Automatic Extraction of Abstract-Object-State Machines Based on Branch Coverage

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Agenda

- Motivation
- Related Work
- Example
- Object State Machine (OSM)
- Framework
- Conclusion and Future work

Motivation

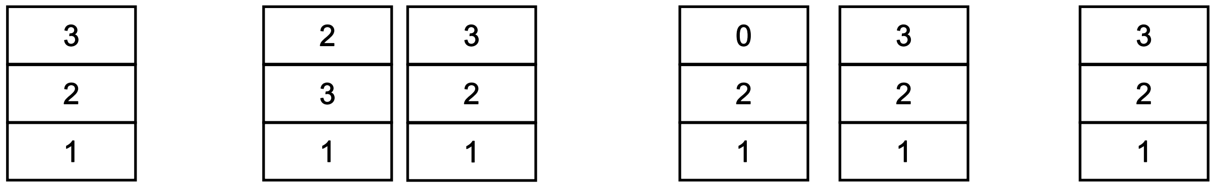
- Software specifications are useful
  - but they often do not exist
- Object State Machine (OSM) can be inferred from program executions
  - but inferred concrete OSM are too complex to understand
- We propose Brastra to abstract concrete OSMs
  - based on branch coverage
  - Inferred OSMs are often succinct and useful

Related Work

- Use return values of observers to abstract concrete states [Xie and Notkin ICFEM 04]
- Use individual field values to abstract concrete states [Xie and Notkin SAVCBS 04]
- Extract statically object state models from source code [Kung et al. COMPSAC 94]
- Extract state models based on only call sequences, without using object-field values or structural coverage [Whaley et al. ISSTA 02].

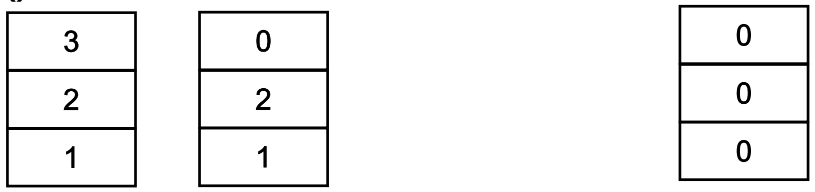
Example - UBStack

- **Unique Bounded Stack**
  - Stack capacity is bounded (e.g., set as 3).
  - No duplicated elements in the stack.
  - push(x):



push(3) **push(3)** **push(3)** **push(4)error**

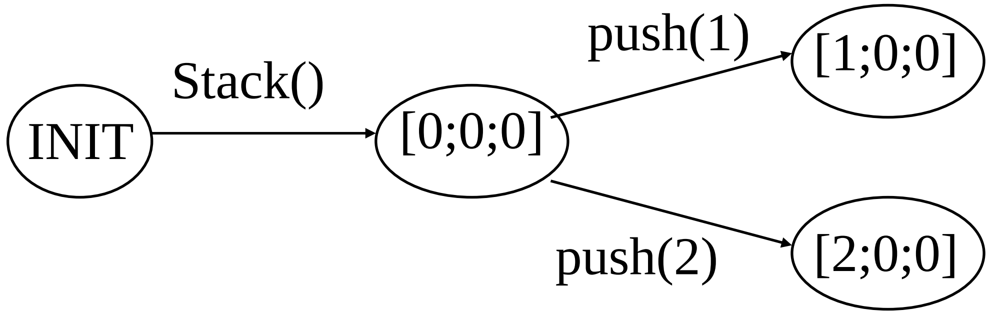
  - Pop():



pop() **pop() error**

Specify Object Behavior with Object State Machine (OSM)

