Stack

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Agenda

01 ADT

Push, pop, peek, isEmpty, clear

02 Examples

Algebraic expression, program stack, undo/redo etc

03 Linked Stack

UML model & methods

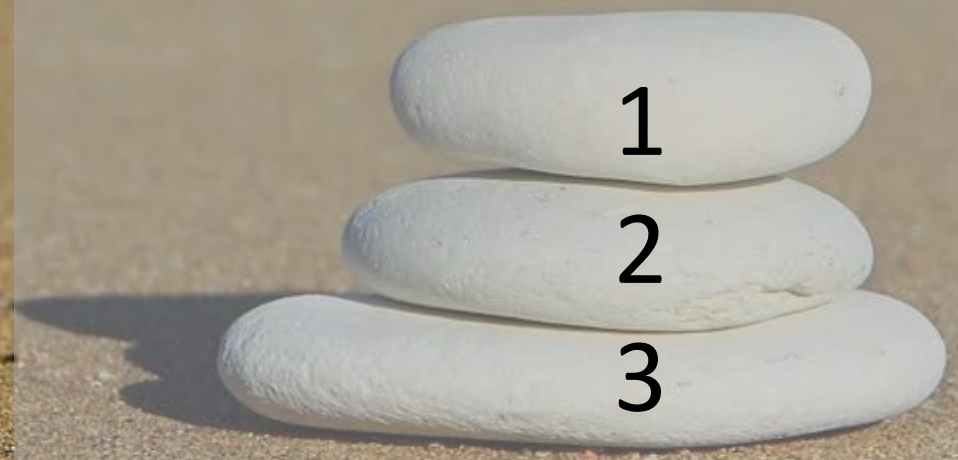
04 Array-based Stack

UML model & methods

ADT of Stack

Stack

- A stack is a data structure that removes items in the reverse order of which they were ins erted
- LIFO: Last In First Out
- A linked structure that inserts and deletes only at the head of the list is a stack



ADT if a Stack

- push:
  =add
  - Task: add a given element to the top of the stack.
  - Input: newEntry is a new entry.
- pop:
  =remove, pull
  - Task: if the stack is not empty, delete and return its top element.
  - Output: returns the task's top entry.
- peek:
  getTop
  - Task: if the stack is not empty, return its top element.
  - Output: returns the task's top entry.
- isEmpty:
  - Task: detects whether the stack is empty.
  - Output: returns true if the stack is empty.
- clear:
  - Task: removes all entries from the stack

Stack

+push(newEntry : T):void
+pop(): T
+peek(): T
+isEmpty(): Boolean
+clear(): void

An interface of the ADT Stack

```
public interface StackInterface<T>{
    /** Adds a new entry to the top of this stack.
    @param newEntry an object to be added to the stack */
    public void push(T newEntry);
    /** Removes and returns this stack's top entry.
    @return either the object at the top of the stack or, if the
    stack is empty before the operation, null */
    public T pop();
    /** Retrieves this stack's top entry.
    @return either the object at the top of the stack or null if
    the stack is empty */
    public T peek();
    /** Detects whether this stack is empty.
    @return true if the stack is empty */
    public boolean isEmpty();
    /** Removes all entries from this stack */
    public void clear();
} // end StackInterface
```

Stack
+push(newEntry : T):void +pop(): T +peek(): T +isEmpty(): Boolean +clear(): void

Build-in library, Stack

- included in java.util package

- peek: If the stack is not empty, return its top element.
- pop: If the stack is not empty, delete and return its top element.
- push: Add a given element to the top of the stack.
- size: Return the number of elements in the stack.

Usage of a Stack

- Demonstrating the stack methods: a stack of Toys

Red yoyo

black cookie man

Blue ninja

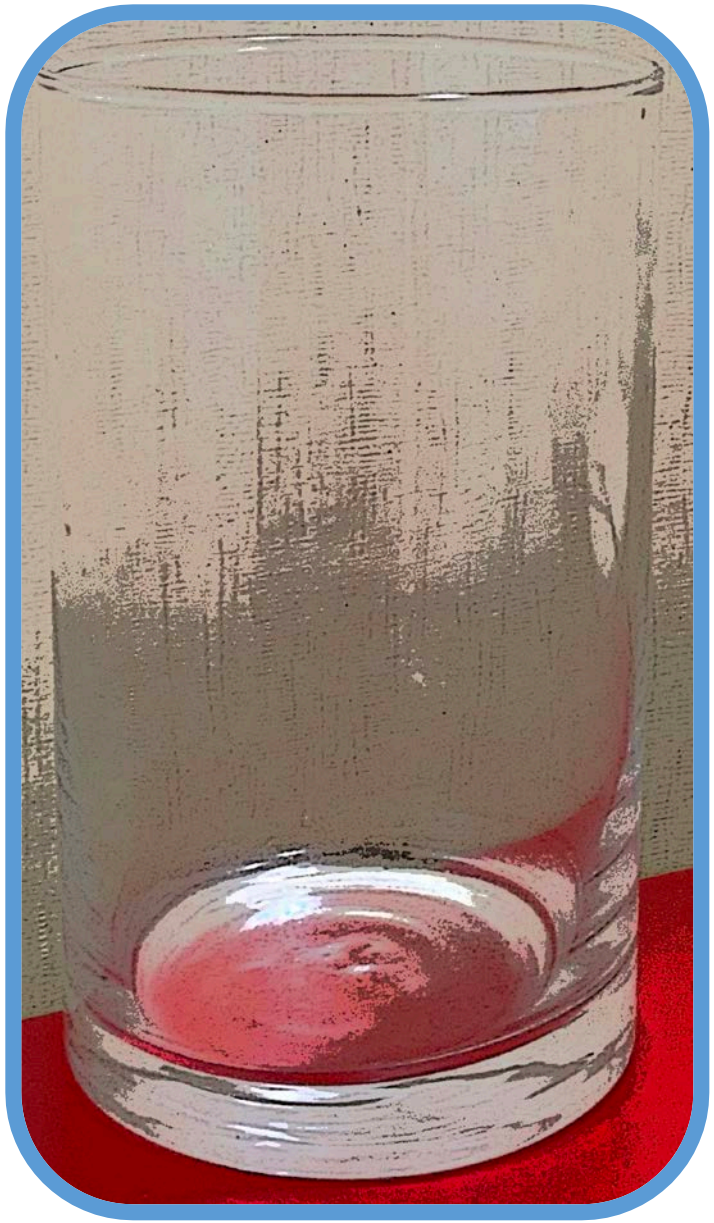
Yellow yoyo

- Demo
  1. Push

  2. Push

  3. Push

  4. Peek
  5. Size
  6. Pop
  7. Push



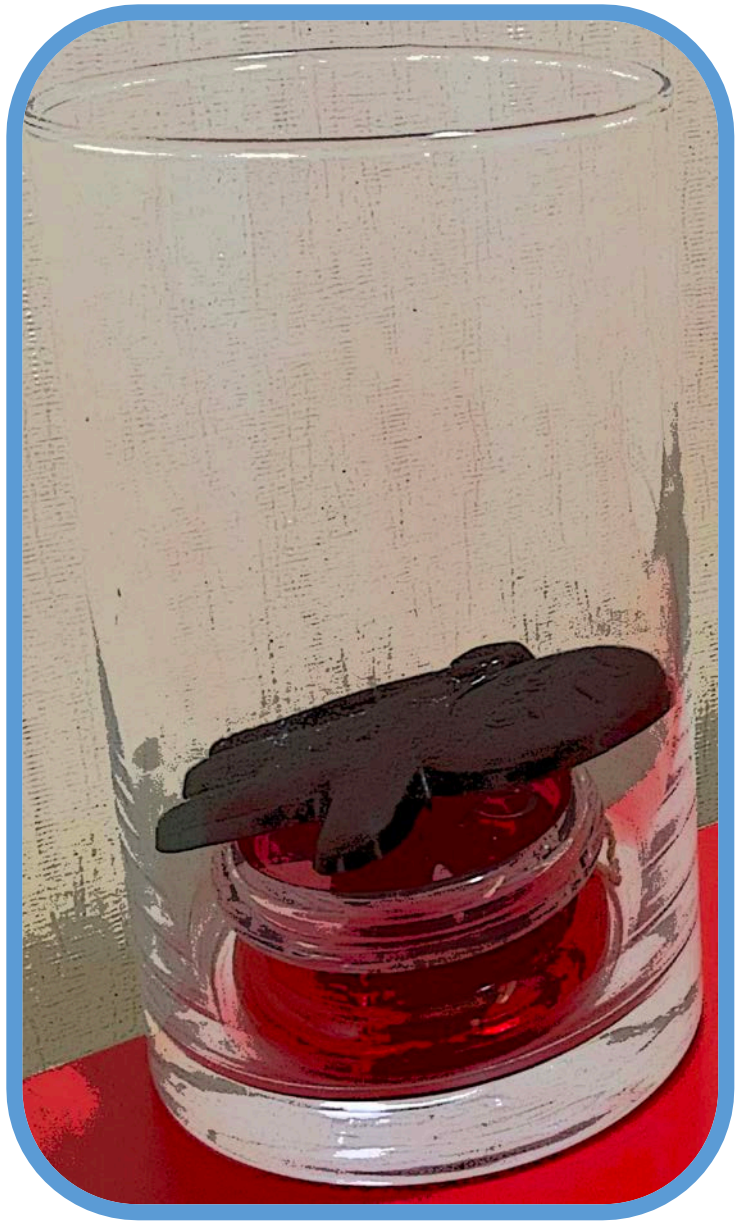
Initializing

ToyStack.java

```
1 import java.util.*;
2 public class ToyStack {
3     public static void main(String[] args) {
4         Stack<String> toys = new Stack<>();
5     }
6 }
```

