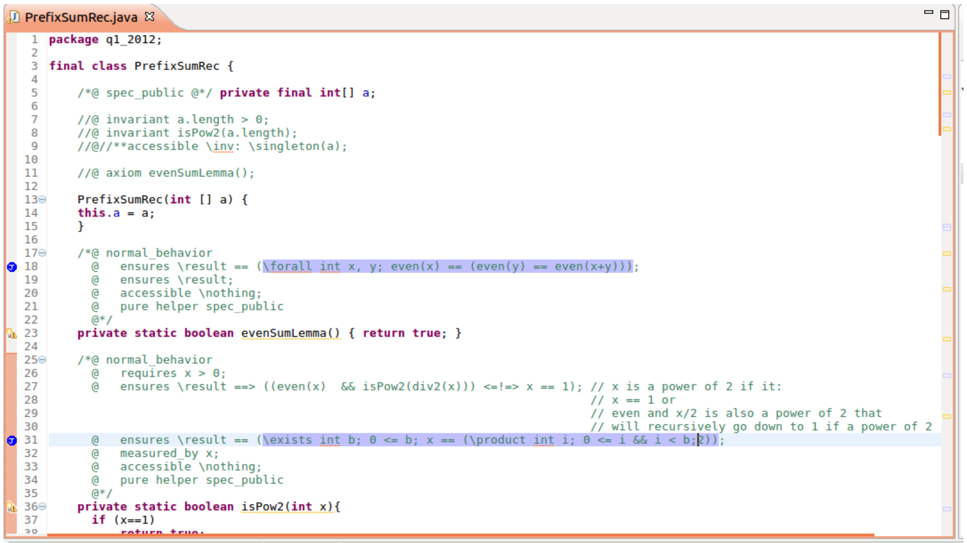
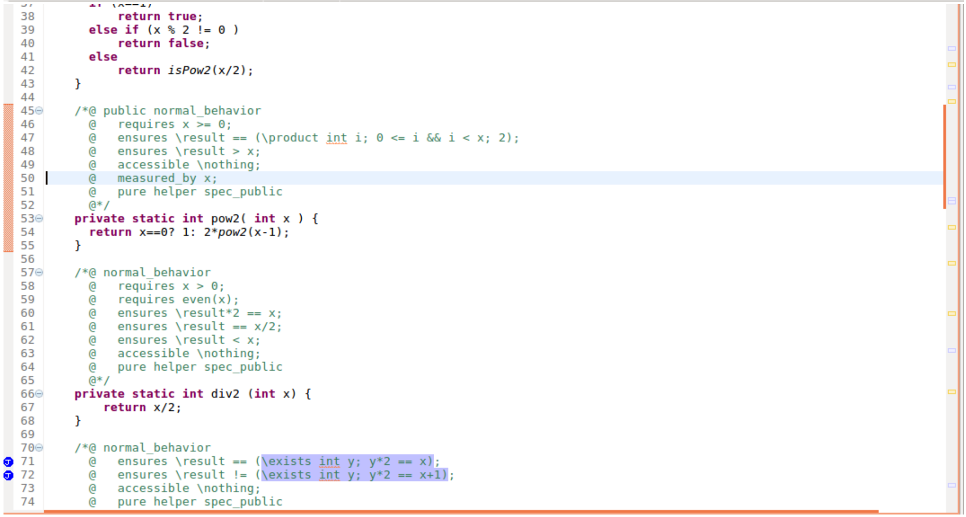
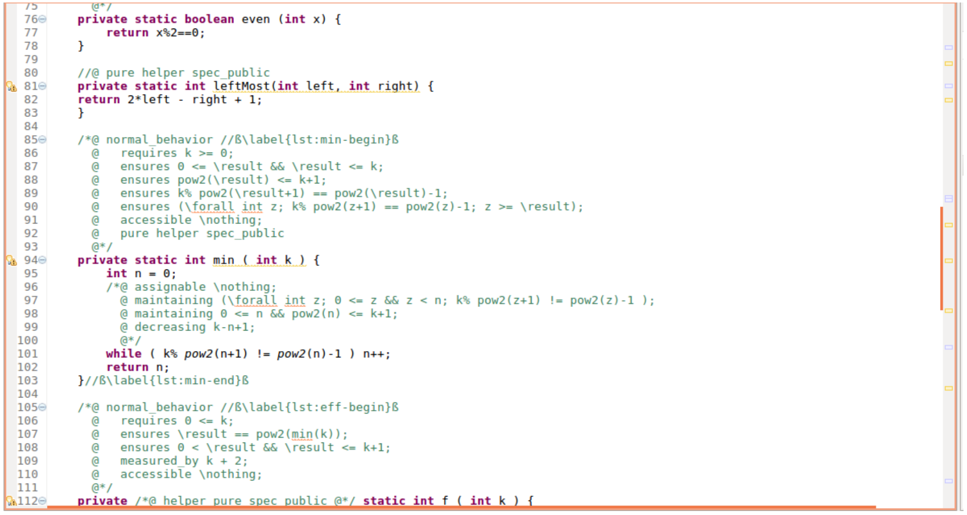


```
package q1_2012;

final class PrefixSumRec {

    /*@ spec_public @*/ private final int[] a;

    //@ invariant a.length > 0;
    //@ invariant isPow2(a.length);
    //@//**accessible \inv: \singleton(a);

    //@ axiom evenSumLemma();

    PrefixSumRec(int [] a) {
    this.a = a;
    }

    /*@ normal_behavior
      @   ensures \result == (\forall int x, y; even(x) == (even(y) == even(x+y)));
      @   ensures \result;
      @   accessible \nothing;
      @   pure helper spec_public
      @*/
    private static boolean evenSumLemma() { return true; }

    /*@ normal_behavior
      @   requires x > 0;
      @   ensures \result ==> ((even(x)  && isPow2(div2(x))) <=!=> x == 1); // x is a power of 2 if it:
                                                                            // x == 1 or
                                                                            // even and x/2 is also a power of 2 that
                                                                            // will recursively go down to 1 if a power of 2
      @   ensures \result == (\exists int b; 0 <= b; x == (\product int i; 0 <= i && i < b;2));
      @   measured_by x;
      @   accessible \nothing;
      @   pure helper spec_public
      @*/
    private static boolean isPow2(int x){
      if (x==1)
```



```
          return true;
      else if (x % 2 != 0 )
          return false;
      else
          return isPow2(x/2);
    }

    /*@ public normal_behavior
      @   requires x >= 0;
      @   ensures \result == (\product int i; 0 <= i && i < x; 2);
      @   ensures \result > x;
      @   accessible \nothing;
      @   measured_by x;
      @   pure helper spec_public
      @*/
    private static int pow2( int x ) {
      return x==0? 1: 2*pow2(x-1);
    }

    /*@ normal_behavior
      @   requires x > 0;
      @   requires even(x);
      @   ensures \result*2 == x;
      @   ensures \result == x/2;
      @   ensures \result < x;
      @   accessible \nothing;
      @   pure helper spec_public
      @*/
    private static int div2 (int x) {
        return x/2;
    }

    /*@ normal_behavior
      @   ensures \result == (\exists int y; y*2 == x);
      @   ensures \result != (\exists int y; y*2 == x+1);
      @   accessible \nothing;
      @   pure helper spec_public
```



```
      @*/
    private static boolean even (int x) {
        return x%2==0;
    }

    //@ pure helper spec_public
    private static int leftMost(int left, int right) {
    return 2*left - right + 1;
    }

    /*@ normal_behavior //ß\label{lst:min-begin}ß
      @   requires k >= 0;
      @   ensures 0 <= \result && \result <= k;
      @   ensures pow2(\result) <= k+1;
      @   ensures k% pow2(\result+1) == pow2(\result)-1;
      @   ensures (\forall int z; k% pow2(z+1) == pow2(z)-1; z >= \result);
      @   accessible \nothing;
      @   pure helper spec_public
      @*/
    private static int min ( int k ) {
        int n = 0;
        /*@ assignable \nothing;
          @ maintaining (\forall int z; 0 <= z && z < n; k% pow2(z+1) != pow2(z)-1 );
          @ maintaining 0 <= n && pow2(n) <= k+1;
          @ decreasing k-n+1;
          @*/
        while ( k% pow2(n+1) != pow2(n)-1 ) n++;
        return n;
    }//ß\label{lst:min-end}ß

    /*@ normal_behavior //ß\label{lst:eff-begin}ß
      @   requires 0 <= k;
      @   ensures \result == pow2(min(k));
      @   ensures 0 < \result && \result <= k+1;
      @   measured_by k + 2;
      @   accessible \nothing;
      @*/
    private /*@ helper pure spec_public @*/ static int f ( int k ) {
```