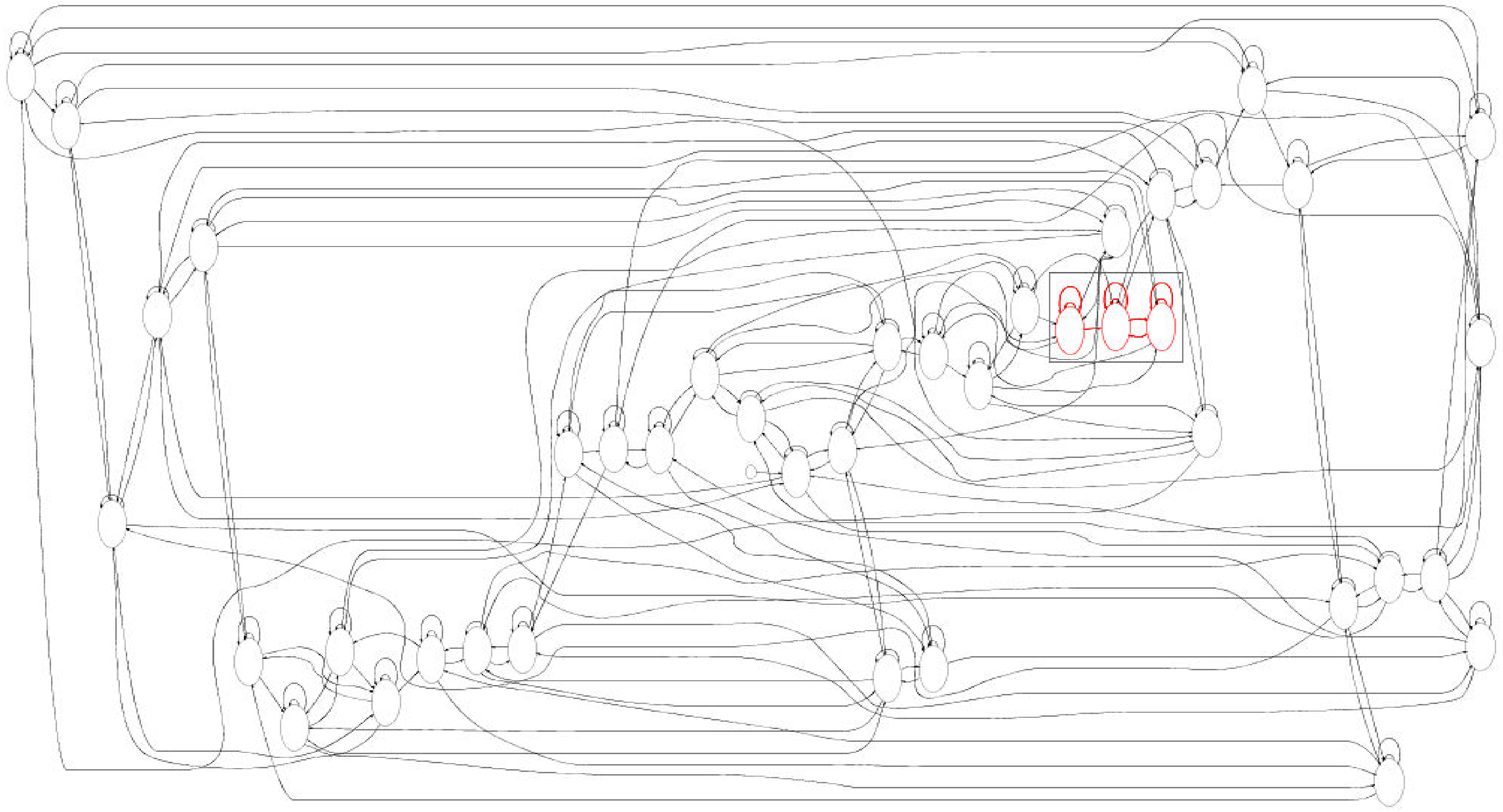
- **OSM: A sextuple (I, O, S, δ , λ , INIT)**
  - I: set of method calls in the class interface.
  - O: set of return values of the method calls.
  - S: set of object’s states.
  - INIT∈S: initial state of the state machine.
  - δ : state transition function. S x I ➔ P(S)
  - λ : output function. S x I ➔ P(O)
  - P(S) and P(O) are power set of S and O, respectively.



