The RISC ProofNavigator
Second Status Report

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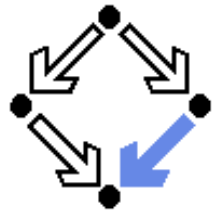
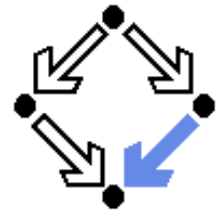


Motivation

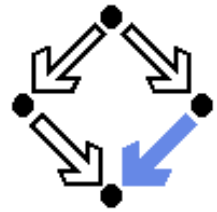


Component of an envisioned integrated program reasoning environment.

- Based on 2005 evaluation of various proving assistants.
  - PVS, Isabelle/HOL, Coq.
- Key goals:
  - Aggressive proof state simplification.
  - User-friendly proof state presentation.
  - Intuitive proof tree navigation.
  - Helpful proof automation (proving on the small scale).
  - Open to human guidance (proving on the large scale).
- Principle of "least surprise"
  - If in doubt, do the least surprising thing.
  - E.g., start potentially costly simplifications only at explicit request.
- Open source implementation
  - Java-based application and class library.
  - Stanford CVCL (Cooperating Validity Checker Lite)

http://www.risc.uni-linz.ac.at/research/formal/software/ProofNavigator

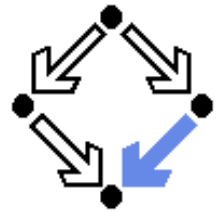
Conclusions in November 2005



- Basic framework operational and stable.
  - About 150 classes and 20000 lines of code.
  - But only toy examples have been tested so far.
- Next: better CVCL interaction.
  - Error detection and recovery.
  - Re-translation of canonized formulas to human-friendly form.
  - Decomposing formulas for validity checking of individual parts.
- Goal: run my test cases successfully and analyze the results.
  - Certainly more work will arise from this...
- Finally: documentation and paper.
  - Release of system planned for first half of 2006.
- Perhaps: extension by other automated decision procedures.
  - Interfaces for Simplify and ICS may be interesting.

Hopefully I can show some more examples soon.

Status in March 2006

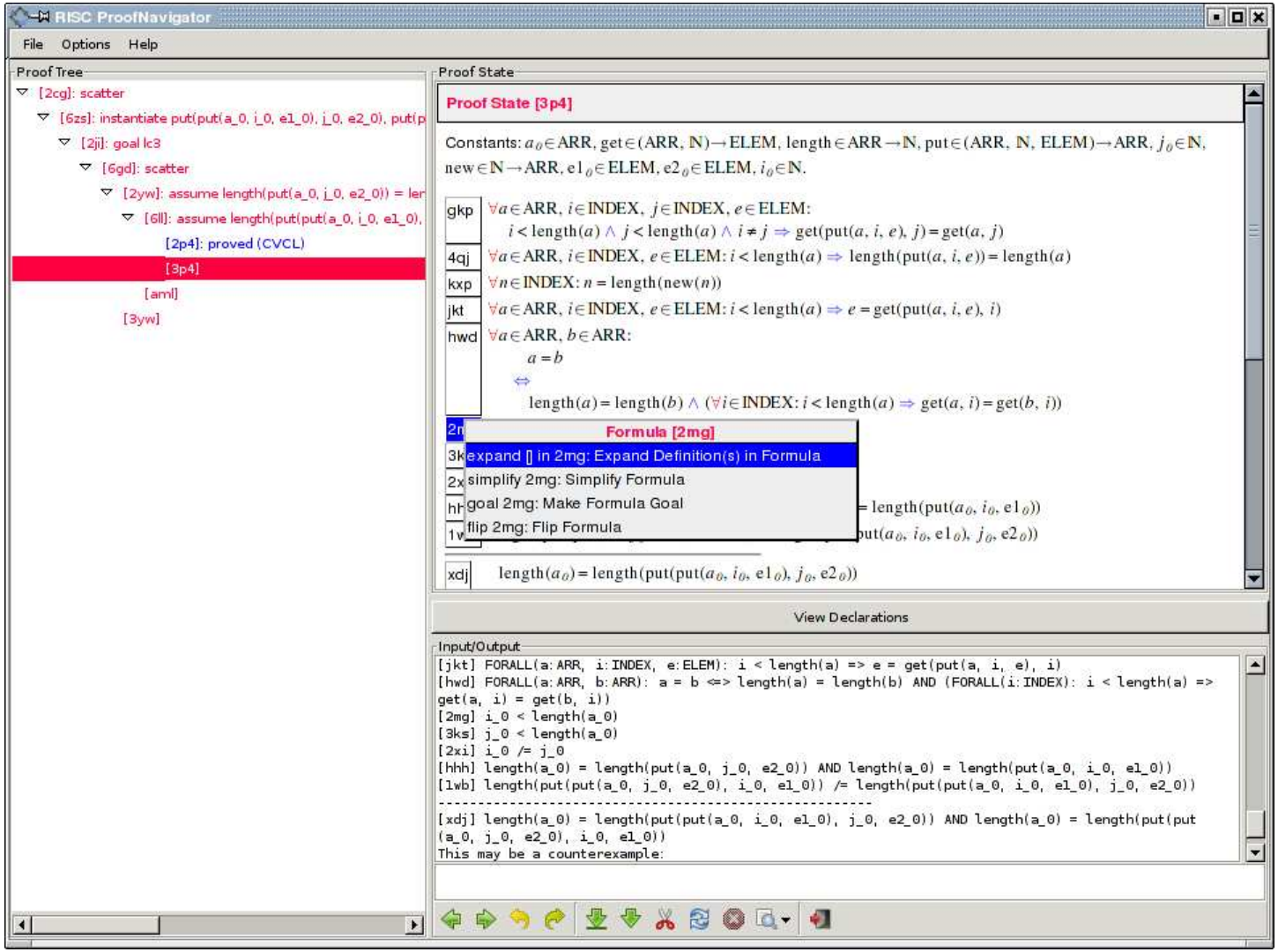


ProofNavigator version 0.5 installed in the RISC environment.