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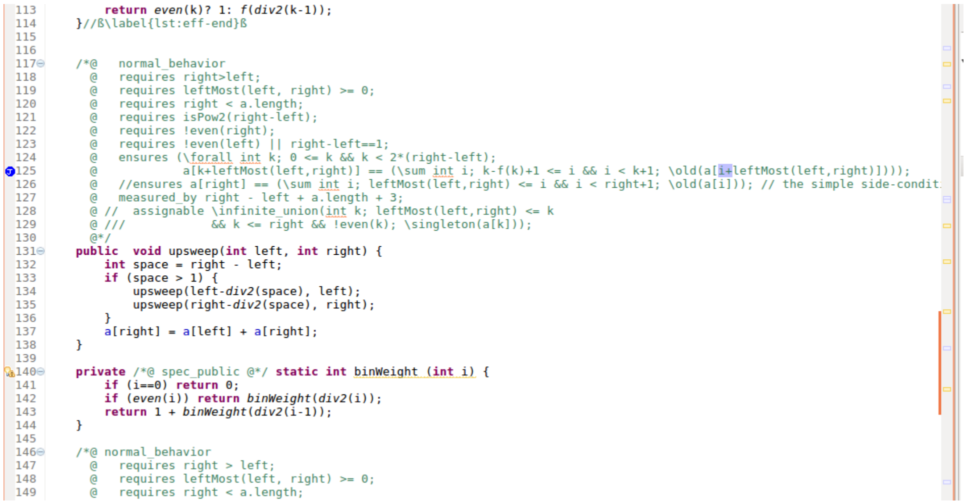
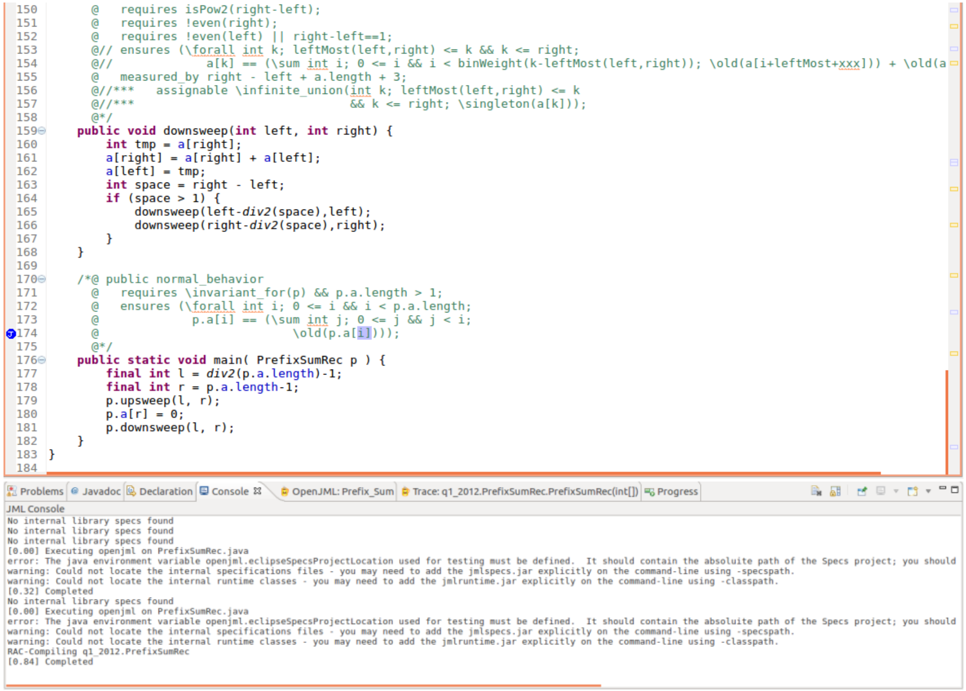


```
        return even(k)? 1: f(div2(k-1));
    }//ß\label{lst:eff-end}ß


    /*@   normal_behavior
      @   requires right>left;
      @   requires leftMost(left, right) >= 0;
      @   requires right < a.length;
      @   requires isPow2(right-left);
      @   requires !even(right);
      @   requires !even(left) || right-left==1;
      @   ensures (\forall int k; 0 <= k && k < 2*(right-left);
      @             a[k+leftMost(left,right)] == (\sum int i; k-f(k)+1 <= i && i < k+1; \old(a[i+leftMost(left,right)])));
      @   //ensures a[right] == (\sum int i; leftMost(left,right) <= i && i < right+1; \old(a[i])); // the simple side-condit
      @   measured_by right - left + a.length + 3;
      @ //  assignable \infinite_union(int k; leftMost(left,right) <= k
      @ ///            && k <= right && !even(k); \singleton(a[k]));
      @*/
    public  void upsweep(int left, int right) {
        int space = right - left;
        if (space > 1) {
            upsweep(left-div2(space), left);
            upsweep(right-div2(space), right);
        }
        a[right] = a[left] + a[right];
    }

    private /*@ spec_public @*/ static int binWeight (int i) {
        if (i==0) return 0;
        if (even(i)) return binWeight(div2(i));
        return 1 + binWeight(div2(i-1));
    }

    /*@ normal_behavior
      @   requires right > left;
      @   requires leftMost(left, right) >= 0;
      @   requires right < a.length;
```



```
      @   requires isPow2(right-left);
      @   requires !even(right);
      @   requires !even(left) || right-left==1;
      @// ensures (\forall int k; leftMost(left,right) <= k && k <= right;
      @//             a[k] == (\sum int i; 0 <= i && i < binWeight(k-leftMost(left,right)); \old(a[i+leftMost+xxx])) + \old(a
      @   measured_by right - left + a.length + 3;
      @//***   assignable \infinite_union(int k; leftMost(left,right) <= k
      @//***                          && k <= right; \singleton(a[k]));
      @*/
    public void downsweep(int left, int right) {
        int tmp = a[right];
        a[right] = a[right] + a[left];
        a[left] = tmp;
        int space = right - left;
        if (space > 1) {
            downsweep(left-div2(space),left);
            downsweep(right-div2(space),right);
        }
    }

    /*@ public normal_behavior
      @   requires \invariant_for(p) && p.a.length > 1;
      @   ensures (\forall int i; 0 <= i && i < p.a.length;
      @             p.a[i] == (\sum int j; 0 <= j && j < i;
      @                            \old(p.a[i])));
      @*/
    public static void main( PrefixSumRec p ) {
        final int l = div2(p.a.length)-1;
        final int r = p.a.length-1;
        p.upsweep(l, r);
        p.a[r] = 0;
        p.downsweep(l, r);
    }
}
```

```
No internal library specs found
No internal library specs found
No internal library specs found
[0.00] Executing openjml on PrefixSumRec.java
error: The java environment variable openjml.eclipseSpecsProjectLocation used for testing must be defined.  It should contain the absoluite path of the Specs project; you should
warning: Could not locate the internal specifications files - you may need to add the jmlspecs.jar explicitly on the command-line using -specspath.
warning: Could not locate the internal runtime classes - you may need to add the jmlruntime.jar explicitly on the command-line using -classpath.
[0.32] Completed
No internal library specs found
[0.00] Executing openjml on PrefixSumRec.java
error: The java environment variable openjml.eclipseSpecsProjectLocation used for testing must be defined.  It should contain the absoluite path of the Specs project; you should
warning: Could not locate the internal specifications files - you may need to add the jmlspecs.jar explicitly on the command-line using -specspath.
warning: Could not locate the internal runtime classes - you may need to add the jmlruntime.jar explicitly on the command-line using -classpath.
RAC-Compiling q1_2012.PrefixSumRec
[0.84] Completed
```