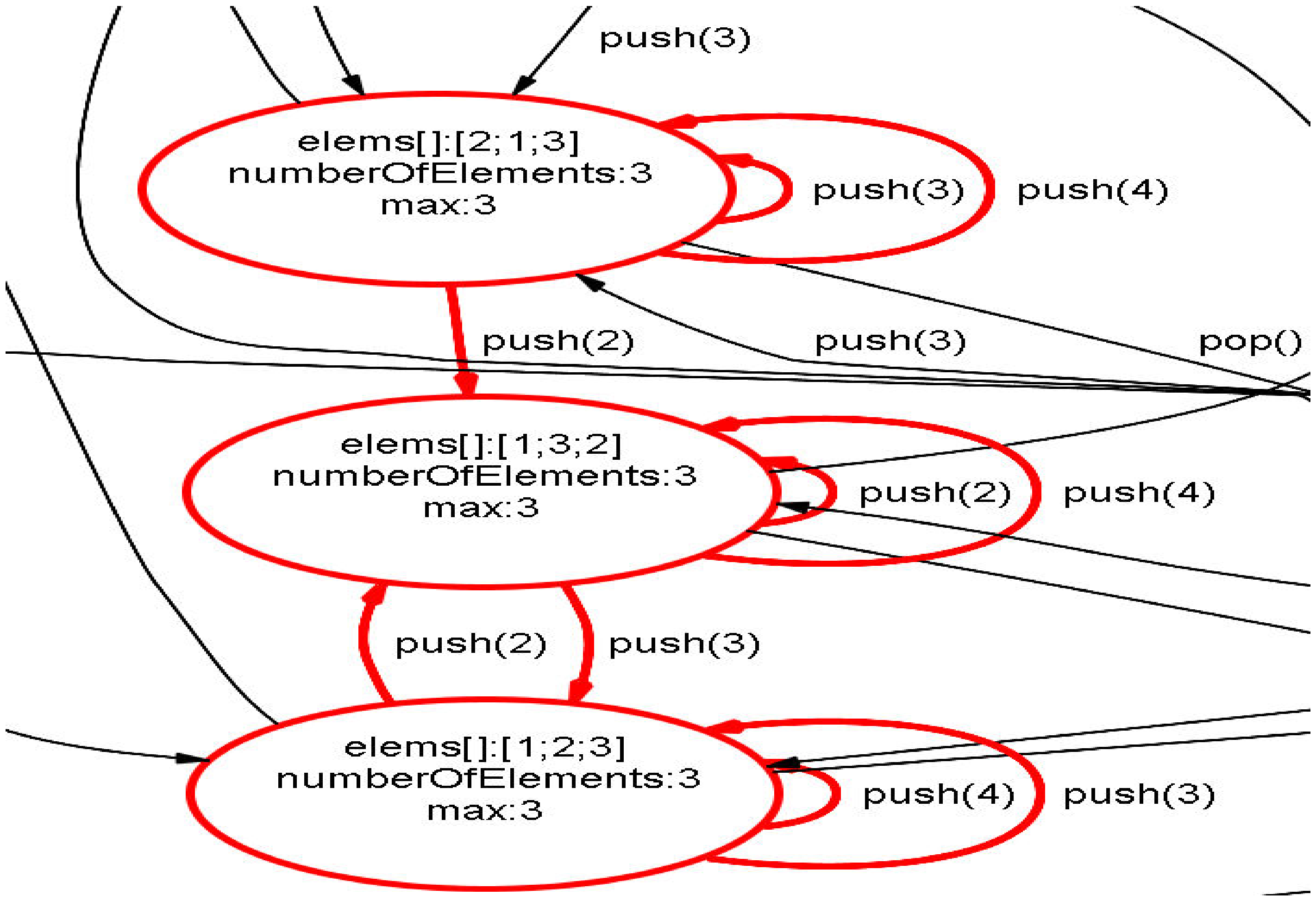
Build Concrete OSMs

- **Generate tests for UBStack**
  - Manually configure push’s argument to be 1,2,3,4
  - Default stack elements are 0.
  - Automatically generate 263 test cases with Rostra [Xie et al. ASE 04]
- **Collect test execution information with Daikon** [Ernst et al. TSE 01]**.**
- **Build concrete OSMs from Daikon traces.**
  - State: values of object fields.
  - Transition: method calls (with arguments).
  - 41 states and 142 transitions.