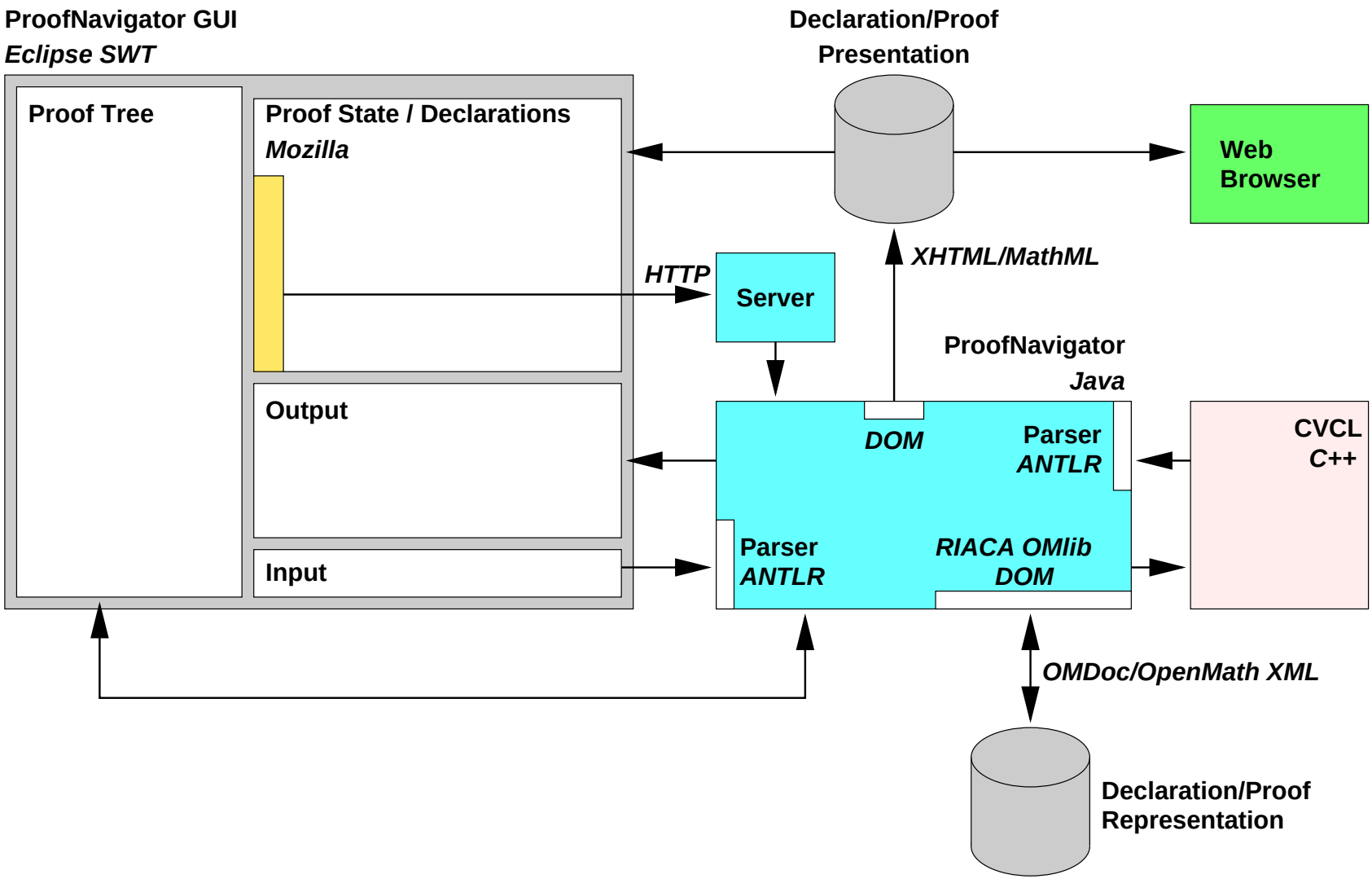
- New point-and-click interface.
  - Proof navigation.
  - Proof state manipulation.
- Improvement of CVCL interaction.
  - Manual abortion of validity check.
  - Translation of simplification results to human-friendly form.
- Numerous internal modifications.
  - Fixing bugs and conceptual errors, replacing hacks by real solutions.
  - Fine-tuning to minimize user surprise.
- Successfully proved most test cases.
  - Axiomatic arrays with proof of "commutes" property.
  - Constructive arrays with proofs of "commutes" and extensionality.
  - Verification of linear search.
  - Verification of binary search.

Status almost as planned.

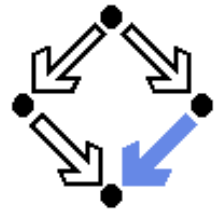
ProofNavigator GUI



ProofNavigator Architecture



Proof Examples

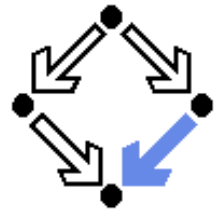


Examples contained in 0.5 release.

- Induction proofs: `sum` and `sum0`.
- Quantifier proofs: `quant` and `quant0`.
- Axiomatization of arrays: `arrays1`.
- Constructive definition of arrays: `arrays2`.
- Linear search: `linsearch`.
- Binary search: `binarysearch`.