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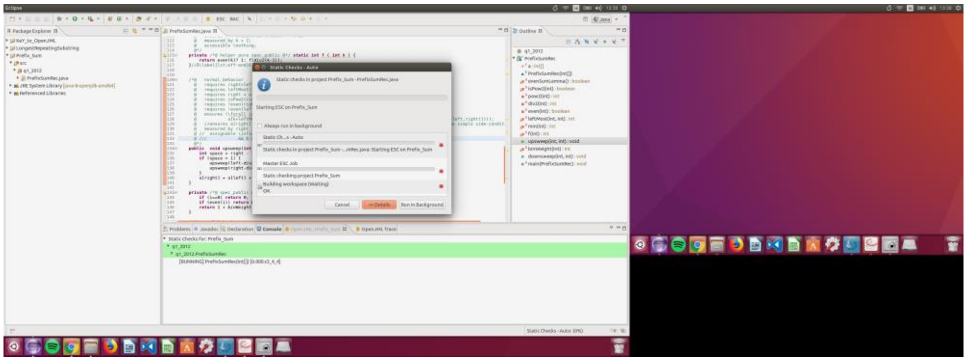
ESC

Eclipse

1. 13:38 - First Attempt at RAC/ESC on PrefixSumArray in Eclipse



Static Checks - Auto

Static checks in project Prefix_Sum - PrefixSumRec.java

Starting ESC on Prefix_Sum

☐ Always run in background

Static Ch...s - Auto

Static checks in project Prefix_Sum - ...mRec.java: Starting ESC on Prefix_Sum

Master ESC Job

Static checking project Prefix_Sum

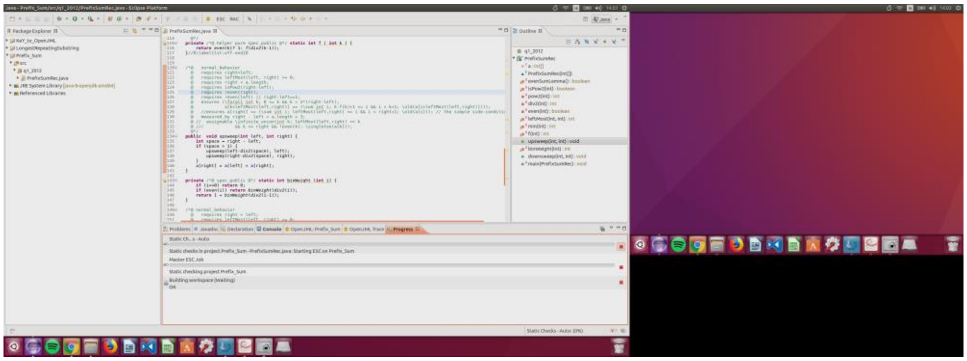
Building workspace (Waiting)
OK

Cancel | << Details | Run in Background

```
Static Checks for: Prefix_Sum
  q1_2012
    q1_2012.PrefixSumRec
      [RUNNING] PrefixSumRec(int[]) [0.000 z3_4_4]
```

Static Checks - Auto: (0%)

14:03 - 0% progress



```
public  void upsweep(int left, int right) {
    int space = right - left;
    if (space > 1) {
        upsweep(left-div2(space), left);
        upsweep(right-div2(space), right);
    }
    a[right] = a[left] + a[right];
}

private /*@ spec_public @*/ static int binWeight (int i) {
    if (i==0) return 0;
    if (even(i)) return binWeight(div2(i));
    return 1 + binWeight(div2(i-1));
}
```

Static Ch...s - Auto

Static checks in project Prefix_Sum - PrefixSumRec.java: Starting ESC on Prefix_Sum

