Array Program Verifier

A tool for verification and bug localization for simple program involving arrays

Content:

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- Given the program in our predefined grammar, we convert the program into set of **z3** assertions while converting it to Static Single Assignment form.
- We get the precondition P, postcondition Q and the program as S. Then we perform the verification as described earlier.

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- Given the Hoare Tuple $\{P\}\, S\, \{Q\}$ for the program, as the program is incorrect, $P\ \wedge\ S \wedge \backsim Q$ would be SAT. We find the model $\mathcal{M}$ for the assertion $P\ \wedge\ S \wedge \backsim Q$. Notice that the program fails under this model.

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- Under the model $\mathcal{M}$, the assertion $P \wedge S \wedge Q$ would be **UNSAT**. We find the MUC for the assertion $P \wedge S \wedge Q \wedge M$,where M is the conjunction of clauses as per the values assigned by the model $\mathcal{M}$.

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  3. **Verifier:** Given the precondition, postcondition and the program execution encoded as Z3 constraints, we proceed to verify the program by calling the solver on the constraints as described earlier.
  4. **Bug Localizer:** If the program verification fails in the 3rd module, then this module tries to find the unsat core of the constraint system, as described previously, to localize the possible statements cause of the error.

Structure of the Tool (Contd.)

The grammar of the program (broadly) is described below:

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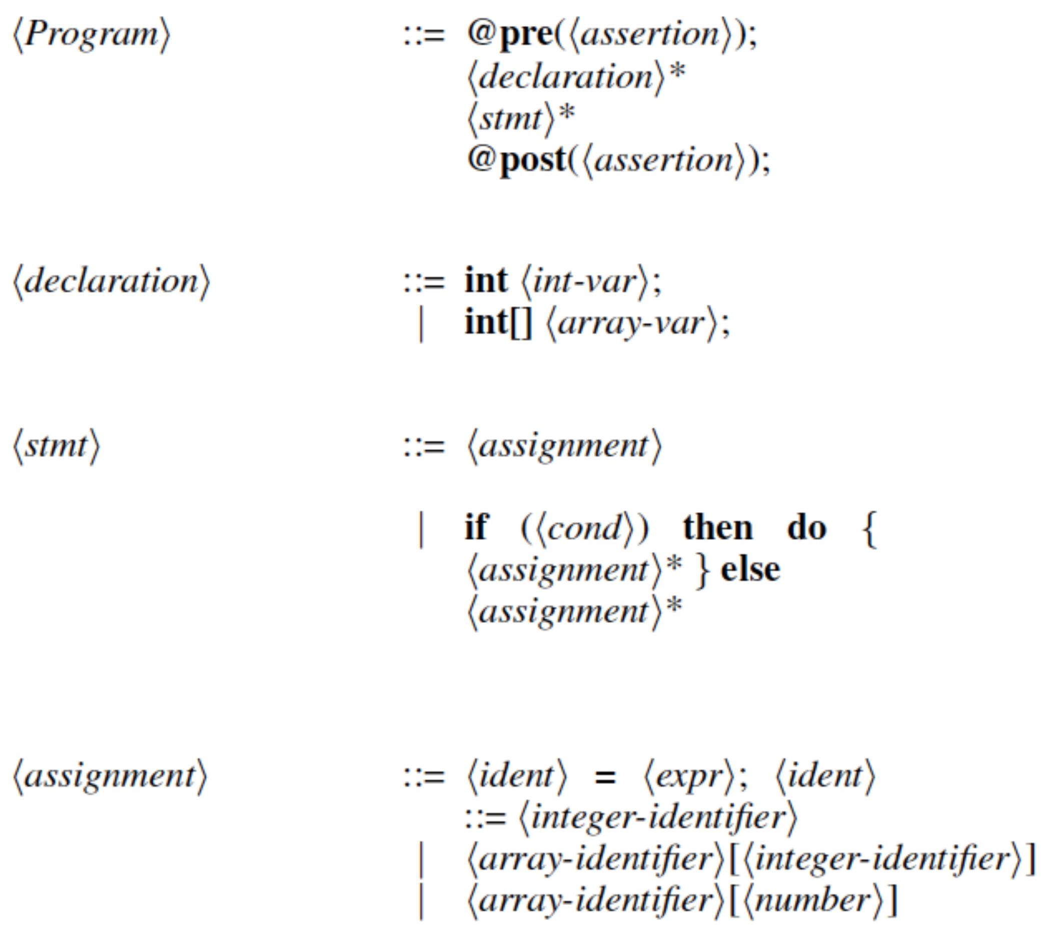


```
⟨Program⟩          ::= @pre(⟨assertion⟩);
                       ⟨declaration⟩*
                       ⟨stmt⟩*
                       @post(⟨assertion⟩);

⟨declaration⟩      ::= int ⟨int-var⟩;
                     | int[] ⟨array-var⟩;

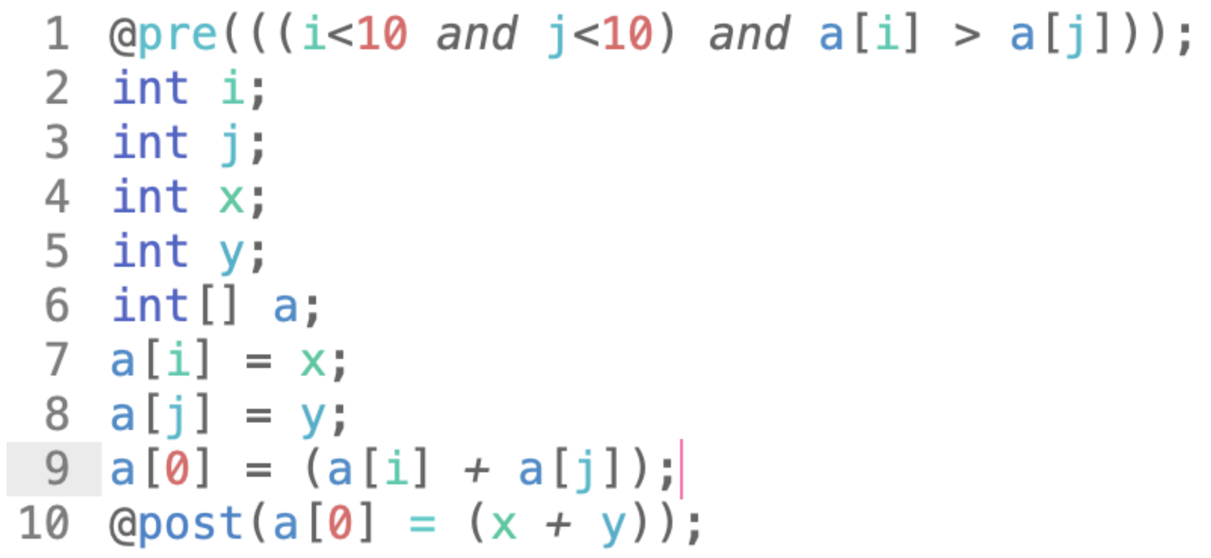
⟨stmt⟩             ::= ⟨assignment⟩

                     | if (⟨cond⟩) then do {
                       ⟨assignment⟩* } else
                       ⟨assignment⟩*

⟨assignment⟩       ::= ⟨ident⟩ = ⟨expr⟩; ⟨ident⟩
                       ::= ⟨integer-identifier⟩
                     | ⟨array-identifier⟩[⟨integer-identifier⟩]
                     | ⟨array-identifier⟩[⟨number⟩]
```