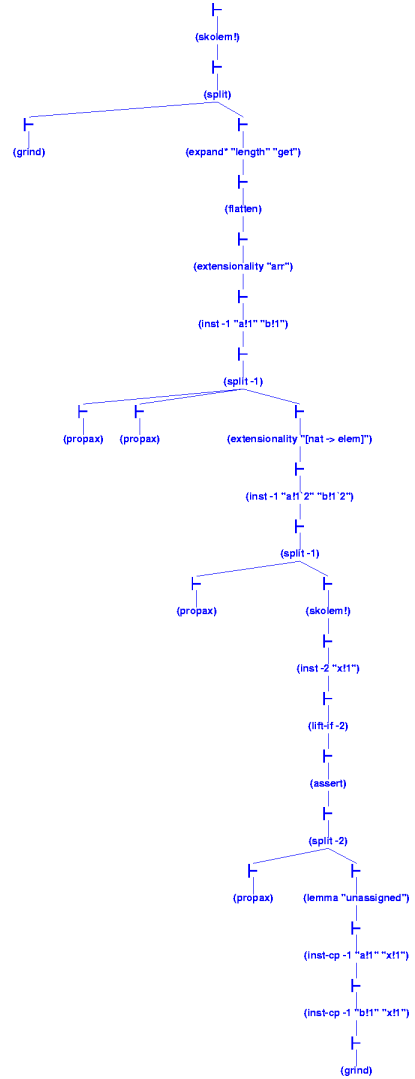
Now for some online demonstrations.

Constructive Definition of Arrays

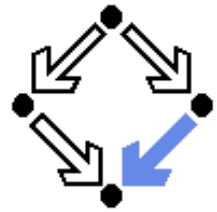


ProofNavigator versus PVS.

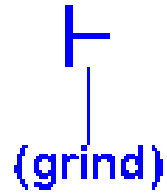
```
[adt]: expand length get content
  [cw2]: scatter
    [qey]: proved (CVCL)
    [rey]: goal th1
      [zpt]: assume b_0.1 = a_0.1
        [rga]: proved (CVCL)
        [sga]: instantiate a_0.1, b_0.1 in 1fm
          [aj1]: goal 2sq
            [czu]: scatter
              [qaz]: instantiate a_0, i_0 in 3p3
                [sxn]: instantiate b_0, i_0 in 3p3
                  [amc]: instantiate i_0 in ruq
                    [ccv]: proved (CVCL)
```



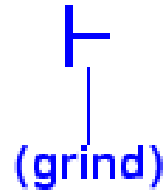
Linear Search: Conditions A and B1



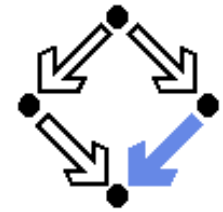
```
[bca]: expand Input Invariant length get obk
  [fuo]: scatter
    [bxg]: proved (Goal cqi is TRUE)
```



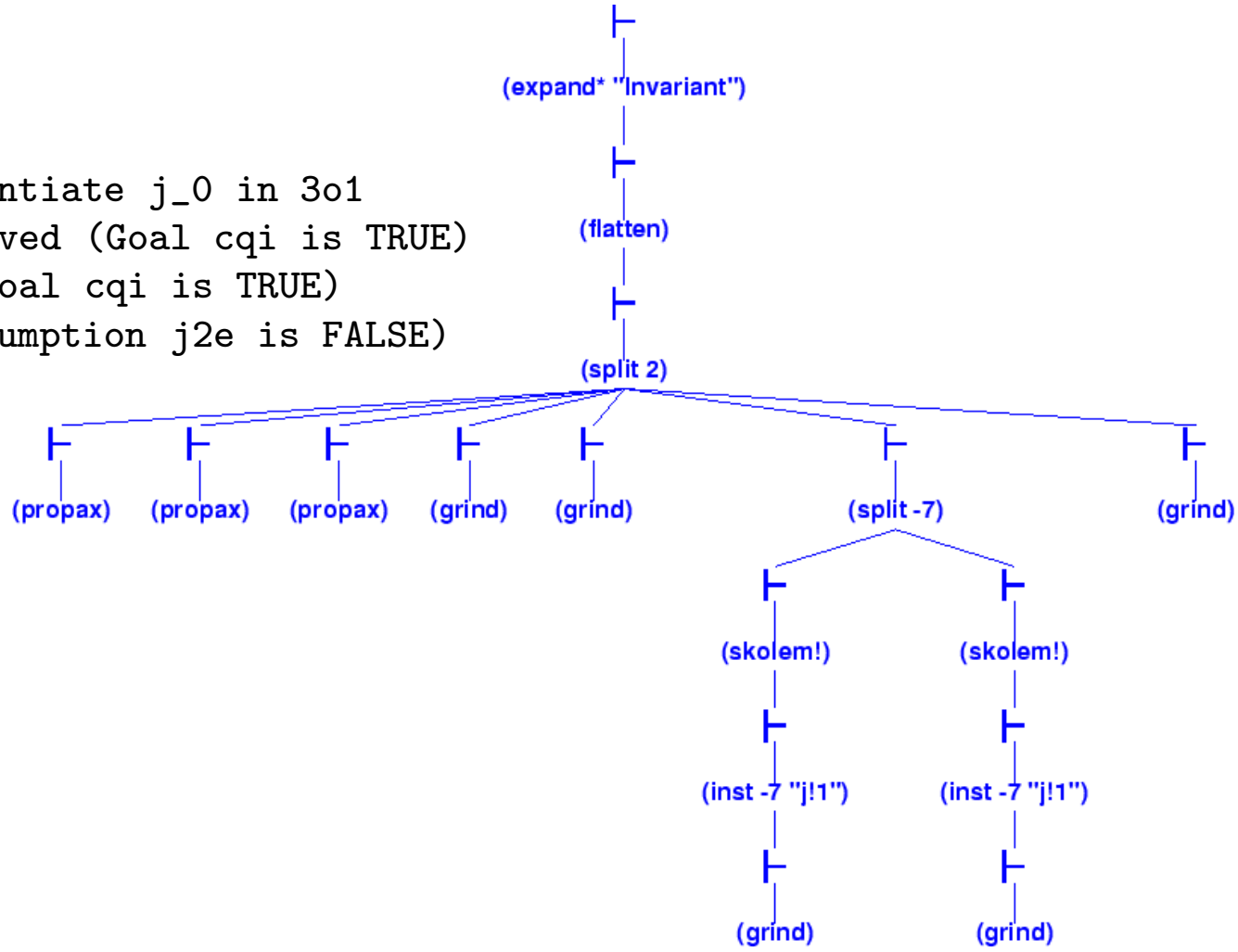

```
[p1b]: expand Invariant length get ykw
  [lf6]: proved (Goal cqi is TRUE)
```