Push


```java
import java.util.*;
public class ToyStack {
    public static void main(String[] args) {
        Stack<String> toys = new Stack<>();
        toys.push("Red YOYO");
    }
}
```



Push

```
import java.util.*;
public class ToyStack {
    public static void main(String[] args) {
        Stack<String> toys = new Stack<>();
        toys.push("Red YOYO");
        toys.push("Black COOKIE MAN");
    }
}
```

Push

```
import java.util.*;
public class ToyStack {
    public static void main(String[] args) {
        Stack<String> toys = new Stack<>();
        toys.push("Red YOYO");
        toys.push("Black COOKIE MAN");
        toys.push("Blue NINJA");
    }
}
```

Peek, size

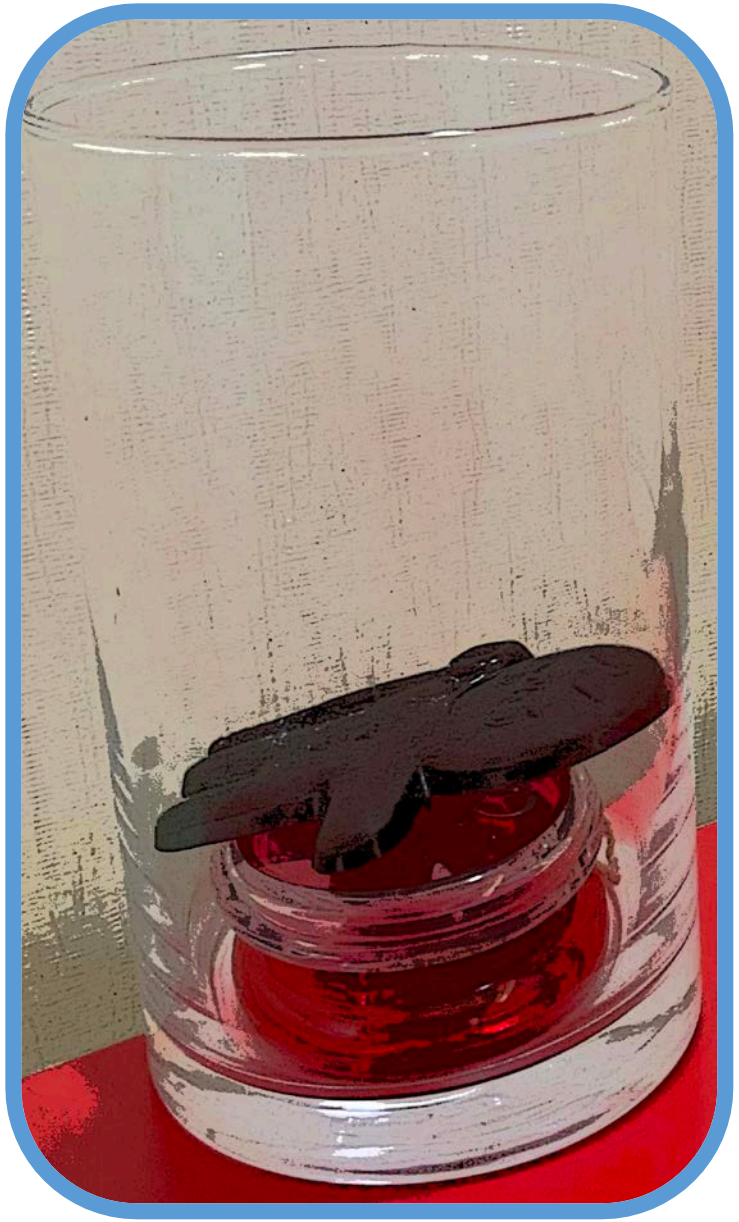
ToyStack.java

```
1  import java.util.*;
2  public class ToyStack {
3      public static void main(String[] args) {
4          Stack<String> toys = new Stack<>();
5          toys.push("Red YOYO");
6          toys.push("Black COOKIE MAN");
7          toys.push("Blue NINJA");
8          System.out.println("peek: "+ toys.peek());
9          System.out.println("size: "+ toys.size());
10     }
11 }
```

Problems Javadoc Declaration Console

<terminated> ToyStack [Java Application] C:₩Program Files₩Java₩jdk-14.0.2₩bin₩javaw.exe (2020. 9. 27. 오후 4:10:50 – 오후

```
peek: Blue NINJA
size: 3
```



pop

*ToyStack.java

```
1  import java.util.*;
2  public class ToyStack {
3      public static void main(String[] args) {
4          Stack<String> toys = new Stack<>();
5          toys.push("Red YOYO");
6          toys.push("Black COOKIE MAN");
7          toys.push("Blue NINJA");
8          System.out.println("peek: "+ toys.peek());
9          System.out.println("size: "+ toys.size());
10         System.out.println("pop: "+ toys.pop());
11     }
12 }
```

Problems Javadoc Declaration Console

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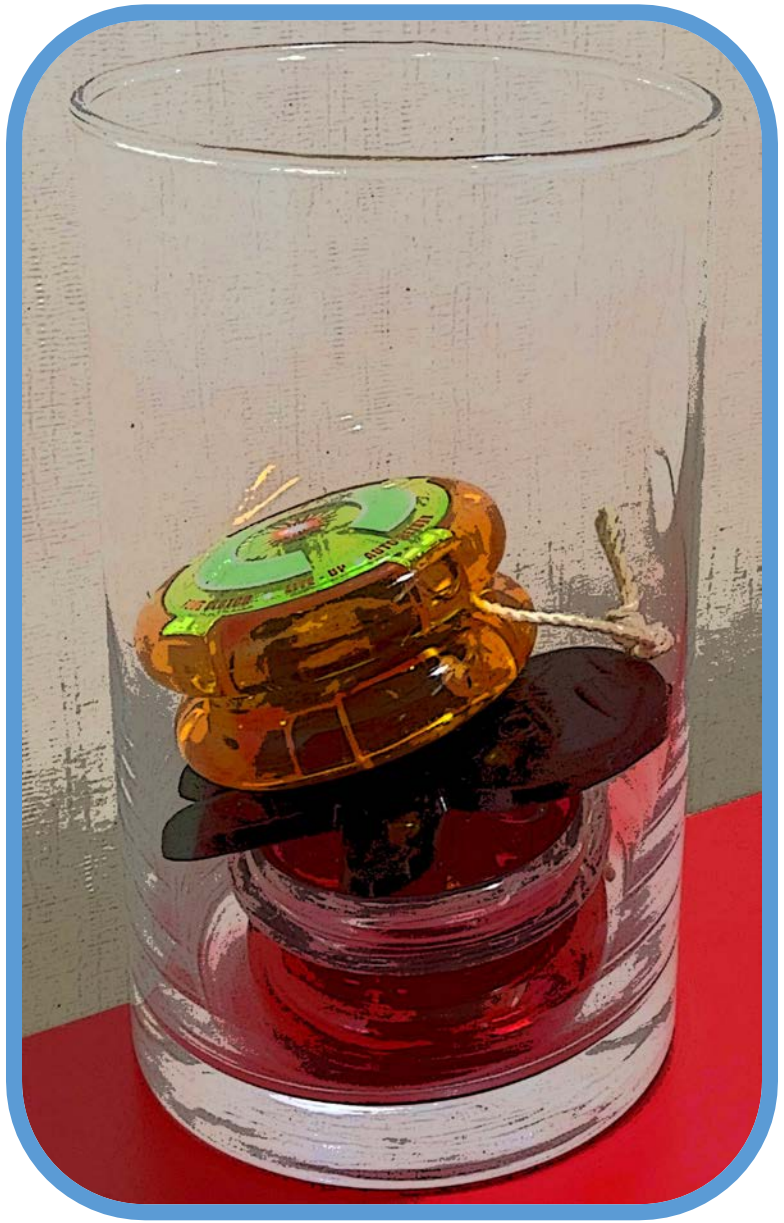
```
peek: Blue NINJA
size: 3
pop: Blue NINJA
```



Push

ToyStack.java

```
1  import java.util.*;
2  public class ToyStack {
3      public static void main(String[] args) {
4          Stack<String> toys = new Stack<>();
5          toys.push("Red YOYO");
6          toys.push("Black COOKIE MAN");
7          toys.push("Blue NINJA");
8          System.out.println("peek: "+ toys.peek());
9          System.out.println("size: "+ toys.size());
10         System.out.println("pop: "+ toys.pop());
11         toys.push("Yellow YOYO");
12         System.out.println(toys.toString());
13     }
14 }
```