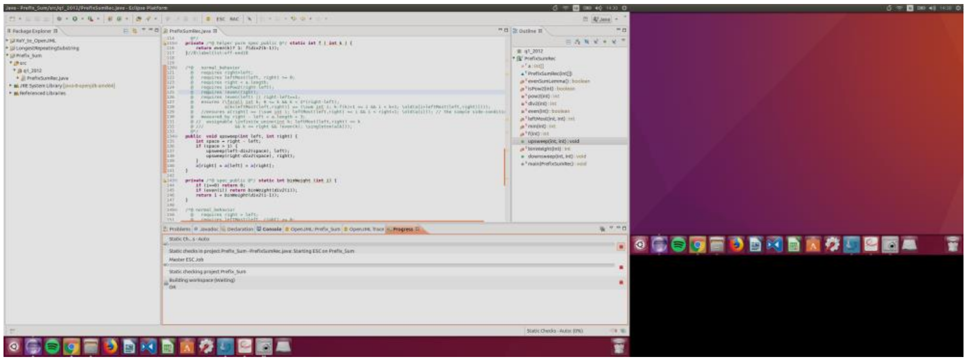
Master ESC Job

Static checking project Prefix_Sum

Building workspace (Waiting)
OK

Static Checks - Auto: (0%)

14:29 – 0% Progress (Eclipse ESC cancelled)



Static Ch...s - Auto

Static checks in project Prefix_Sum - PrefixSumRec.java: Starting ESC on Prefix_Sum

Master ESC Job

Static checking project Prefix_Sum

Building workspace (Waiting)
OK

Static Checks - Auto: (0%)

14:42 Eclipse hung when cancelling operation

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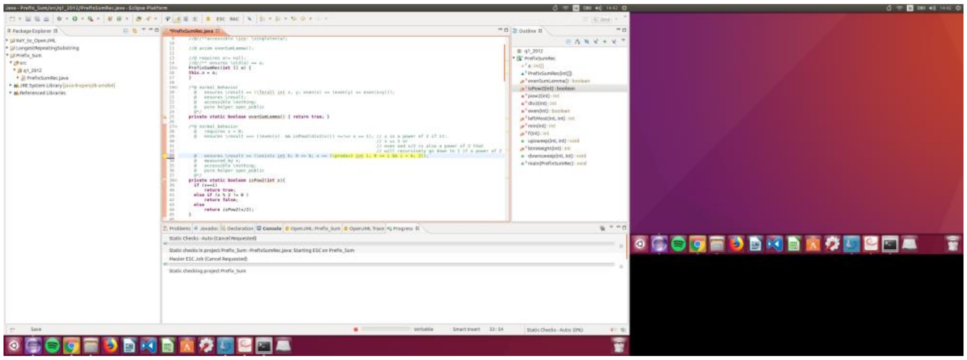
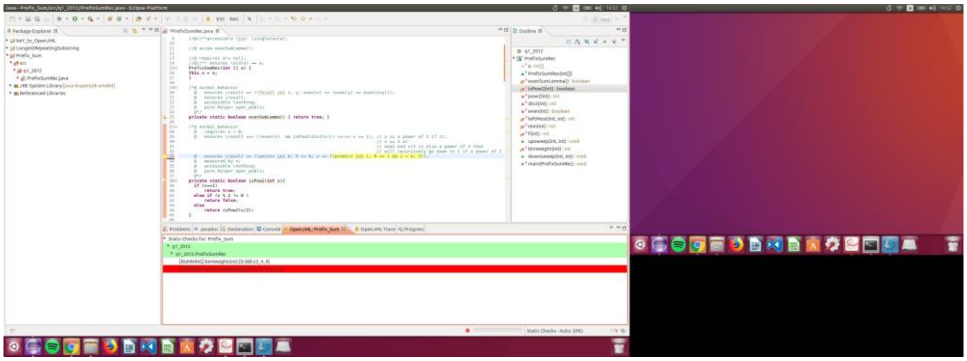
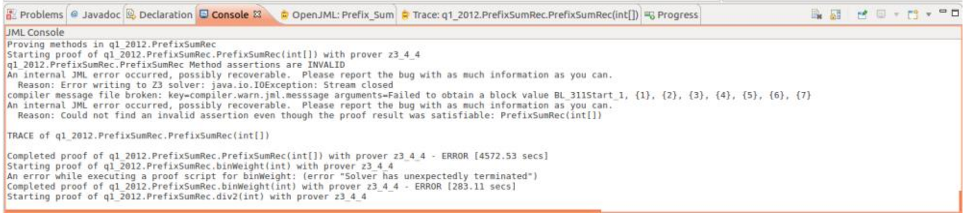


14:52 – Eclipse won't exit and continues to try ESC with a result after z3 process was forcefully stopped



14:57 – Error appears to be with binWeight method

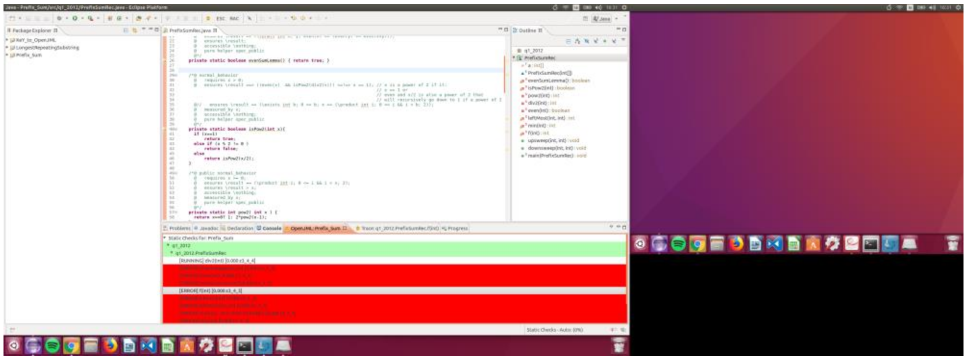


```
Proving methods in q1_2012.PrefixSumRec
Starting proof of q1_2012.PrefixSumRec.PrefixSumRec(int[]) with prover z3_4_4
q1_2012.PrefixSumRec.PrefixSumRec Method assertions are INVALID
An internal JML error occurred, possibly recoverable.  Please report the bug with as much information as you can.
  Reason: Error writing to Z3 solver: java.io.IOException: Stream closed
compiler message file broken: key=compiler.warn.jml.messsage arguments=Failed to obtain a block value BL_311Start_1, {1}, {2}, {3}, {4}, {5}, {6}, {7}
An internal JML error occurred, possibly recoverable.  Please report the bug with as much information as you can.
  Reason: Could not find an invalid assertion even though the proof result was satisfiable: PrefixSumRec(int[])

TRACE of q1_2012.PrefixSumRec.PrefixSumRec(int[])

Completed proof of q1_2012.PrefixSumRec.PrefixSumRec(int[]) with prover z3_4_4 - ERROR [4572.53 secs]
Starting proof of q1_2012.PrefixSumRec.binWeight(int) with prover z3_4_4
An error while executing a proof script for binWeight: (error "Solver has unexpectedly terminated")
Completed proof of q1_2012.PrefixSumRec.binWeight(int) with prover z3_4_4 - ERROR [283.11 secs]
Starting proof of q1_2012.PrefixSumRec.div2(int) with prover z3_4_4
```