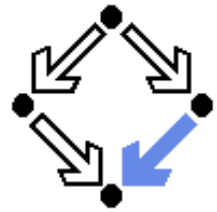
Linear Search: Condition B2



```
[q1b]: expand Invariant length get content d1k
  [slx]: scatter
    [a1y]: split l54
      [cch]: goal pyf
        [qnu]: scatter
          [se2]: instantiate j_0 in 3o1
            [avs]: proved (Goal cqi is TRUE)
      [dch]: proved (Goal cqi is TRUE)
    [b1y]: proved (Assumption j2e is FALSE)
```

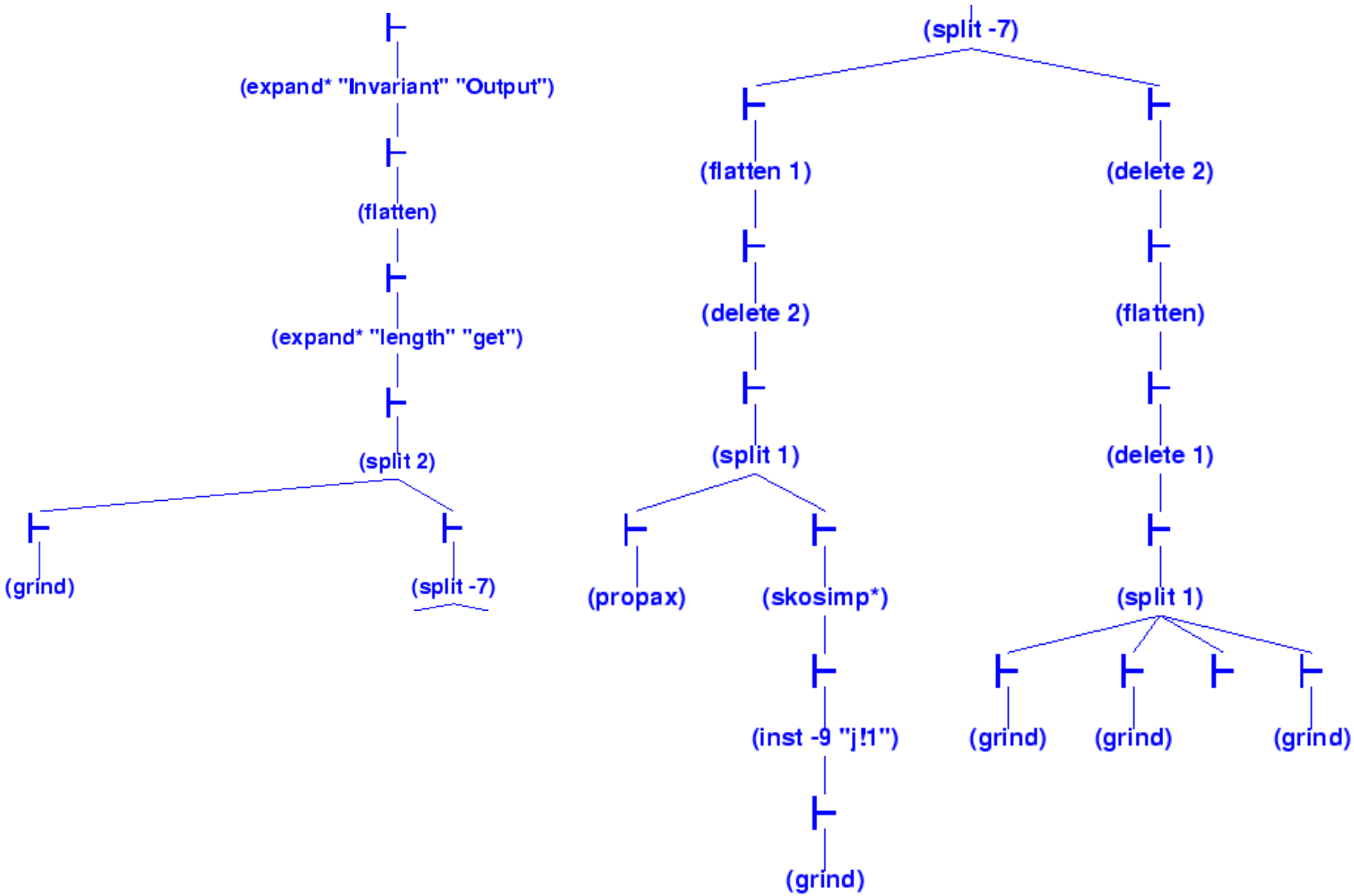


Linear Search: Condition C

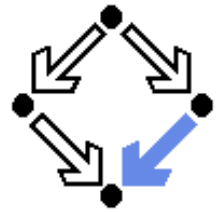


```
[dca]: expand Output Invariant length content get 53u
  [tvy]: scatter
    [dcu]: instantiate j_0 in 3o1
      [t4c]: proved (Goal cqi is TRUE)
    [ecu]: split hee
      [kel]: goal ahc
        [ulf]: proved (Assumption j2e is FALSE)
      [lel]: proved (Goal cqi is TRUE)
      [mel]: proved (Goal cqi is TRUE)
```