Problems Javadoc Declaration Console

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```
peek: Blue NINJA
size: 3
pop: Blue NINJA
[Red YOYO, Black COOKIE MAN, Yellow YOYO]
```

Design Issue: pop or peek from an empty stack

- Return null
  - Methods such as peek and pop must b ehave reasonably when the stack is em pty.
  - In that case, the methods cannot retur n anything, so return null.

- Throws exception

pop

`public E pop()`

Removes the object at the top of this stack and returns that object as the value of this function.

Returns:

The object at the top of this stack (the last item of the `Vector` object).

Throws:

`EmptyStackException` - if this stack is empty.

peek

`public E peek()`

Looks at the object at the top of this stack without removing it from the stack.

Returns:

the object at the top of this stack (the last item of the `Vector` object).

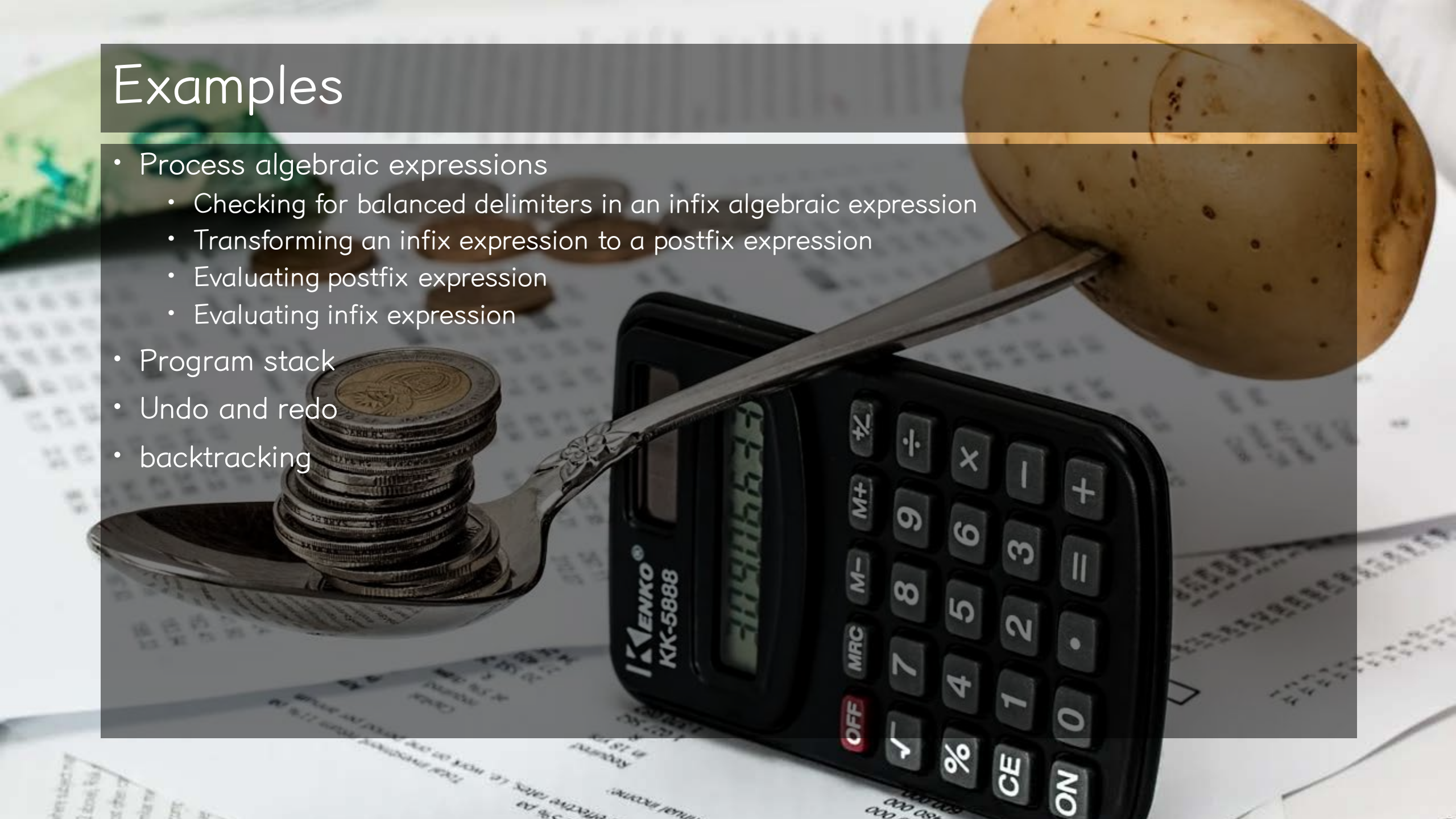
Throws:

`EmptyStackException` - if this stack is empty.

Examples of Stack

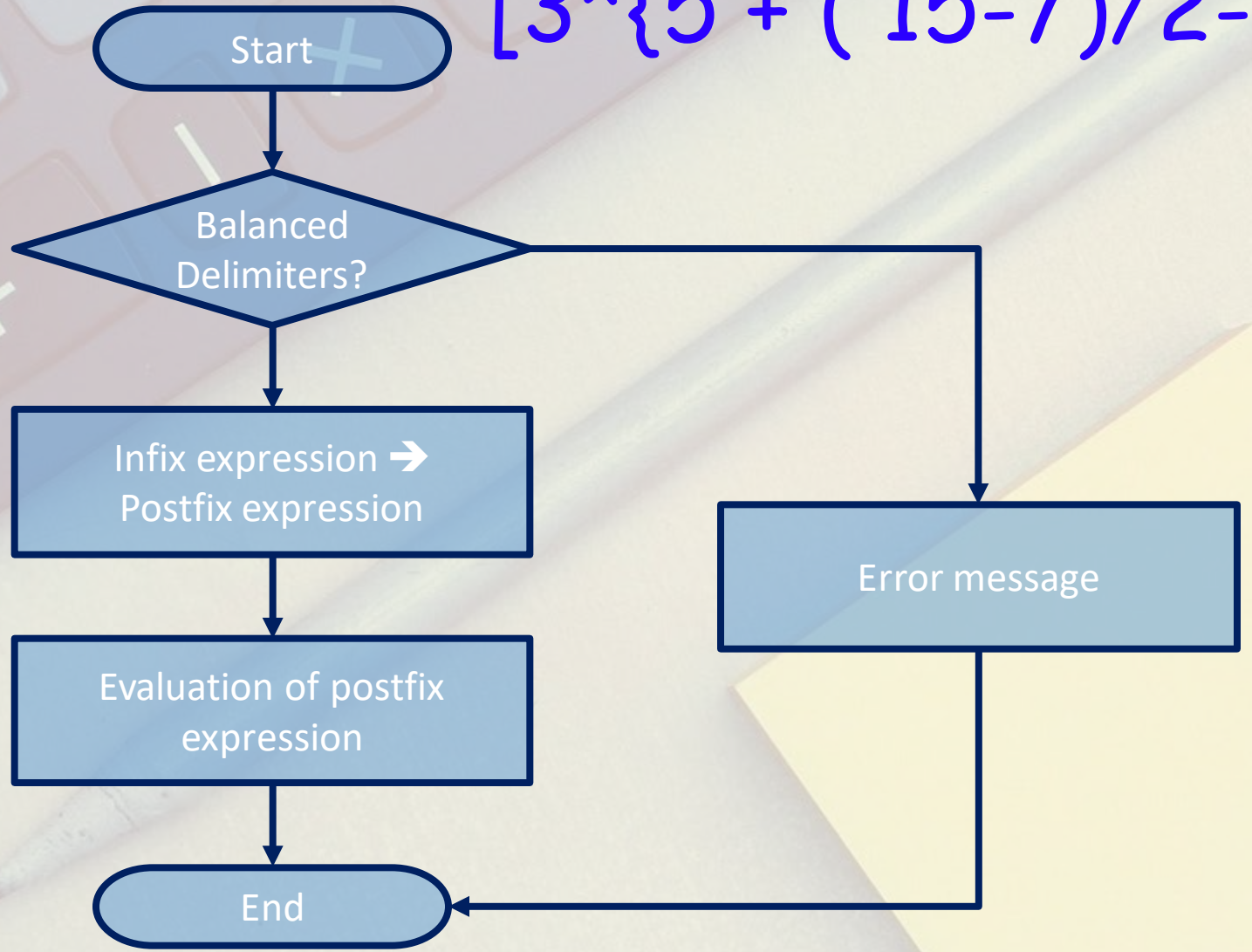
Examples

- Process algebraic expressions
  - Checking for balanced delimiters in an infix algebraic expression
  - Transforming an infix expression to a postfix expression
  - Evaluating postfix expression
  - Evaluating infix expression
- Program stack
- Undo and redo
- backtracking



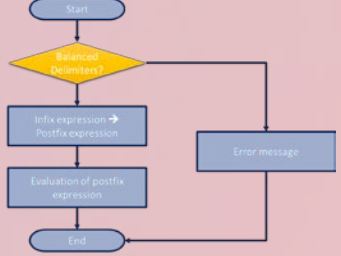
Process algebraic expressions

[3*{5 + (15-7)/2-9} +1]^2



Algebraic expression

- Infix notation
  - Example: a + b
  - A binary operator between its operands
- Prefix notation
  =Polish notation by Jan Łukasiewicz (1920s)
  - Example: + a b
  - A binary operator before its operands
- Postfix notation
  =reverse Polish notation
  Example: a b +
  - A binary operator before its operands

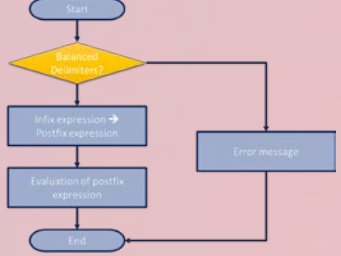


Checking for balance delimiters in an infix notation

- The type of delimiters
  - [{

- Balanced expression

[3*{5 + (15-7)/2-9} +1]^2

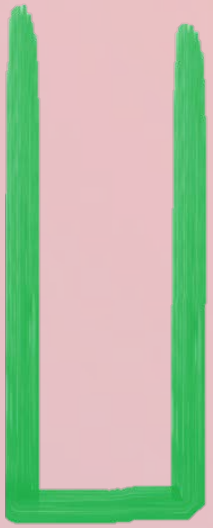


Checking for balance delimiters in an infix notation

- The type of delimiters
  - [{

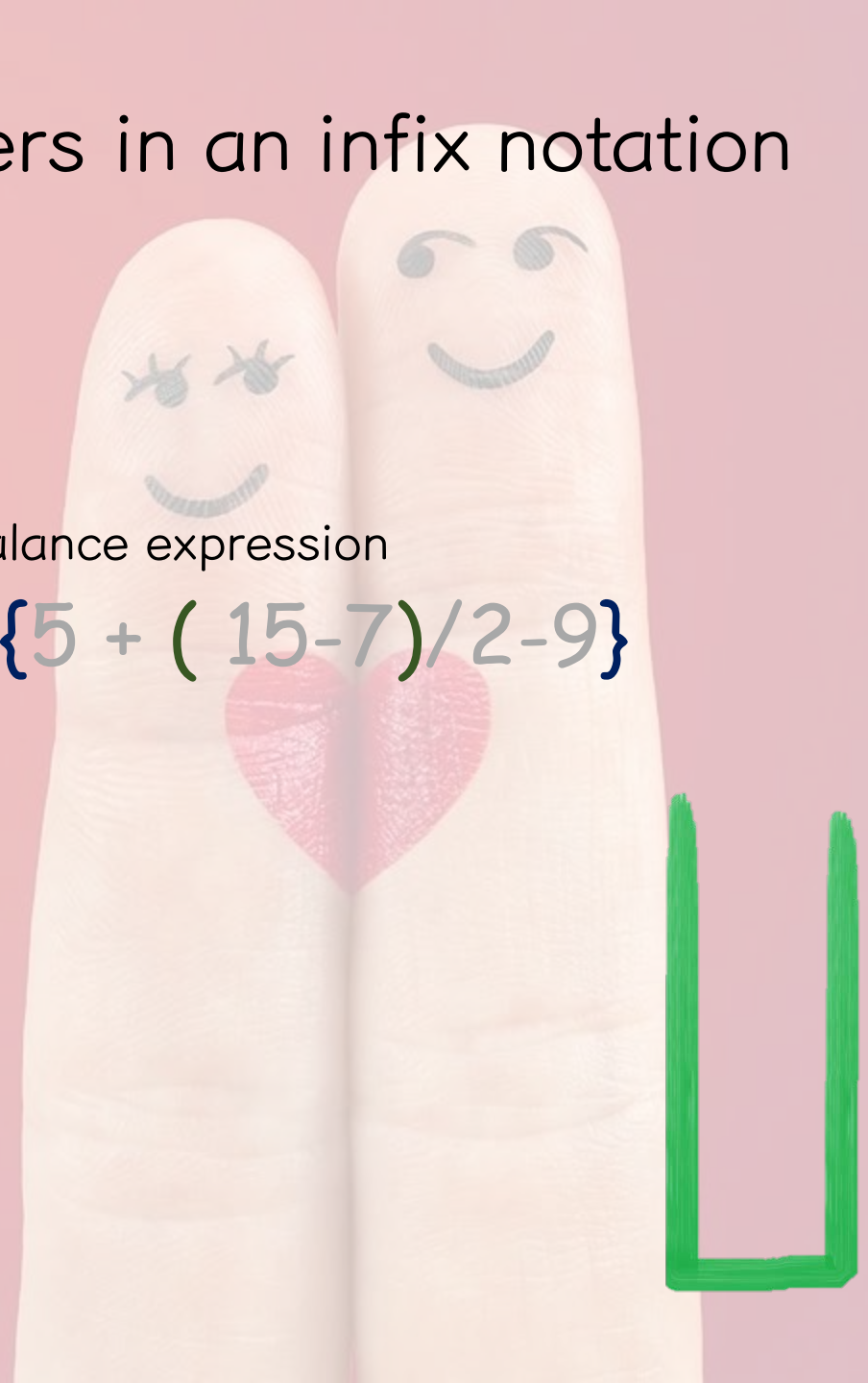
- intersecting pairs of delimiters.

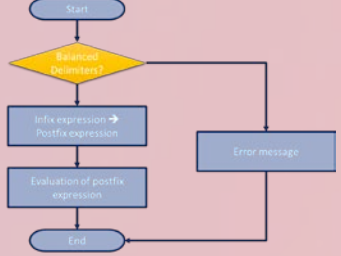
[3*{5 + (15-7}/2-9) +1]^2



- Unbalance expression

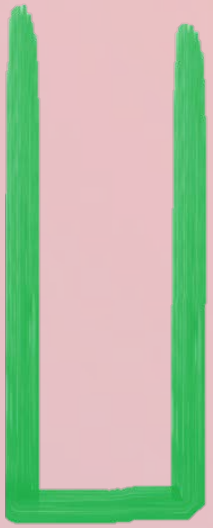
[3*{5 + (15-7)/2-9}



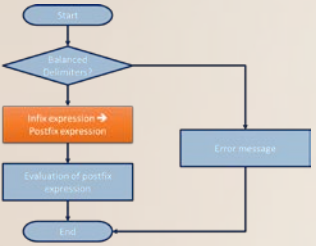


Implementation

[3*{5 + (15-7)/2-9} +1]^2