2. Second ESC attempt

16:32 – prover error

- Eclipse not recognizing prover executable despite setting it in preferences



- Prover started working

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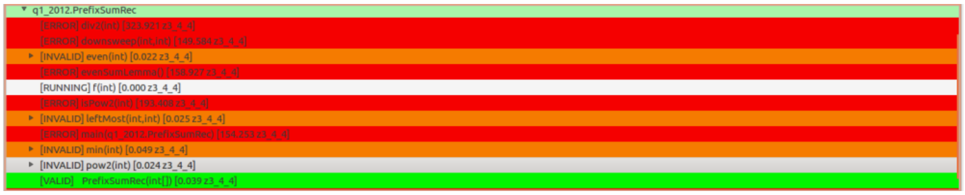
- Note: A measured by clause can be used in a termination argument for a recursive specification
  - A pure method or constructor must also be provably terminating.(19) Recursion is permitted, both in the implementation of pure methods and the data structures they manipulate, and in the specifications of pure methods. When recursion is used in a specification, the proof of well-formedness for the specification involves the use of JML's measured_by clause.
    - *Dc.fi.udc.es. (2018). Preliminary Design of JML - 2. Class and Interface Specifications. [online] Available at: http://www.dc.fi.udc.es/ai/tp/practica/jml/JML/docs/prelimdesign/prelimdesign/prelimdesign_2.html [Accessed 26 Apr. 2018].*

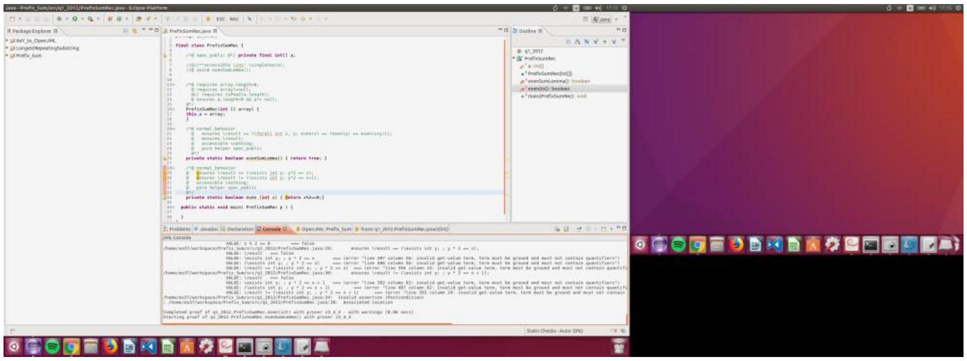


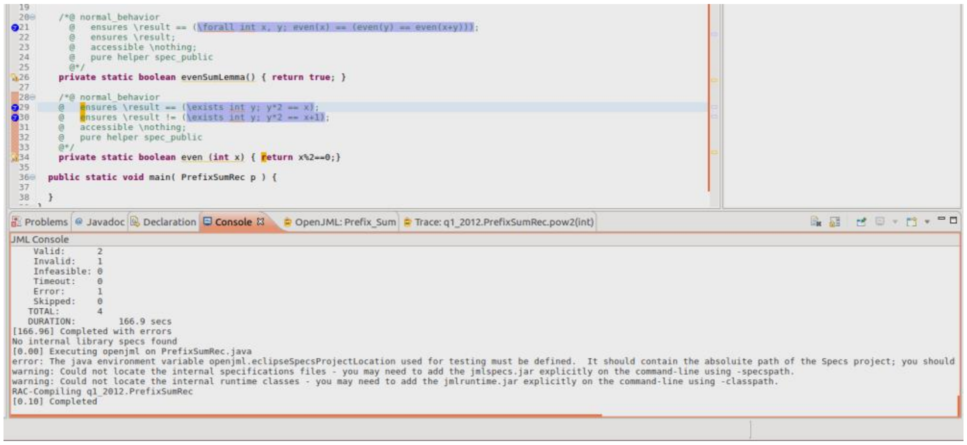
```
▼ q1_2012.PrefixSumRec
    [ERROR] div2(int) [323.921 z3_4_4]
    [ERROR] downsweep(int,int) [149.584 z3_4_4]
  ▸ [INVALID] even(int) [0.022 z3_4_4]
    [ERROR] evenSumLemma() [158.927 z3_4_4]
    [RUNNING] f(int) [0.000 z3_4_4]
    [ERROR] isPow2(int) [193.408 z3_4_4]
  ▸ [INVALID] leftMost(int,int) [0.025 z3_4_4]
    [ERROR] main(q1_2012.PrefixSumRec) [154.253 z3_4_4]
  ▸ [INVALID] min(int) [0.049 z3_4_4]
  ▸ [INVALID] pow2(int) [0.024 z3_4_4]
    [VALID]   PrefixSumRec(int[]) [0.039 z3_4_4]
```

17:02 – Too many errors found to work through, we will have to verify each method individually as they all call each other in their own specifications

17:15 – Starting with evenSumLemma method which requires the even method in its spec

- Error verifiying the even method
  - z3 does not support evaluation of quantified formulas
  - OpenJML cannot evalutate this separately to other parts of the spec. Major issue





```
   /*@ normal_behavior
     @   ensures \result == (\forall int x, y; even(x) == (even(y) == even(x+y)));
     @   ensures \result;
     @   accessible \nothing;
     @   pure helper spec_public
     @*/
   private static boolean evenSumLemma() { return true; }

   /*@ normal_behavior
   @   ensures \result == (\exists int y; y*2 == x);
   @   ensures \result != (\exists int y; y*2 == x+1);
   @   accessible \nothing;
   @   pure helper spec_public
   @*/
   private static boolean even (int x) { return x%2==0;}

 public static void main( PrefixSumRec p ) {

 }
```

```
    Valid:      2
    Invalid:    1
    Infeasible: 0
    Timeout:    0
    Error:      1
    Skipped:    0
   TOTAL:       4
   DURATION:         166.9 secs
[166.96] Completed with errors
No internal library specs found
[0.00] Executing openjml on PrefixSumRec.java
error: The java environment variable openjml.eclipseSpecsProjectLocation used for testing must be defined.  It should contain the absoluite path of the Specs project; you should
warning: Could not locate the internal specifications files - you may need to add the jmlspecs.jar explicitly on the command-line using -specspath.
warning: Could not locate the internal runtime classes - you may need to add the jmlruntime.jar explicitly on the command-line using -classpath.
RAC-Compiling q1_2012.PrefixSumRec
[0.10] Completed
```