Examples.
1. Simple Sum

- We pass the following program for verification to our tool:



```
@pre(((i<10 and j<10) and a[i] > a[j]));
int i;
int j;
int x;
int y;
int[] a;
a[i] = x;
a[j] = y;
a[0] = (a[i] + a[j]);
@post(a[0] = (x + y));
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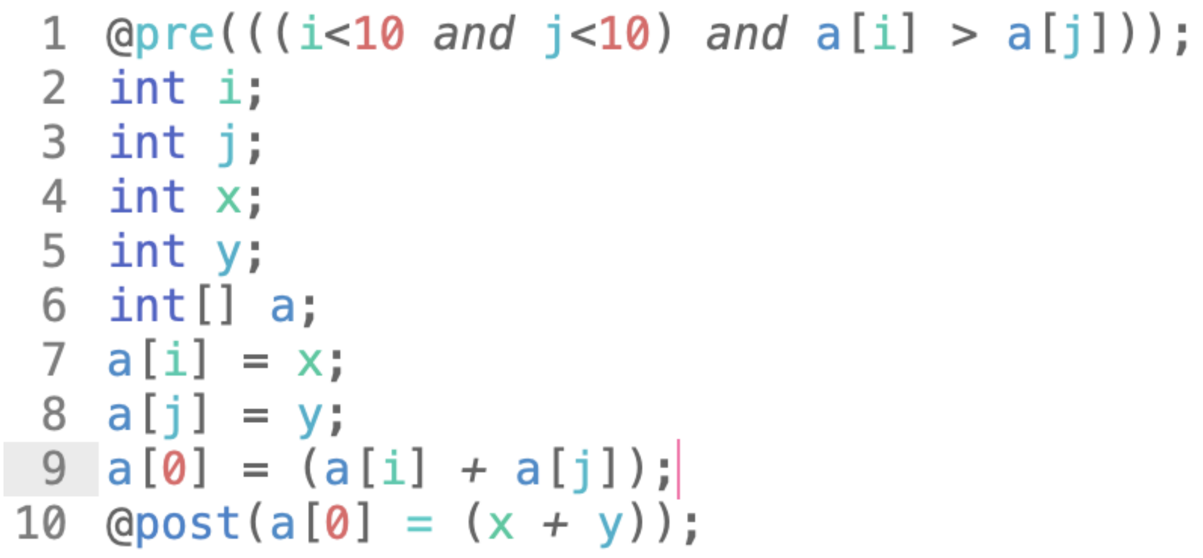

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@pre(((i<10 and j<10) and a[i] > a[j]));
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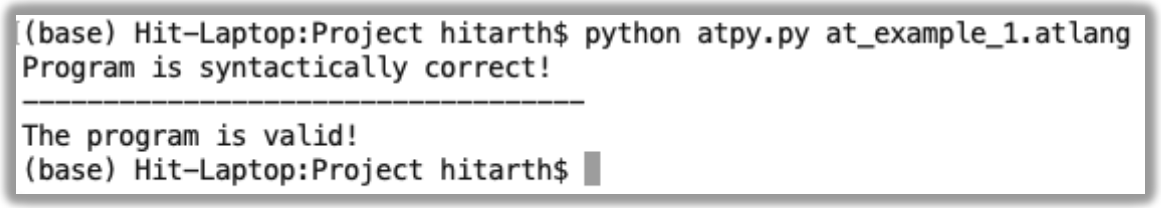
a[0] = (a[i] + a[j]);
@post(a[0] = (x + y));
```

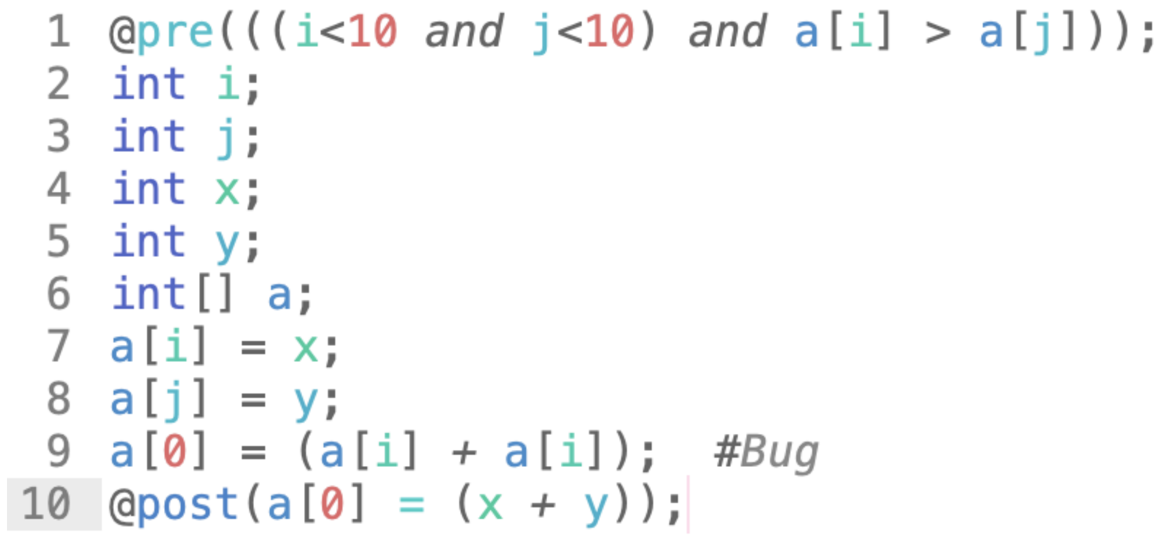
- The tool identifies the program is valid!



```
(base) Hit-Laptop:Project hitarth$ python atpy.py at_example_1.atlang
Program is syntactically correct!
--------------------------------
The program is valid!
(base) Hit-Laptop:Project hitarth$ 
```