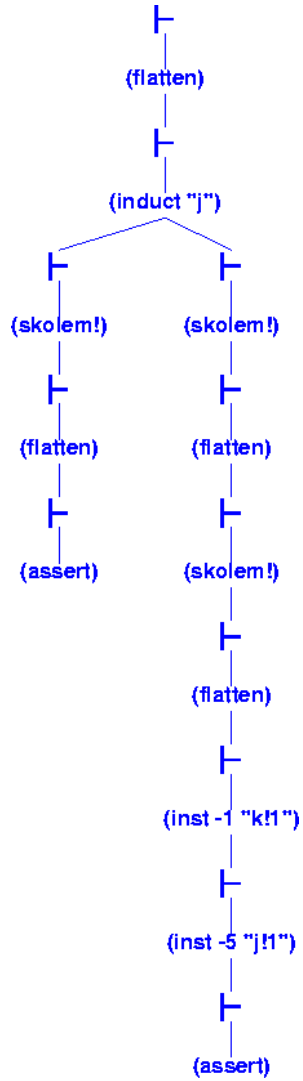
Linear Search: Condition C (Contd)



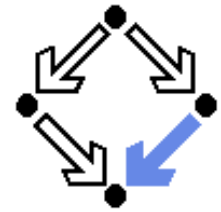
Binary Search: Lemma L



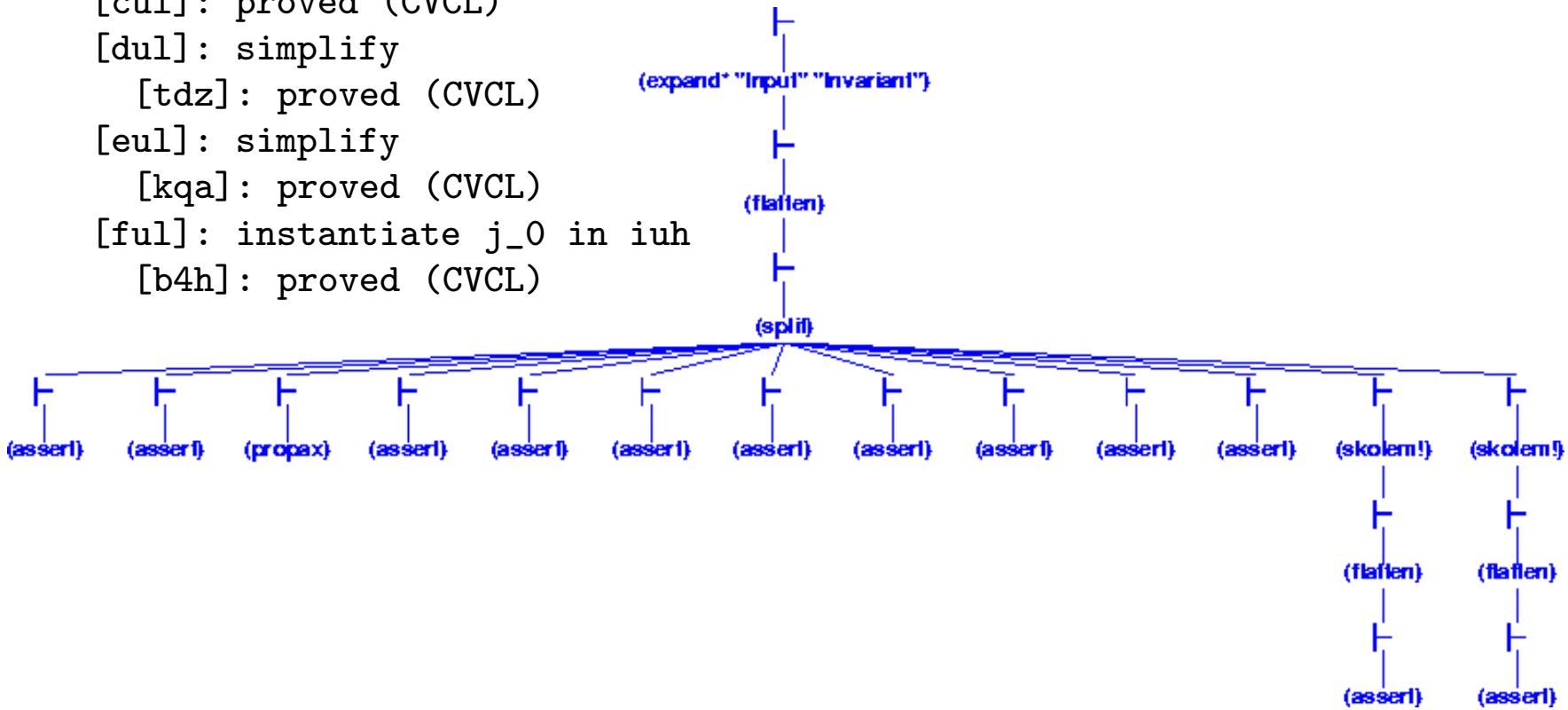
```
[mca]: flatten
  [c3f]: induction j z42
    [3da]: scatter
      [s3k]: proved (CVCL)
    [4da]: scatter
      [jdt]: instantiate k_0 in cgs
        [4kl]: instantiate j_0 in iuh
          [ji1]: proved (CVCL)
```