17:38 – Removed two quantifed formulas from even method

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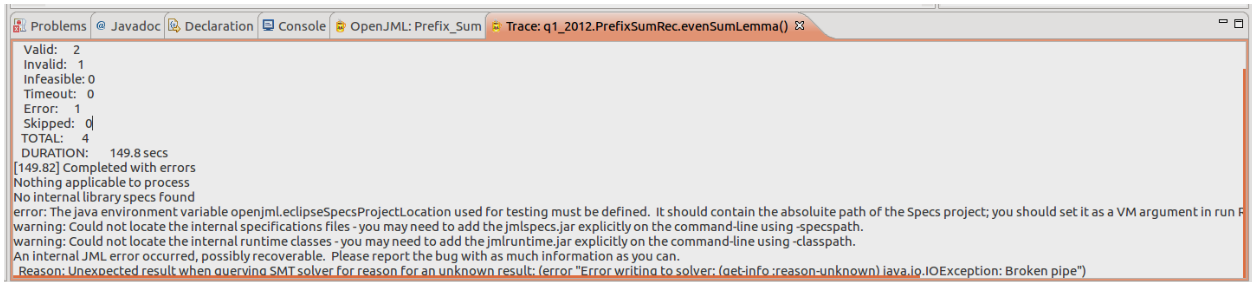
- even method now passes
- Internal error with io pipe for evenSumLemma method
- Line 21: @   ensures \result == (\forall int x, y; even(x) == (even(y) == even(x+y))); is causing the prover to timeout

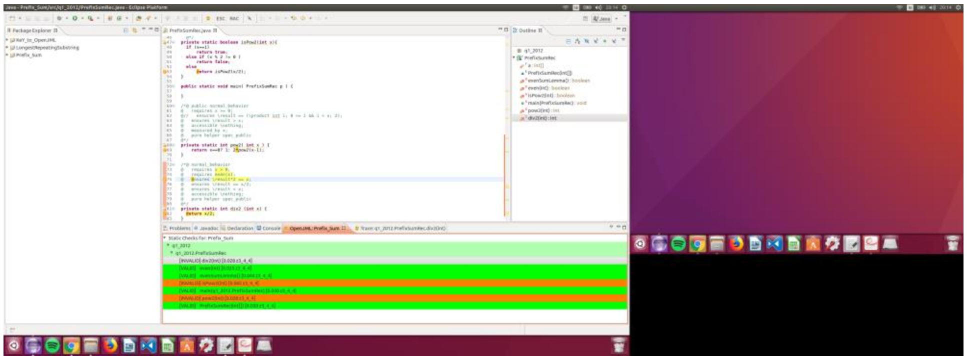


```
 Valid:    2
 Invalid:   1
 Infeasible: 0
 Timeout:   0
 Error:    1
 Skipped:   0
 TOTAL:    4
 DURATION:      149.8 secs
[149.82] Completed with errors
Nothing applicable to process
No internal library specs found
error: The java environment variable openjml.eclipseSpecsProjectLocation used for testing must be defined.  It should contain the absoluite path of the Specs project; you should set it as a VM argument in run F
warning: Could not locate the internal specifications files - you may need to add the jmlspecs.jar explicitly on the command-line using -specspath.
warning: Could not locate the internal runtime classes - you may need to add the jmlruntime.jar explicitly on the command-line using -classpath.
An internal JML error occurred, possibly recoverable.  Please report the bug with as much information as you can.
 Reason: Unexpected result when querying SMT solver for reason for an unknown result: (error "Error writing to solver: (get-info :reason-unknown) java.io.IOException: Broken pipe")
```

20:12 – Added in pow2, div2 and isPow2 methods

- div2 specification is invalid
  - div2 method: @ ensures \result*2 == x;

```
TRACE of q1_2012.PrefixSumRec.div2(int)

/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:73:     requires x > 0;

/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:74:     requires even(x);

/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:82:     return x / 2;

        VALUE: x     === 1

        VALUE: 2     === 2

        VALUE: x / 2     === 0

/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:82:     ArithmeticOperationRange assertion: !(x == -2147483648 && 2 == -1)

        VALUE: !(x_2233_0___1 == -2147483648 && 2 == -1)     === true

/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:75:     ensures \result * 2 == x;

/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:82:  Invalid assertion (Postcondition)

: /home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:75:  Associated location
```



Static Checks for: Prefix_Sum
q1_2012
q1_2012.PrefixSumRec
[INVALID] div2(int) [0.020 z3_4_4]

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20:21 – div2 method fixed, pow2 error

- pow2 method: return x==0? 1: 2*pow2(x-1);
    - ArithmeticOperationRange exception

```
TRACE of q1_2012.PrefixSumRec.pow2(int)

/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:39:     requires x >= 0;

        VALUE: x     === 1237

        VALUE: 0     === 0

        VALUE: x >= 0     === true

/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:47:     return x == 0 ? 1 : 2 * pow2(x - 1);

        VALUE: x     === 1237

        VALUE: 0     === 0

        VALUE: x == 0     === false

        VALUE: 2     === 2

        VALUE: x     === 1237

        VALUE: 1     === 1

        VALUE: x - 1     === 1236

        VALUE: 2 * pow2(x - 1)     === ( - 2147483648 )

        VALUE: x == 0 ? 1 : 2 * pow2(x - 1)     === 0

/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:47:     ArithmeticOperationRange assertion: !(0 < x && 1 < 0) || x <=
2147483647 + 1

        VALUE: !(0 < x_1225_0___1 && 1 < 0) || x_1225_0___1 <= 2147483647 + 1     === true

/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:47:     ArithmeticOperationRange assertion: !(x < 0 && 0 < 1) || -
2147483648 + 1 <= x

        VALUE: !(x_1225_0___1 < 0 && 0 < 1) || -2147483648 + 1 <= x_1225_0___1     === true

/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:39:     Precondition assertion: _$CPRE__6

/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:47:     ArithmeticOperationRange assertion: -2147483648 <= 2 *
_JML__tmp71 && 2 * _JML__tmp71 <= 2147483647

        VALUE: -2147483648 <= 2 * _JML__tmp71 && 2 * _JML__tmp71 <= 2147483647     === false

/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:47:  Invalid assertion (ArithmeticOperationRange)n
```