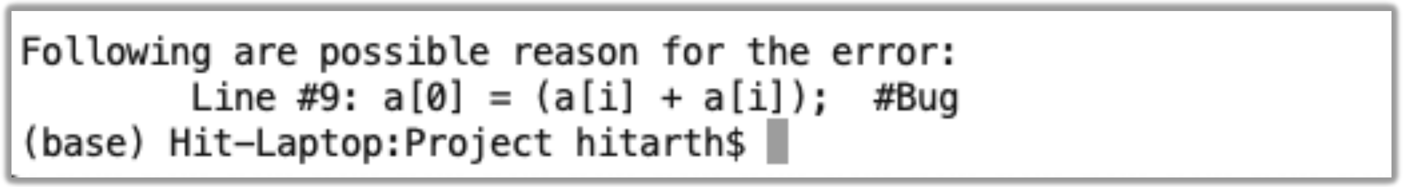
Examples.
2. Simple Sum (Buggy)

- We pass the following program for verification to our tool:



```
1  @pre(((i<10 and j<10) and a[i] > a[j]));
2  int i;
3  int j;
4  int x;
5  int y;
6  int[] a;
7  a[i] = x;
8  a[j] = y;
9  a[0] = (a[i] + a[i]);  #Bug
10 @post(a[0] = (x + y));
```

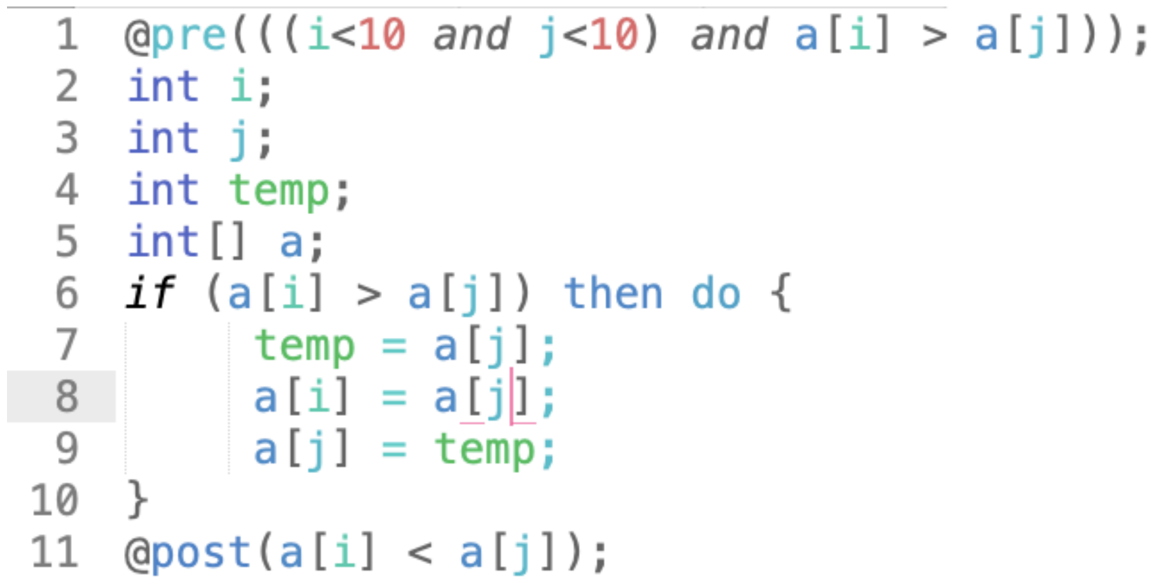
- The tool identifies the program is **invalid** and also identifies the buggy line!!



```
Following are possible reason for the error:
        Line #9: a[0] = (a[i] + a[i]);  #Bug
(base) Hit-Laptop:Project hitarth$ 
```