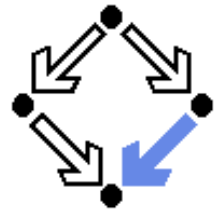
Binary Search: Condition A



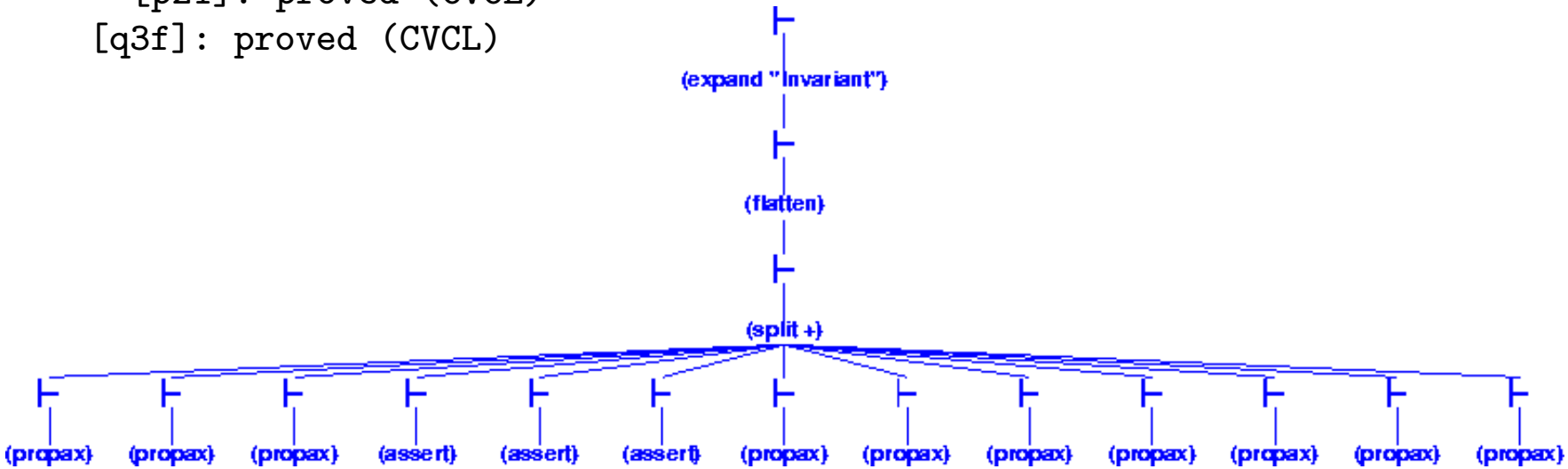
```
[bca]: expand Input Invariant ne5
  [fuo]: scatter
    [bxg]: goal iae
      [ft4]: scatter
        [bul]: proved (CVCL)
        [cul]: proved (CVCL)
        [dul]: simplify
          [tdz]: proved (CVCL)
        [eul]: simplify
          [kqa]: proved (CVCL)
        [ful]: instantiate j_0 in iuh
          [b4h]: proved (CVCL)
```



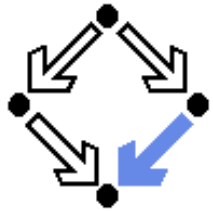
Binary Search: Condition B1



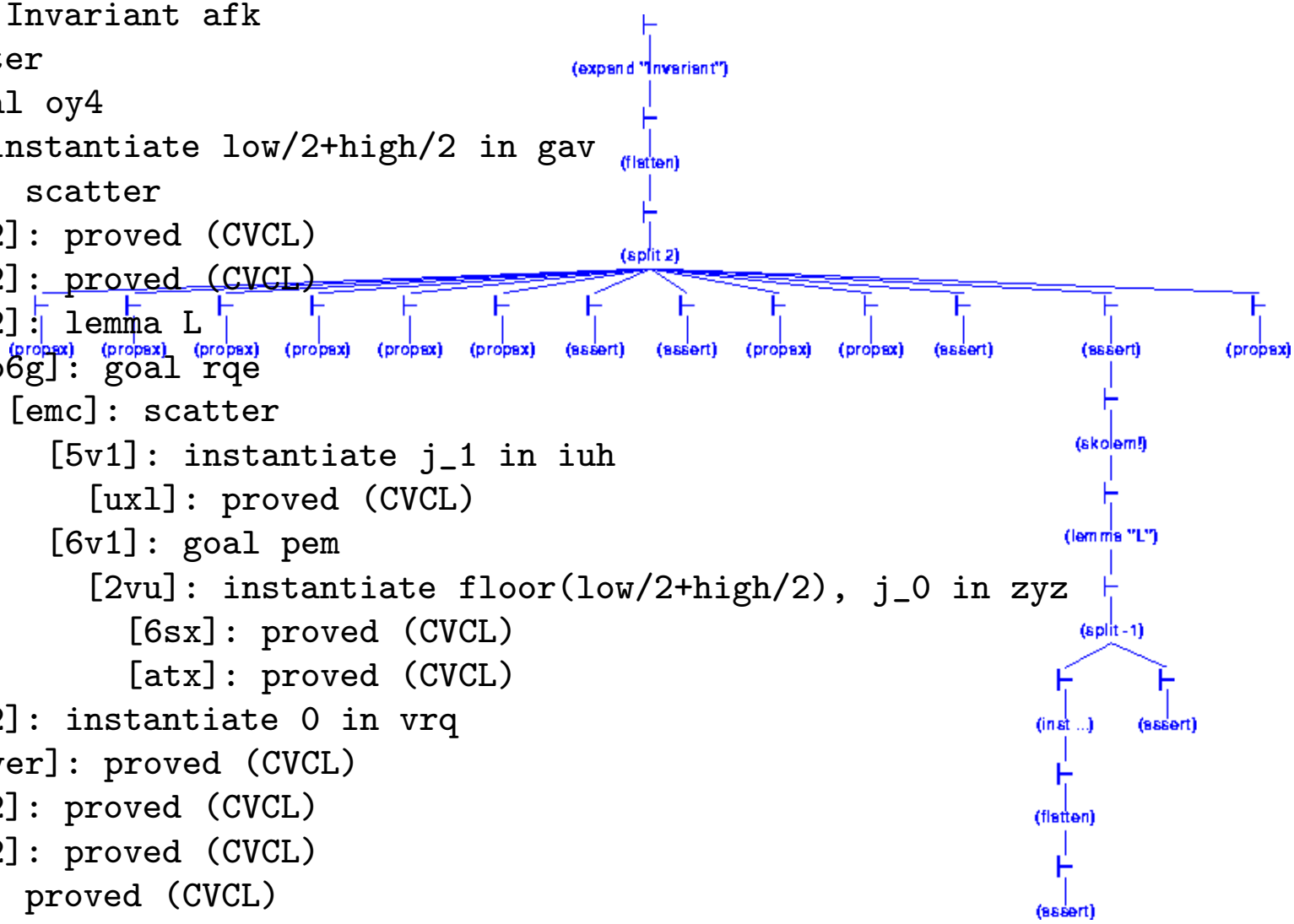
```
[p1b]: expand Invariant esp
  [lf6]: scatter
    [p6i]: goal 6qm
      [l3h]: instantiate low/2+high/2 in gav
        [p3f]: scatter
          [l21]: proved (CVCL)
          [m21]: proved (CVCL)
          [n21]: proved (CVCL)
          [o21]: instantiate 0 in vrq
            [eb2]: proved (CVCL)
          [p21]: proved (CVCL)
        [q3f]: proved (CVCL)
```