```java
/**
 * Decide whether the parentheses, brackets,
 * and braces in a string occurs in left/right pairs.
 * @param ex a string to be checked
 * @return True if the delimiters are paired correctly
 */
public boolean checkBalance(String ex) {
    // list of considering open parentheses
    Stack<Character> parenStack = new Stack<Character>();
    int charCount = ex.length();
    boolean isBalanced = true; // the absence of delimiters is balanced
    char nextCharacter = ' '; // the next character in expression
    for(int i = 0 ; isBalanced && i < charCount ; i++) {
        nextCharacter = ex.charAt(i);
        switch(nextCharacter) {
        case '(' : case '[': case '{':
            // push nextCharacter onto stack
            parenStack.push(nextCharacter);
            break;
        case ')': case ']': case '}' :
            // when we meet the right pair but there is no left pair in the stack
            if(parenStack.isEmpty()) isBalanced = false;
            // if the stack is not empty, the value of isBalanced is the
            // result of comparison between delimiters
            // of the next character and the top of the stack
            else isBalanced = isPaired(parenStack.pop(), nextCharacter);
            break;
        }
    }
    //if the stack still has open delimiters after see all string,
    // the delimiters are not paired correctly.
    if(!parenStack.isEmpty()) isBalanced = false;
    return isBalanced;
}
/**
 * Decide whether open and close make a pair correctly.
 * @param open one of open parentheses, brackets, or braces
 * @param close one of close parentheses, brackets, or braces
 * @return True if the given characters, open and close, form
 * a pair of parentheses, brackets, or braces
 */
private boolean isPaired(char open, char close) {
    return (open == '(' && close == ')') ||
           (open == '[' && close == ']') ||
           (open == '{' && close == '}') ;
}
```

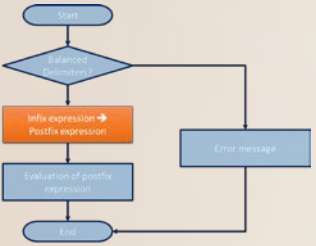


Infix notation → postfix notation

- Examples of infix and postfix expressions

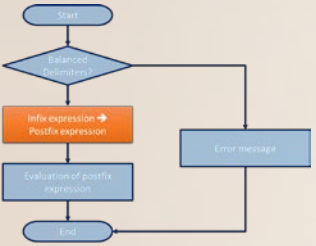
infix	postfix
a+b	a b +
(a+b)*c	a b + c*
a+b*c	a b c * +

- The evaluation of an infix expression is complex because of
  - the precedence of the operators
  - parentheses.
  - Solution:
    - Fully parenthesized infix notation: ((a+b)*c), (a+(b*c))
    - Infix expression ➔ postfix expression



Conversion rule

Next character	Action
Operand such as number(1, 2, 3 …) or variables	Append each operand to the end of the output expression.
Operator ^	Push ^ onto the stack.
Operator +, -, * , or /	Pop operators from the stack, appending them to the output expression, until the stack is empty or its top entry has a lower precedence than the new operator. Then push the new operator onto the stack.
Open parenthesis, bracket, brace	Push it onto the stack.
Close parenthesis, bracket, brace	Pop operators from the stack and append them to the output expression until an open parenthesis is popped. Discard both parentheses.



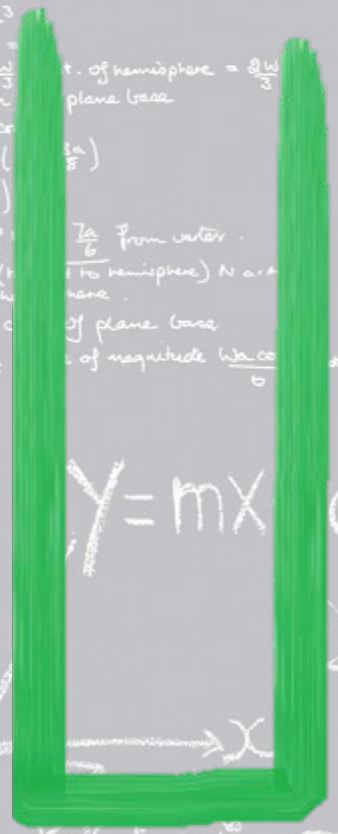
Implementation

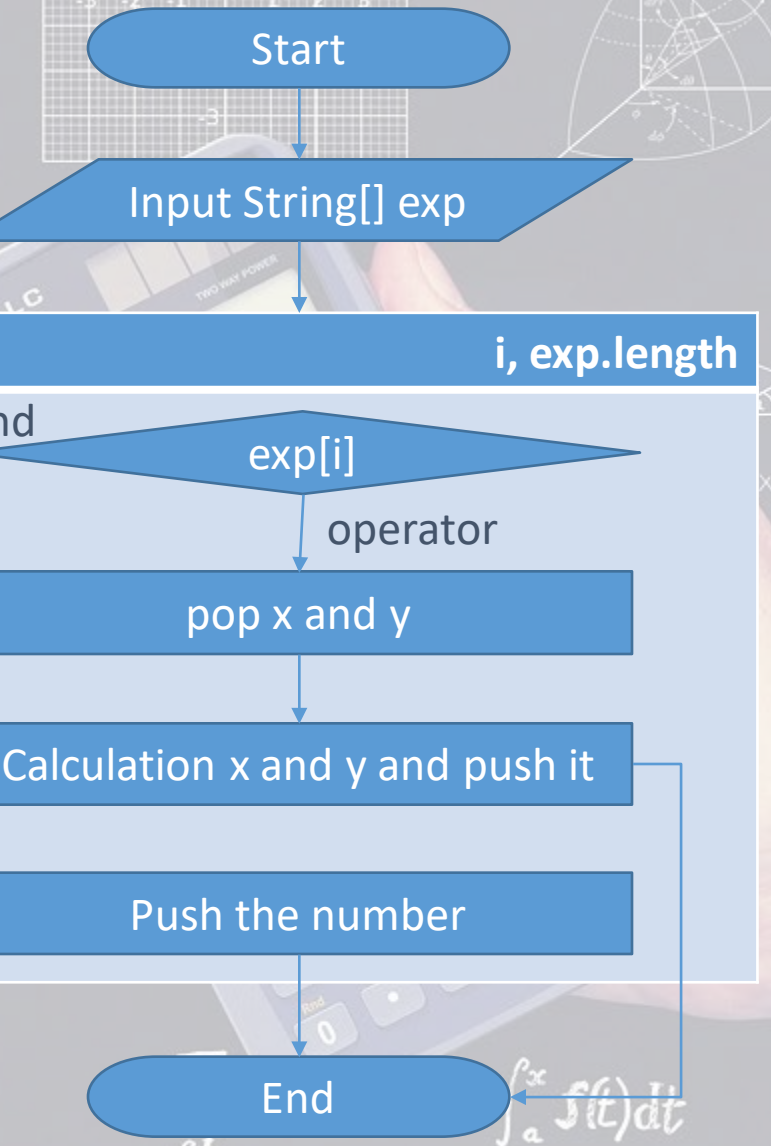
- [3*{5 + (15-7)/2-9} +1]^2
- Result:

```
public String[] infix2postfix(String[] infix) {
    Stack<String> operatorStack = new Stack<>();    // a new empty stack
    System.out.println(Arrays.toString(infix));
    String[] postfix = new String[infix.length]; // a new empty string
    int size = 0;
    try {
        for(int i = 0 ; i < infix.length ; i++) {
            String next = infix[i]; // next non character left to parse
            switch(next) {
            case "^":
                operatorStack.push(next);
                break;
            case "+": case "-": case "*": case "/":
                while(!operatorStack.isEmpty() &&
                      precedence(next) <= precedence(operatorStack.peek()))
                        postfix[size++]=operatorStack.pop();
                operatorStack.push(next);
                break;
                case "(": case "{":case "[":
                    operatorStack.push(next);
                    break;
                case ")": case "}": case "]":
                    String topOperator = operatorStack.pop();
                    while("({[".indexOf(topOperator)<0) {
                        postfix[size++] = topOperator;
                        topOperator = operatorStack.pop();
                    }
                    break;
                default:
                    postfix[size++]=next;
                    break;
            }
        }
    }catch (Exception e) {
        System.err.println(e.getMessage());
        System.exit(-1);
    }
    while(!operatorStack.isEmpty())
        postfix[size++]= operatorStack.pop();
    String[] result = new String[size];
    for(int i = 0 ; i < size ; i++)
        result[i]=postfix[i];
    return result;
}
```

Algorithm

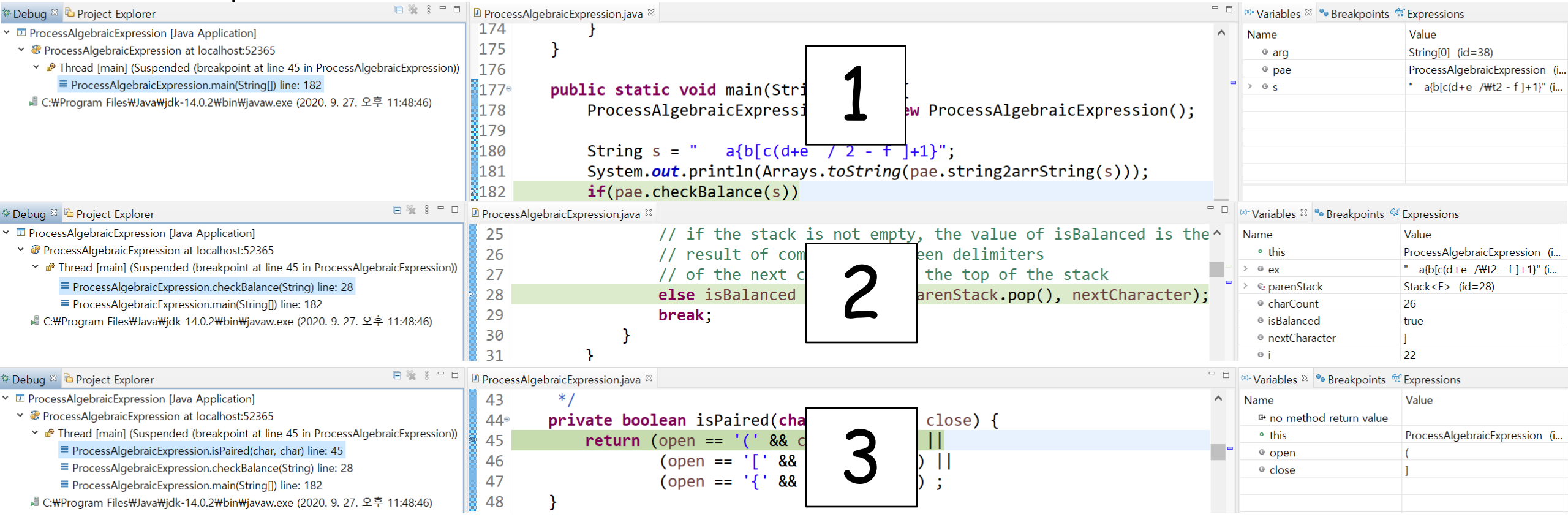
3 5 15 7 - 2 / + 9 - * 1 + 2 ^





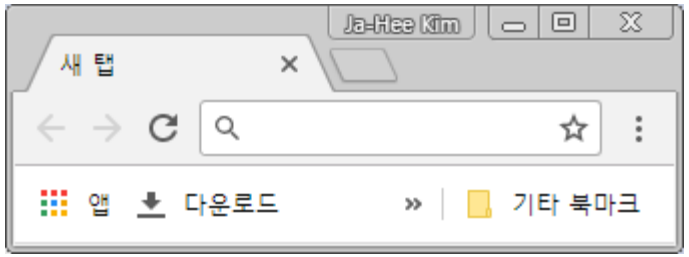
Program stack

- Terminology
  - Program counter references the current instruction.
  - Activation record(frame) is an object tha run-time environment creates for the method.
  - Program stack is a stack onto which an activation record is pushed
- Example: main ➔ checkBalance ➔ isPaired



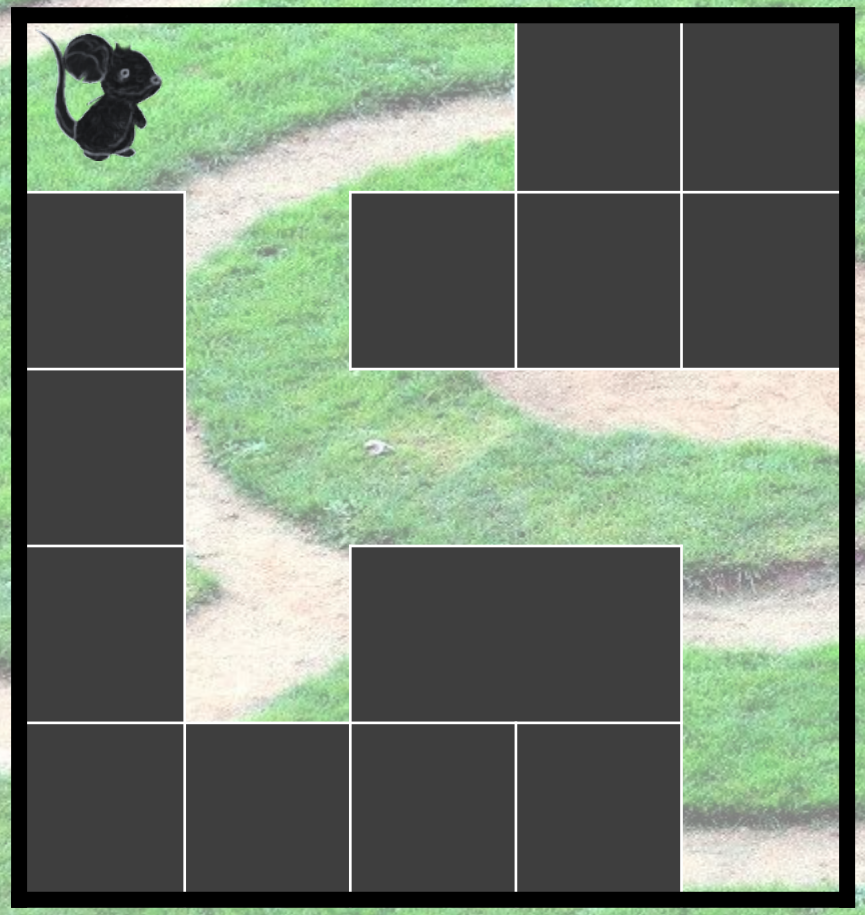
Undo and redo

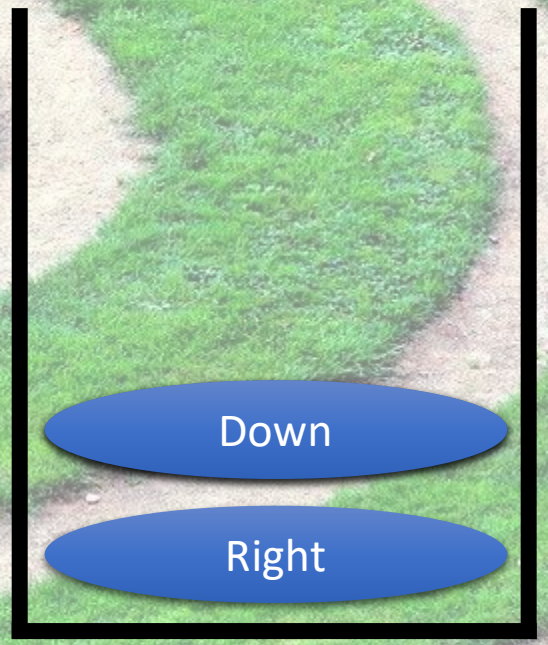
- Backward & Forward button: site address



- Undo and redo: action

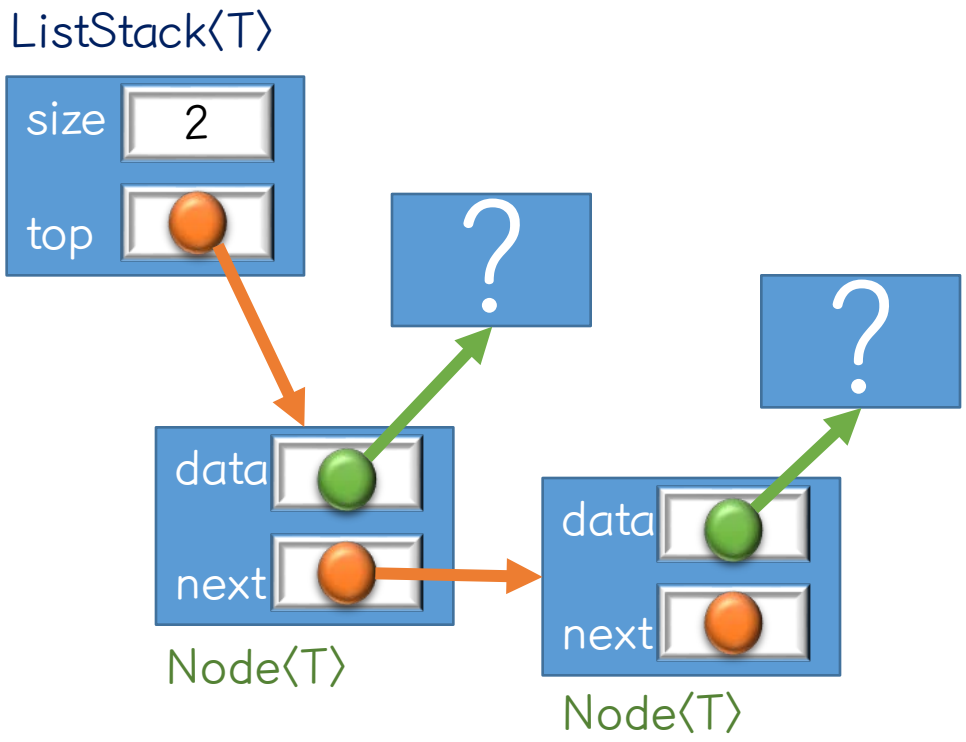
Backtracking





Linked Stack

Outline of the class



the size of the stack

top points the last pushed node

ListStack<T>

- size: int
- top: Node<T>

+ push(T newItem)
+ peek(): T
+ pop(): T
+ isEmpty(): Boolean
+clear(): void
+size():int
+toString(): String

Node<T>

- data: T
- next: Node<T>

+ Node<T>()
+ Node<T>(T data, Node<T> next)

Method push

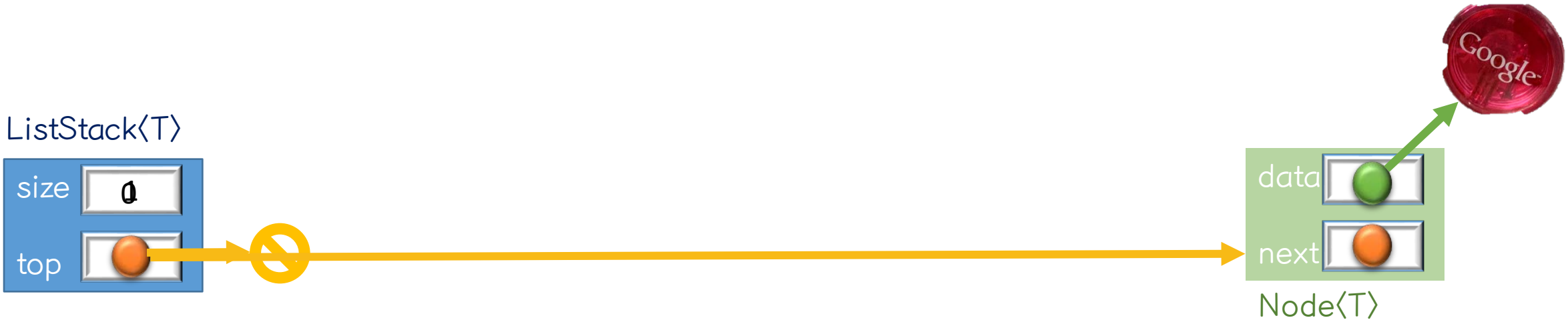
- Client program