Examples.
2. Swap Program

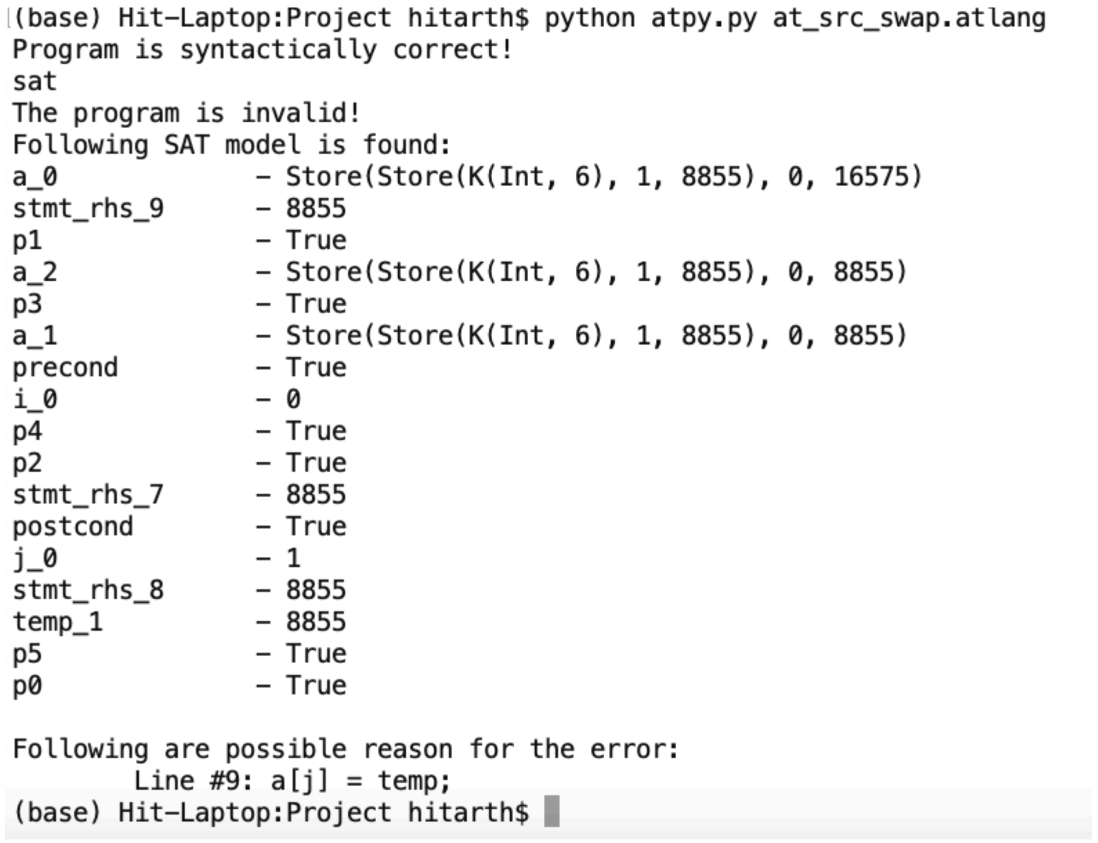
- We pass the following program for verification to our tool:



```
@pre(((i<10 and j<10) and a[i] > a[j]));
int i;
int j;
int temp;
int[] a;
if (a[i] > a[j]) then do {
        temp = a[j];
        a[i] = a[j];
        a[j] = temp;
}
@post(a[i] < a[j]);
```

Examples.
2. Swap Program

- On running this program, our tool **correctly** identifies that the program is not correct. But it outputs the bug to be due to the line #9, which is **not** correctly identified.



```
(base) Hit-Laptop:Project hitarth$ python atpy.py at_src_swap.atlang
Program is syntactically correct!
sat
The program is invalid!
Following SAT model is found:
a_0             - Store(Store(K(Int, 6), 1, 8855), 0, 16575)
stmt_rhs_9      - 8855
p1              - True
a_2             - Store(Store(K(Int, 6), 1, 8855), 0, 8855)
p3              - True
a_1             - Store(Store(K(Int, 6), 1, 8855), 0, 8855)
precond         - True
i_0             - 0
p4              - True
p2              - True
stmt_rhs_7      - 8855
postcond        - True
j_0             - 1
stmt_rhs_8      - 8855
temp_1          - 8855
p5              - True
p0              - True

Following are possible reason for the error:
        Line #9: a[j] = temp;
(base) Hit-Laptop:Project hitarth$ 
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- It cannot always localize the bug correctly, and sometimes can't find the bug at all.
- The tool presently doesn't supports loops. We shall try to include that in future.
- We can make the bug localization better by trying MAXSAT instead of MUC as sometimes Z3 cannot find the unsat core.

The End.