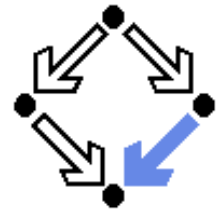
Binary Search: Conditions B2/B3



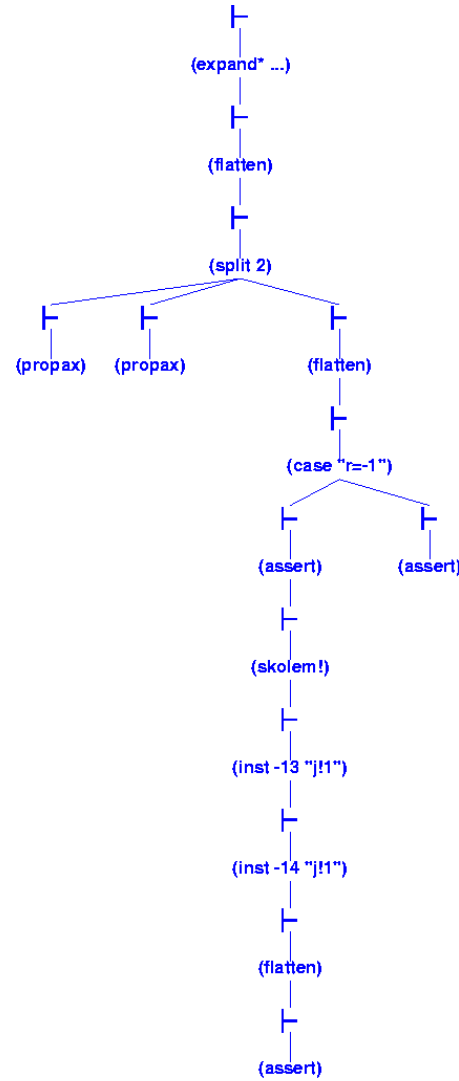
```
[q1b]: expand Invariant afk
  [slx]: scatter
    [a1y]: goal oy4
      [cch]: instantiate low/2+high/2 in gav
        [qnu]: scatter
          [se2]: proved (CVCL)
          [te2]: proved (CVCL)
          [ue2]: lemma L
            [o6g]: goal rqe
              [emc]: scatter
                [5v1]: instantiate j_1 in iuh
                  [uxl]: proved (CVCL)
                [6v1]: goal pem
                  [2vu]: instantiate floor(low/2+high/2), j_0 in zyz
                    [6sx]: proved (CVCL)
                    [atx]: proved (CVCL)
          [ve2]: instantiate 0 in vrq
            [ver]: proved (CVCL)
          [we2]: proved (CVCL)
          [xe2]: proved (CVCL)
        [rnu]: proved (CVCL)
```



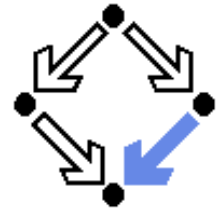
Binary Search: Condition C



```
[dca]: expand Output Invariant btq
  [tvy]: scatter
    [dcu]: split 1ve
      [t4c]: scatter
        [dcu]: instantiate j_0 in nqx
          [tfd]: instantiate j_0 in 6wc
            [dcq]: proved (Goal cqi is TRUE)
      [u4c]: goal yy2
        [1l3]: case r = -1
          [ezx]: scatter
            [kce]: instantiate j_0 in nqx
              [uqh]: instantiate j_0 in 6wc
                [13j]: proved (CVCL)
          [fzx]: proved (Goal cqi is TRUE)
```