```
toys.push("Red YOYO");
```

- In class LinkedStack

```
public void push(T newEntry) {
     top = new Node(newEntry, top);
     size++;
}
```

O(1)



Method push

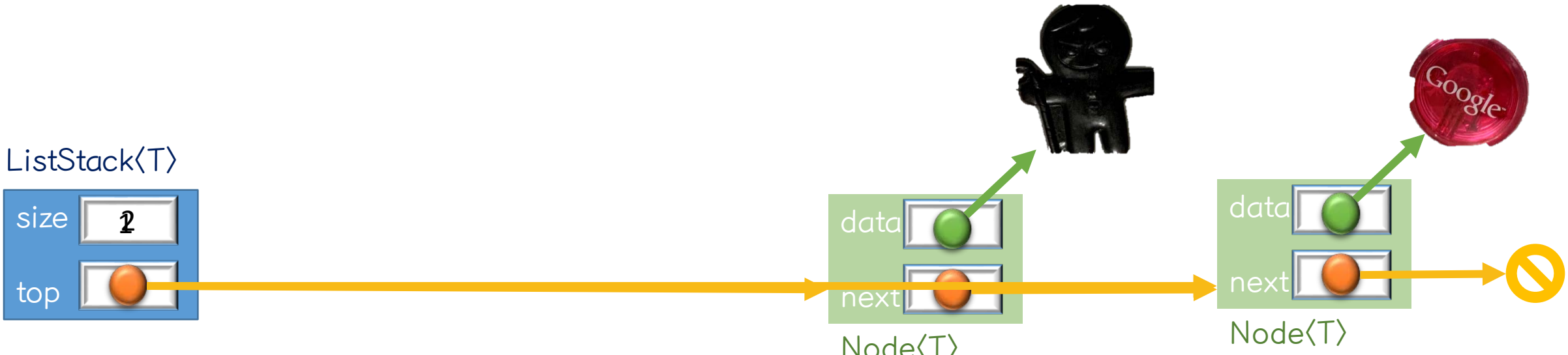
- Client program

```
toys.push("Red YOYO");
toys.push("Black COOKIE MAN");
```

- In class LinkedStack