Concrete OSM of UBStack - Overview

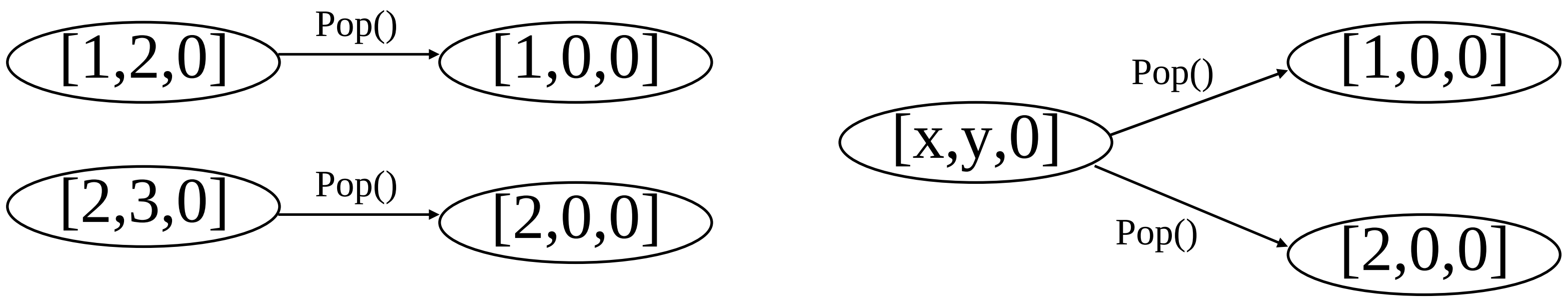


Concrete OSM of UBStack - Details



Brastra Framework

- **Basic idea:**
  - Partition concrete states based on the branch coverage of the methods invoked on these states.



- **Procedure:**
  - Build concrete OSMs from Daikon traces.
  - Collect branch coverage using modified jusc tool [Xie&Notkin JASE 06].
  - Merge concrete states based on branch coverage

Define Branch Coverage with Conditional Set

```
public int pop(){
  int ret = -1;
3:if (numberOfElements > 0) {
    …
n:} else { … }
  return ret;
}
```

A. UBStack.

```
private void syncMenu(){
   …
6: if (bugInstance != null) {
     …
     selectSeverity(severity);
     …
   }
}
private void selectSeverity(int
   severity) {
   …
5: for (int
   i=0;i<severityItemList.length;i++)
   {…}
   …
}
```

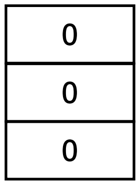
B. findbugs.classify.SeverityClassificationPulldownAction

Collect Branch Coverage

concrete states

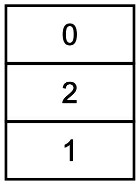
branch coverage

- UBStack:



➔ `pop(): numberOfElements > 0 = false`

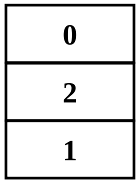
- UBStack:



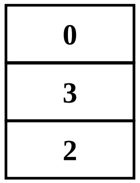
➔ `pop(): numberOfElements > 0 = true`

Group States by Branch Coverage

concrete states | branch coverage

- UBStack: 

➔ `pop(): numberOfElements > 0 = true`

- UBStack: 

➔ `pop(): numberOfElements > 0 = true`

Illustrating Example

```
public void push(int k) {
   int index; boolean alreadyMember = false;
   for(index=0; index<numberOfElements; index++) {
       if (k==elems[index]) {
           …
       }
   }
   if (alreadyMember) {
       for (int j=index; j<numberOfElements-1; j++)
           …
   } else {
       if (numberOfElements < max) {
           …
       } else {
           System.out.println("Stack full");
           return;
       }
   }
}
```