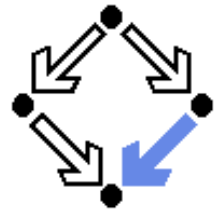


Axiomatic Definition of Arrays

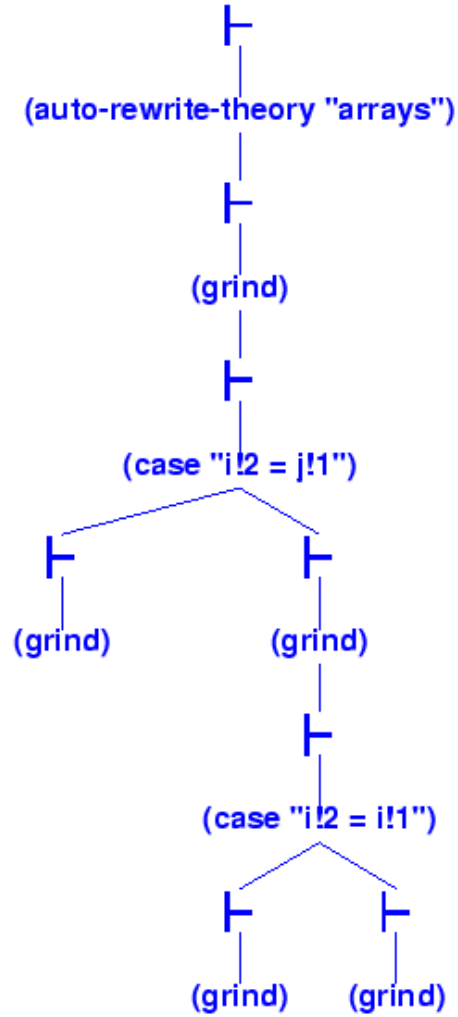


```
[2cg]: scatter
  [6zs]: assume length(put(a_0, i_0, e1_0)) = length(a_0) AND length(put(a_0, j_0, e2_0)) = length(a_0)
    [2ji]: assume length(put(put(a_0, i_0, e1_0), j_0, e2_0)) = length(a_0) AND
                  length(put(put(a_0, j_0, e2_0), i_0, e1_0)) = length(a_0)
      [6gd]: decompose
        [2yw]: instantiate put(put(a_0, j_0, e2_0), i_0, e1_0), put(put(a_0, i_0, e1_0), j_0, e2_0) in hwd
          [6ll]: goal ppq
            [2p4]: scatter
              [6ip]: case i_0 = i_1
                [2oi]: instantiate put(a_0, j_0, e2_0), i_1, e1_0 in jkt
                  [64s]: split jw2
                    [2vd]: proved (CVCL)
                    [3vd]: instantiate put(a_0, i_1, e1_0), j_0, i_1, e2_0 in gkp
                      [gin]: split 514
                        [mbq]: proved (CVCL)
                        [nbq]: proved (CVCL)
                        [obq]: instantiate a_0, i_1, e1_0 in jkt
                          [er1]: proved (CVCL)
                [3oi]: case j_0 = i_1
                  [gvb]: instantiate put(a_0, i_0, e1_0), j_0, e2_0 in jkt
                    [m5b]: split blu
                      [wtx]: proved (CVCL)
                      [xtx]: instantiate put(a_0, j_0, e2_0), i_0, j_0, e1_0 in gkp
                        [dc3]: split nr2
                          [xu6]: proved (CVCL)
                          [yu6]: proved (CVCL)
                          [zu6]: instantiate a_0, j_0, e2_0 in jkt
                            [rzj]: proved (CVCL)
```

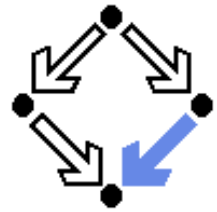
Axiomatic Definition of Arrays (Contd)



```
                [hvb]: instantiate put(a_0, j_0, e2_0), i_0, i_1, e1_0 i
                  [ti2]: split lyr
                    [hgp]: proved (CVCL)
                    [igp]: proved (CVCL)
                    [jgp]: instantiate put(a_0, i_0, e1_0), j_0, i_1, e2
                      [beq]: split 36c
                        [j3l]: proved (CVCL)
                        [k3l]: proved (CVCL)
                        [l3l]: instantiate a_0, i_0, i_1, e1_0 in gkp
                          [p1h]: split srs
                            [lx5]: proved (CVCL)
                            [mx5]: proved (CVCL)
                            [nx5]: instantiate a_0, j_0, i_1, e2_0 in gk
                              [4lv]: proved (CVCL)
  [ahd]: split
    [crr]: instantiate put(a_0, i_0, e1_0), j_0, e2_0 in 4qj
      [qch]: proved (CVCL)
    [drr]: instantiate put(a_0, j_0, e2_0), i_0, e1_0 in 4qj
      [xnb]: proved (CVCL)
[3ji]: split
  [gmn]: instantiate a_0, i_0, e1_0 in 4qj
    [mfr]: proved (CVCL)
  [hmn]: instantiate a_0, j_0, e2_0 in 4qj
    [t4l]: proved (CVCL)
```

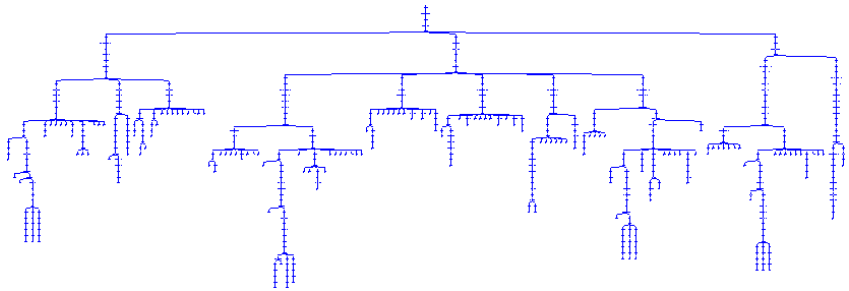


Next Steps



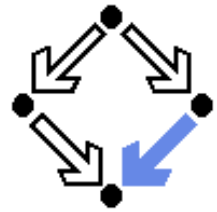
Some more refinements.

- Automatic instantiation before proof state simplification.
  - Instantiate universal assumptions and existential goals.
  - Instantiation values are those ground terms that occur in proof state.
  - Will cut proof trees that only depend on trivial instantiations.
- Refined counterexample construction.
  - Switched off automatic construction.
  - Potentially costly: only on user demand.
  - Potentially large: needs simplification.
- Larger evaluation example.
  - Client/server system.
- User and reference manual.



Release in the second half of the semester.

Acknowledgements



The ProofNavigator is based on various pieces of open source software.

- CVC Lite 2.0
- RIACA OpenMath Library 2.0
- General Purpose Hash Function Algorithms Library
- ANTLR 2.7.6b2
- Eclipse Standard Widget Toolkit 3.1.2
- Mozilla Browser 1.7.8 GTK2
- GIMP Toolkit GTK+ 2.X
- Java Development Kit 5.0
- Tango Icon Library

It is important to contribute to the open source pool.