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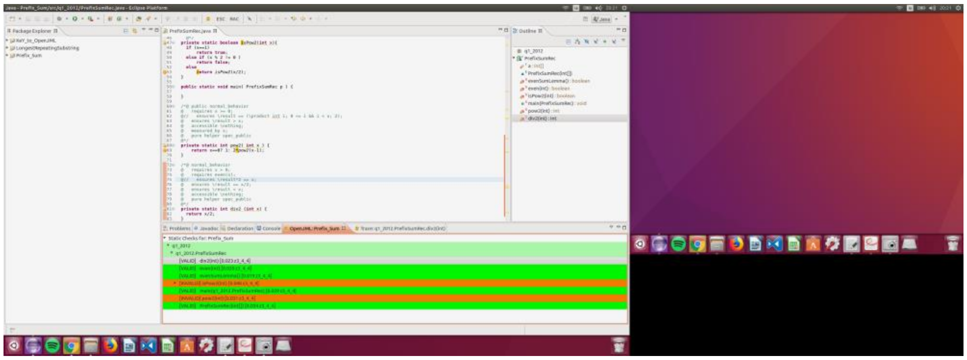
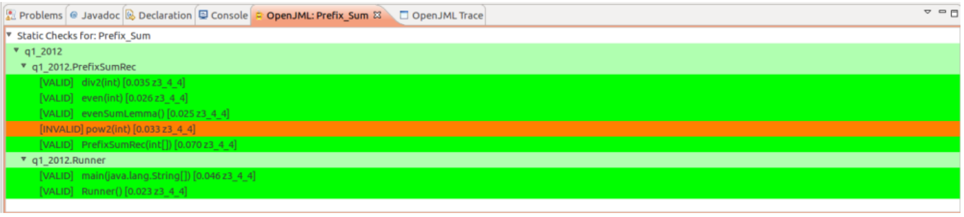
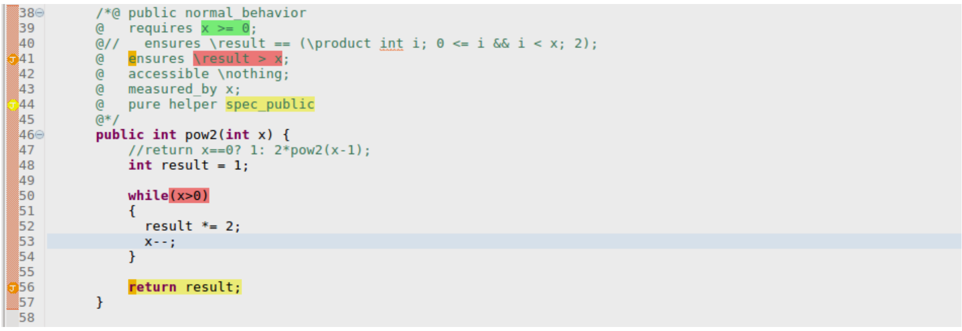


NOTE: isPow2 method is still in the ESC checks from previous run, despite being removed from the program. Need to restart eclipse to remove it from the cache.



```
▾ Static Checks for: Prefix_Sum
  ▾ q1_2012
    ▾ q1_2012.PrefixSumRec
        [VALID]   div2(int) [0.035 z3_4_4]
        [VALID]   even(int) [0.026 z3_4_4]
        [VALID]   evenSumLemma() [0.025 z3_4_4]
        [INVALID] pow2(int) [0.033 z3_4_4]
        [VALID]   PrefixSumRec(int[]) [0.070 z3_4_4]
    ▾ q1_2012.Runner
        [VALID]   main(java.lang.String[]) [0.046 z3_4_4]
        [VALID]   Runner() [0.023 z3_4_4]
```

21:29 – Changed pow2 method to iterative program but verification still fails. Error in prover?



```
38      /*@ public normal_behavior
39      @   requires x >= 0;
40      @//   ensures \result == (\product int i; 0 <= i && i < x; 2);
41      @   ensures \result > x;
42      @   accessible \nothing;
43      @   measured_by x;
44      @   pure helper spec_public
45      @*/
46      public int pow2(int x) {
47          //return x==0? 1: 2*pow2(x-1);
48          int result = 1;
49
50          while(x>0)
51          {
52            result *= 2;
53            x--;
54          }
55
56          return result;
57      }
58
```

TRACE of q1_2012.PrefixSumRec.pow2(int)

/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:39:   requires x >= 0;

VALUE: x   === 0

VALUE: 0   === 0

VALUE: x >= 0   === true

/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:48:   int result = 1

VALUE: 1   === 1

VALUE: result   === 1

/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:50:   Loop test

VALUE: x   === 0

VALUE: 0   === 0

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```
        VALUE: x > 0     === false
        VALUE: (x > 0)     === false
/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:56:      return result;
        VALUE: result     === 0
/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:41:      ensures \result > x;
        VALUE: \result     === 0
        VALUE: x     === 0
        VALUE: \result > x     === false
/home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:56:  Invalid assertion (Postcondition)
: /home/eo37/workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:41:  Associated location
```

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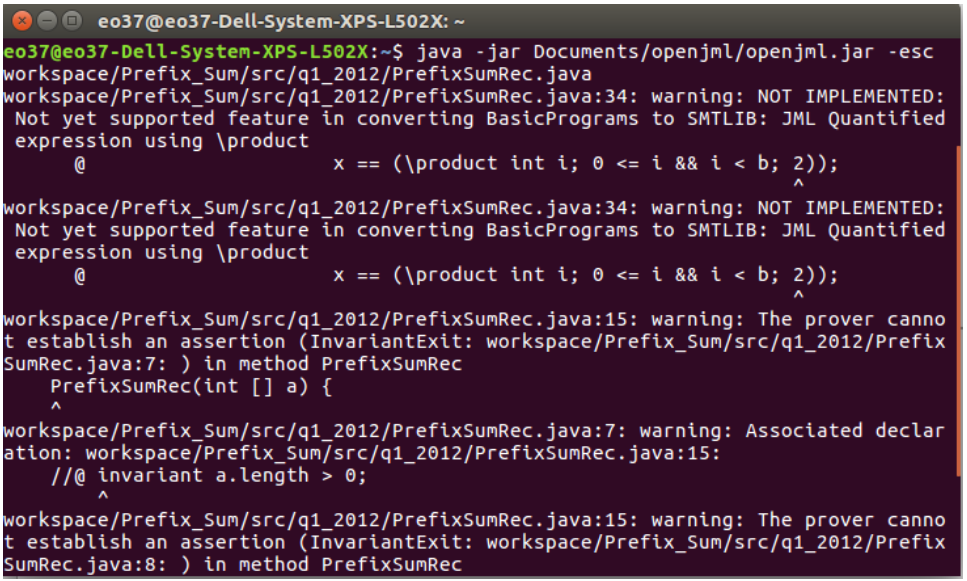
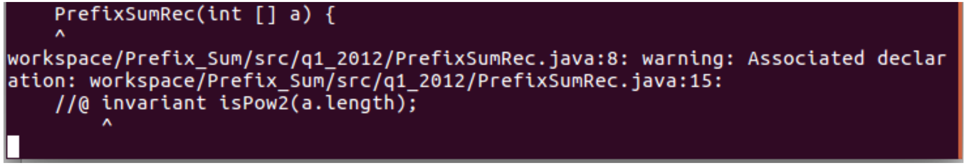
Terminal

14:42

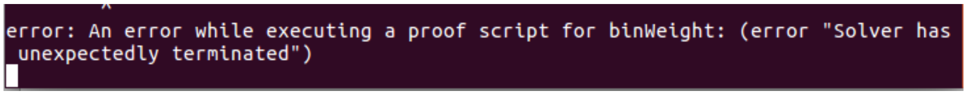