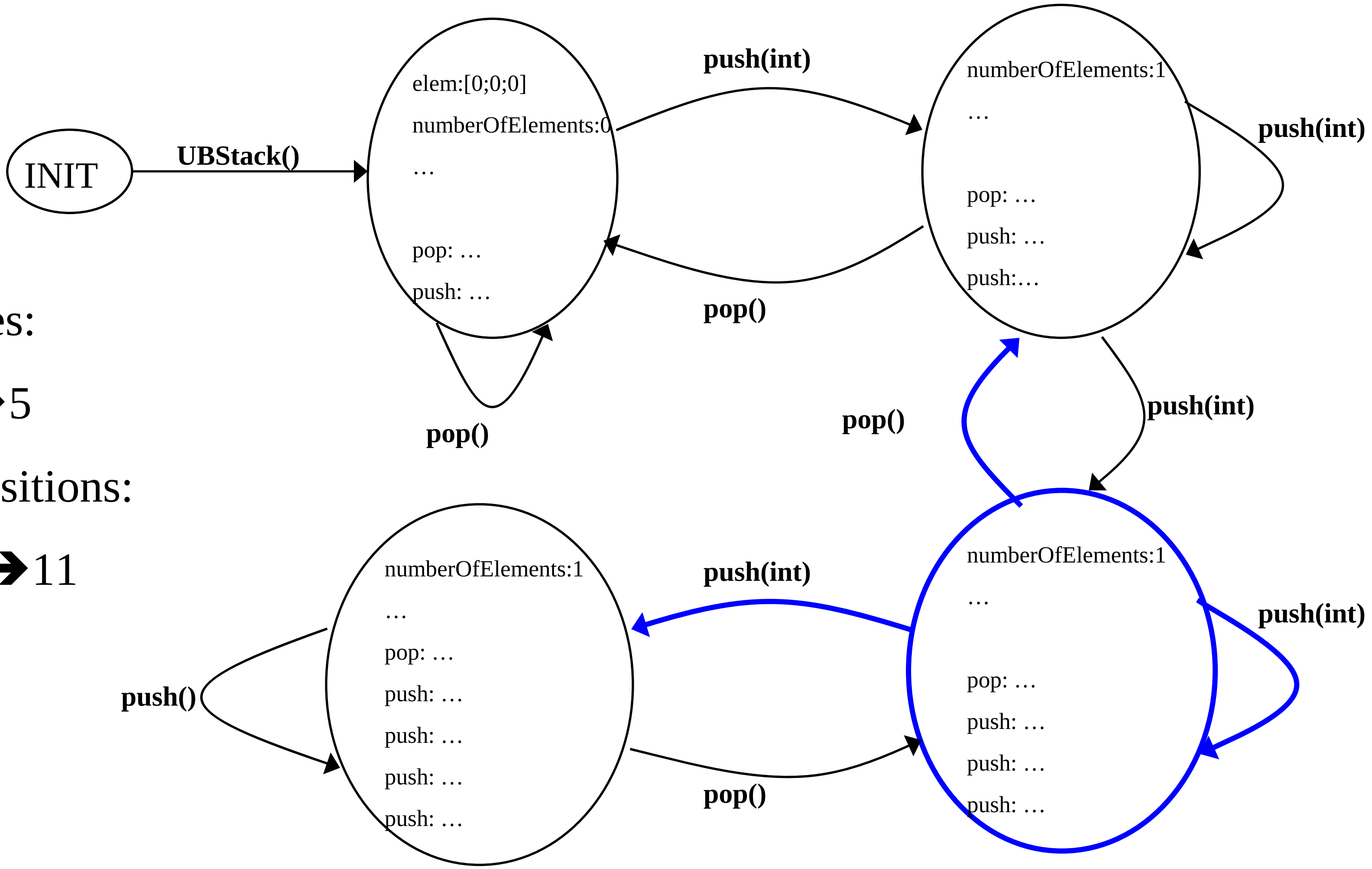
Check if k is already in the stack

k in the stack, switch it to the top

k is not in the stack, and the stack is not full

k is not in the stack, and the stack is full

UBStack – Brastra Result



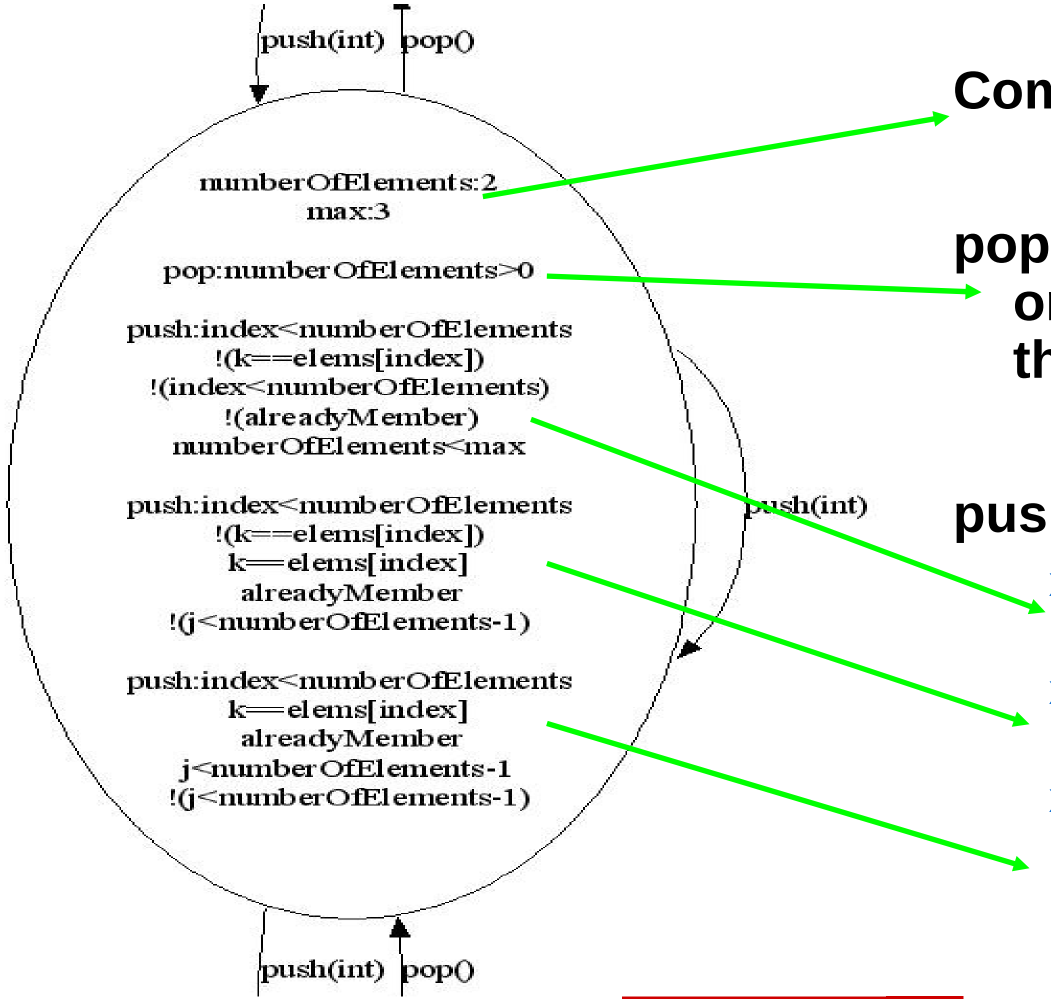
States:

41➔5

Transitions:

142➔11

Abstract State Details



Common field values

pop(): all calls of pop() on the state will take the same branch.

push(x):

- **x not in the stack and stack not full**
- **x in the stack and not at the top of the stack.**
- **x in the stack and at the top of the stack.**

Conclusion

- Software specifications are useful
  - but often do not exist
- Concrete OSMs can be inferred from program exec
  - but too complex to be useful.
- We proposed Brastra to abstract concrete OSM
  - group concrete states based on method call branch coverage
- Initial results of applying Brastra on UBStack show Brastra’s utility.

Future Work

- **Enhance Brastra with existing FSM-based testing techniques**
  - Test generation
  - Test reduction
- **Extend Brastra to multiple classes instead of one**
  - Subsystem behavior
- **Slice on fields of interests for further reduction**
- **Recover non-functional requirements.**

Questions?

Thank You!