```
public void push(T newEntry) {
     top = new Node(newEntry, top);
     size++;
}
```

O(1)



Method push

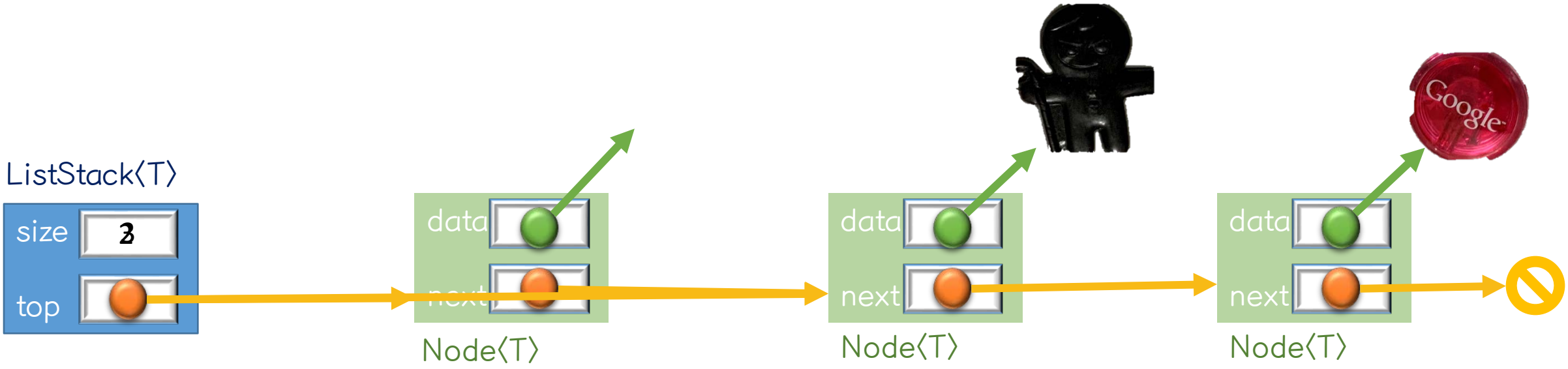
- Client program

```
toys.push("Red YOYO");
toys.push("Black COOKIE MAN");
toys.push("Blue NINJA");
```

- In class LinkedStack

```
public void push(T newEntry) {
     top = new Node(newEntry, top);
     size++;
}
```

O(1)



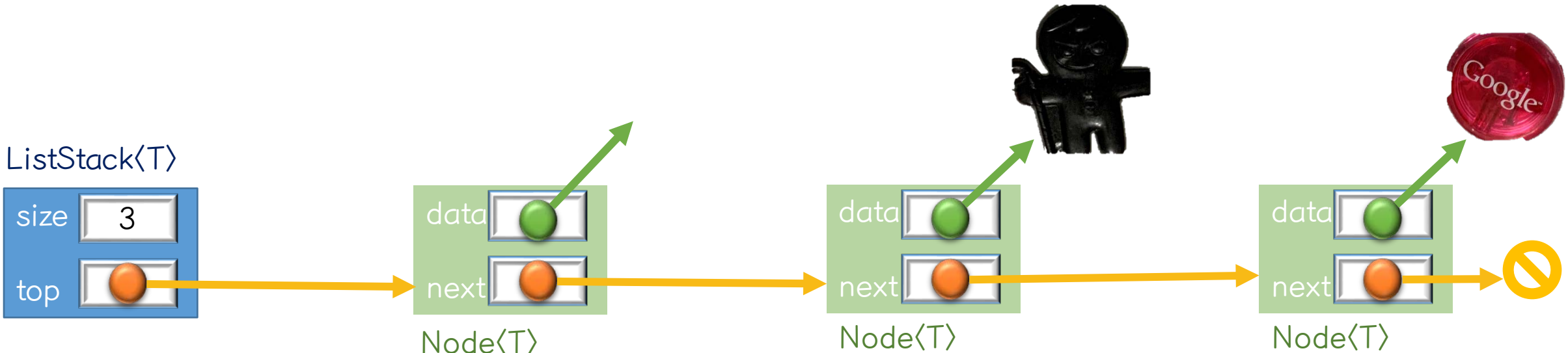
Method peek and size

- Client program

```
System.out.println("peek: "+ toys.peek());
System.out.println("size: "+ toys.size());
```

- In class stack

```
public T peek() {                                    O(1)
    T result = null;
    if(top!=null) result = top.data;
    return result;
}                                                    O(1)
public int size() {
        return size;
}
```



Method pop

- Client program

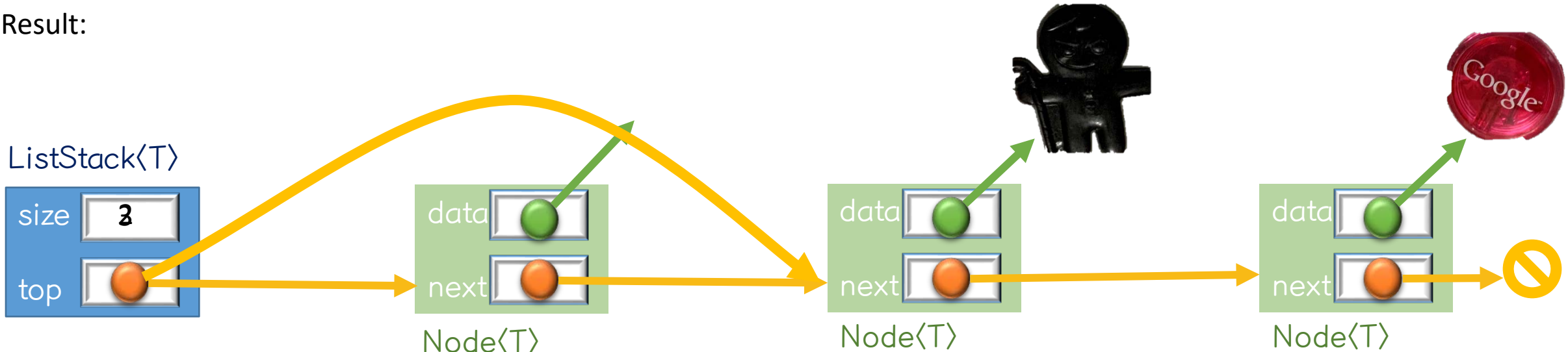
```
System.out.println("pop: "+ toys.pop());
```

- In class stack

```
public T pop() {
    T result = peek();
    if(top!=null) {
        top = top.next;
        size--;
    }
    return result;
}
```

O(1)

Result:



Method isEmpty

- Client program

```
System.out.println("isEmpty: "+
                        toys.isEmpty());
```

- In class stack

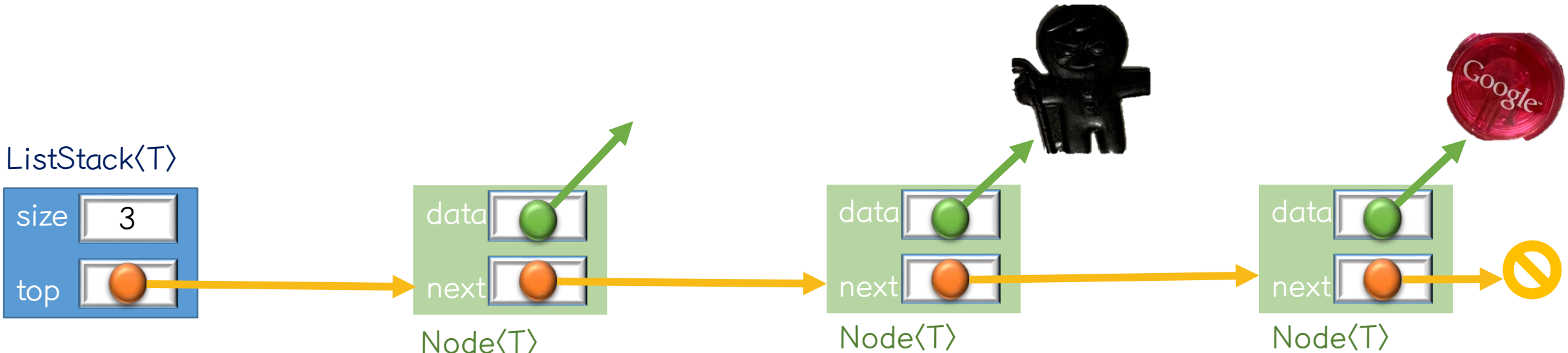
```
public boolean isEmpty() {
        return size==0;
}
```

O(1)

or

```
public boolean isEmpty() {
        return top==null;
}
```

O(1)



Method clear

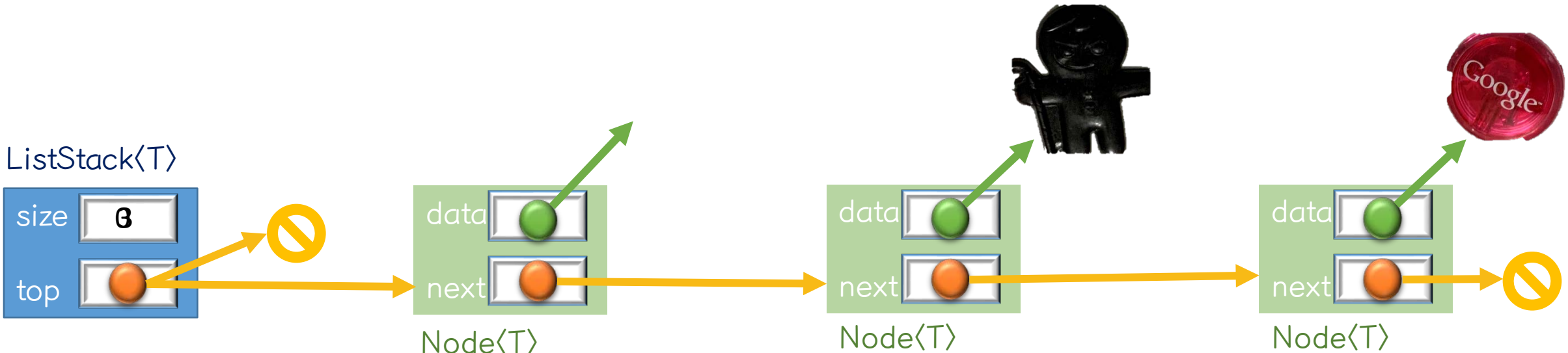
- Client program