```
eo37@eo37-Dell-System-XPS-L502X: ~
eo37@eo37-Dell-System-XPS-L502X:~$ java -jar Documents/openjml/openjml.jar -esc
workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java
workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:34: warning: NOT IMPLEMENTED:
 Not yet supported feature in converting BasicPrograms to SMTLIB: JML Quantified
 expression using \product
      @                     x == (\product int i; 0 <= i && i < b; 2));
                                                                   ^
workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:34: warning: NOT IMPLEMENTED:
 Not yet supported feature in converting BasicPrograms to SMTLIB: JML Quantified
 expression using \product
      @                     x == (\product int i; 0 <= i && i < b; 2));
                                                                   ^
workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:15: warning: The prover canno
t establish an assertion (InvariantExit: workspace/Prefix_Sum/src/q1_2012/Prefix
SumRec.java:7: ) in method PrefixSumRec
    PrefixSumRec(int [] a) {
    ^
workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:7: warning: Associated declar
ation: workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:15:
    //@ invariant a.length > 0;
        ^
workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:15: warning: The prover canno
t establish an assertion (InvariantExit: workspace/Prefix_Sum/src/q1_2012/Prefix
SumRec.java:8: ) in method PrefixSumRec
```



```
    PrefixSumRec(int [] a) {
    ^
workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:8: warning: Associated declar
ation: workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:15:
    //@ invariant isPow2(a.length);
        ^
```

14:46 – Solver terminates unexpectedly working on binWeight method



```
        ^
error: An error while executing a proof script for binWeight: (error "Solver has
 unexpectedly terminated")
```

15:46 – Second terminal attempt

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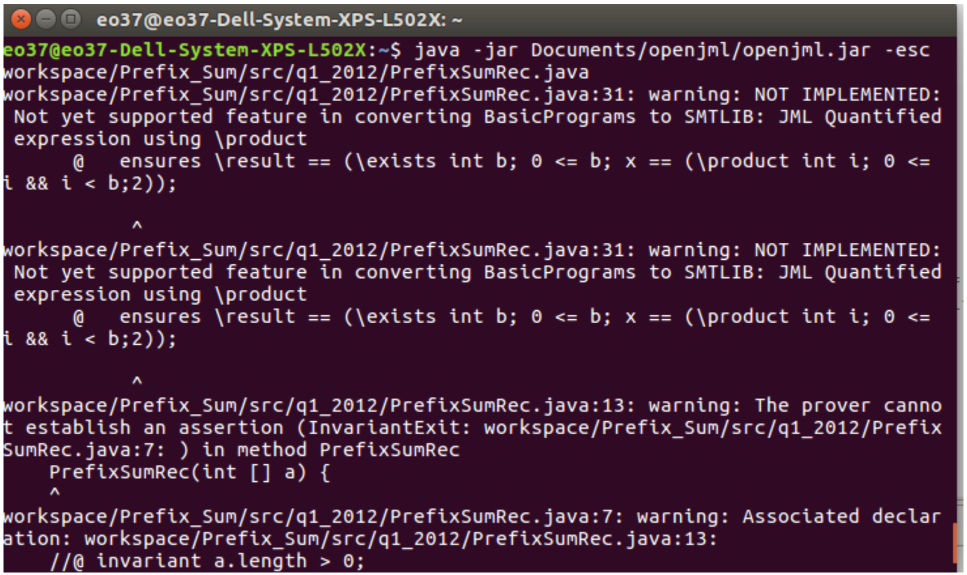
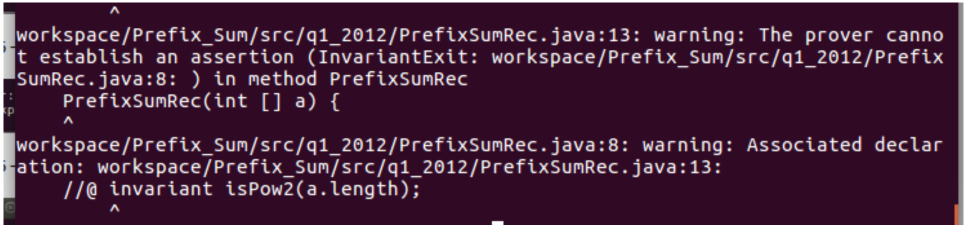


```
eo37@eo37-Dell-System-XPS-L502X: ~
eo37@eo37-Dell-System-XPS-L502X:~$ java -jar Documents/openjml/openjml.jar -esc
workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java
workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:31: warning: NOT IMPLEMENTED:
 Not yet supported feature in converting BasicPrograms to SMTLIB: JML Quantified
 expression using \product
      @   ensures \result == (\exists int b; 0 <= b; x == (\product int i; 0 <=
i && i < b;2));

           ^
workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:31: warning: NOT IMPLEMENTED:
 Not yet supported feature in converting BasicPrograms to SMTLIB: JML Quantified
 expression using \product
      @   ensures \result == (\exists int b; 0 <= b; x == (\product int i; 0 <=
i && i < b;2));

           ^
workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:13: warning: The prover canno
t establish an assertion (InvariantExit: workspace/Prefix_Sum/src/q1_2012/Prefix
SumRec.java:7: ) in method PrefixSumRec
    PrefixSumRec(int [] a) {
    ^
workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:7: warning: Associated declar
ation: workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:13:
    //@ invariant a.length > 0;
```



```
         ^
workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:13: warning: The prover canno
t establish an assertion (InvariantExit: workspace/Prefix_Sum/src/q1_2012/Prefix
SumRec.java:8: ) in method PrefixSumRec
    PrefixSumRec(int [] a) {
    ^
workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:8: warning: Associated declar
ation: workspace/Prefix_Sum/src/q1_2012/PrefixSumRec.java:13:
    //@ invariant isPow2(a.length);
        ^
```

15:48 Third Terminal attempt

- Error on invariant a.length>0
    - Changed the assertion from an 'invariant' to 'ensures' and applied to constructor
    - Variable name 'a' renamed to 'array' to stop naming difficulties with prover
    - array.length>0 added to constructor
    - array!=null assertion added to constructor
    - @ ensures a.length>0 && a!= null added to constructor
- Error on invariant isPow2(a.length) removed completely, can't be enforced so is not needed.
- binWeight method removed, not used by KeY solution so is not needed.
- \product assertion removed, not sure if needed?