```
toys.clear()
```

- In class stack

```
public void clear() {
    top = null;
    size = 0;
}
```

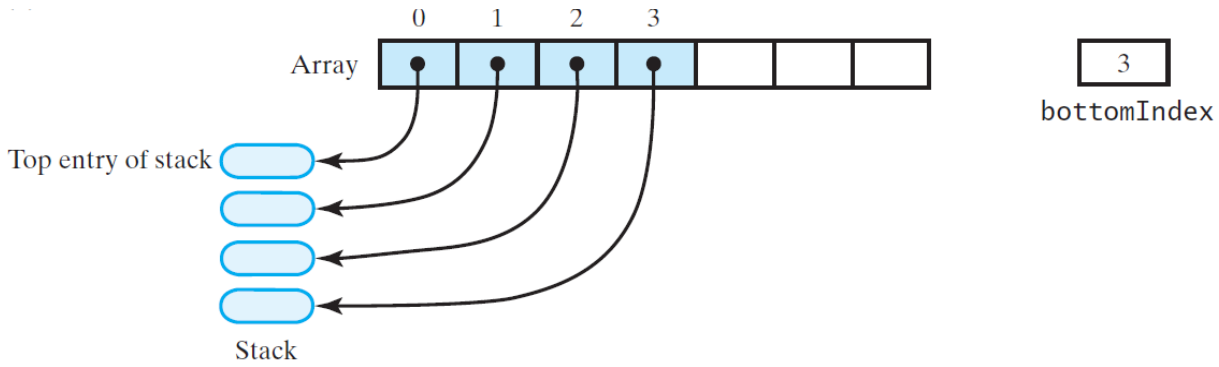
O(1)



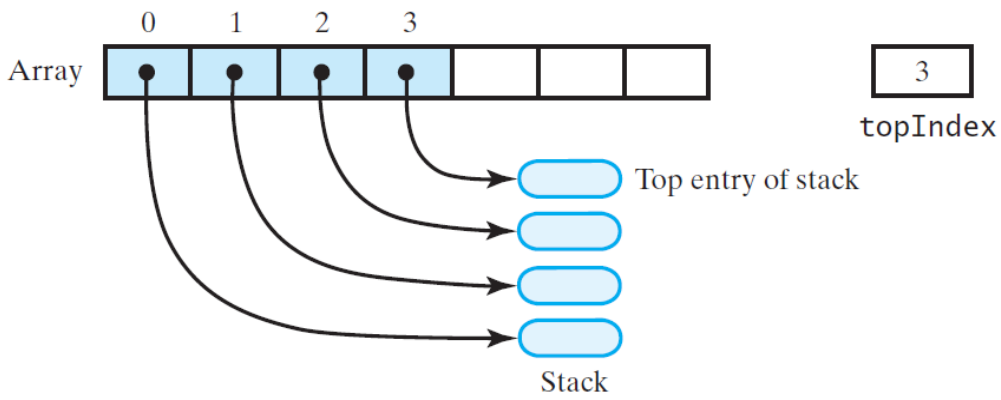
Array Stack

Design Issue: which the array's first element references

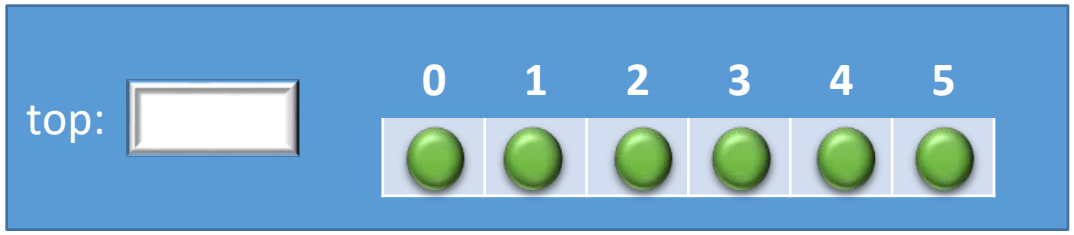
- The stack's top entry



- The stack's bottom entry



Outline of an ArrayStack



the index for the last data

ArrayStack<T>

- top: int
- item: T[]
- integrityOK: boolean
- DEFAULT_CAPACITY: int
- MAX_CAPACITY: int

the array for the data

+ push(T newItem)
+ pop(): T
+ peek(): T
+ isEmpty(): Boolean
+clear(): void
+size():int
+toString(): String
- isFull(): Boolean

Method push

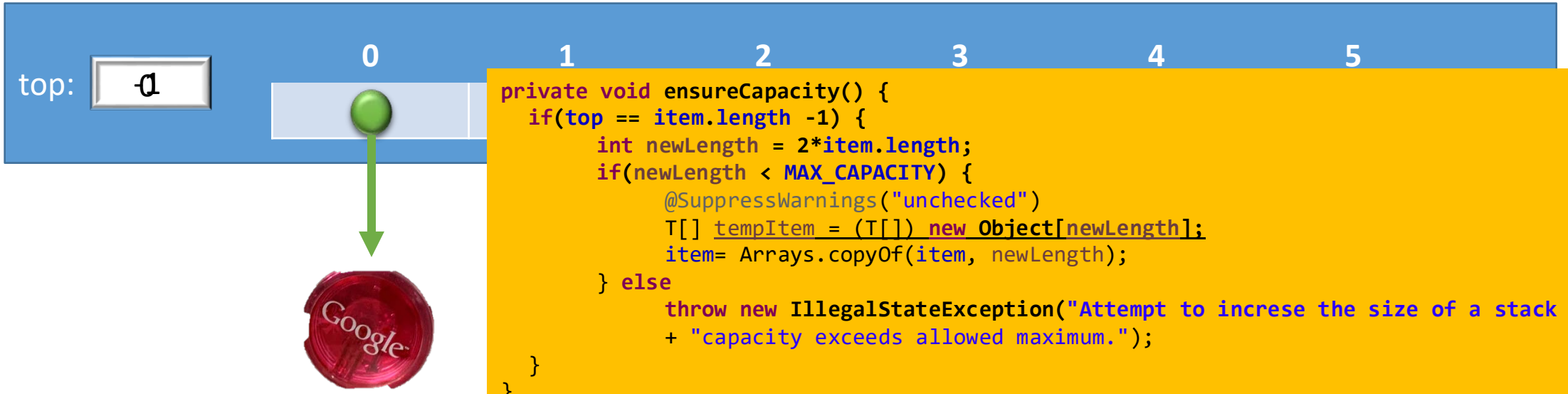
- Client program

```
toys.push("Red YOYO");
```

- In class stack

```
public void push(T newEntry) {
    checkIntegrity();
    ensureCapacity();
    item[++top]=newEntry;
}
```

Usually O(1), if a stack is full, O(n)




```
private void ensureCapacity() {
  if(top == item.length -1) {
       int newLength = 2*item.length;
       if(newLength < MAX_CAPACITY) {
            @SuppressWarnings("unchecked")
            T[] tempItem = (T[]) new Object[newLength];
            item= Arrays.copyOf(item, newLength);
       } else
            throw new IllegalStateException("Attempt to increse the size of a stack whose "
            + "capacity exceeds allowed maximum.");
  }
}
```

Method push

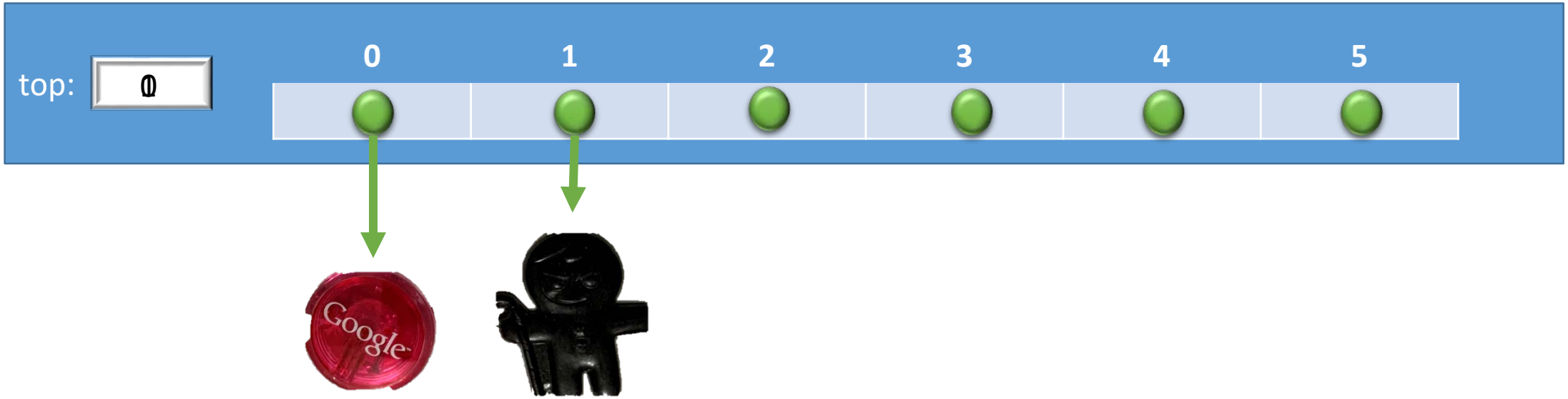
- Client program

```
toys.push("Red YOYO");
toys.push("Black COOKIE MAN");
```

- In class stack

```
public void push(T newEntry) {
     checkIntegrity();
     ensureCapacity();
     item[++top]=newEntry;
}
```

Usually O(1), if a stack is full, O(n)



Method push

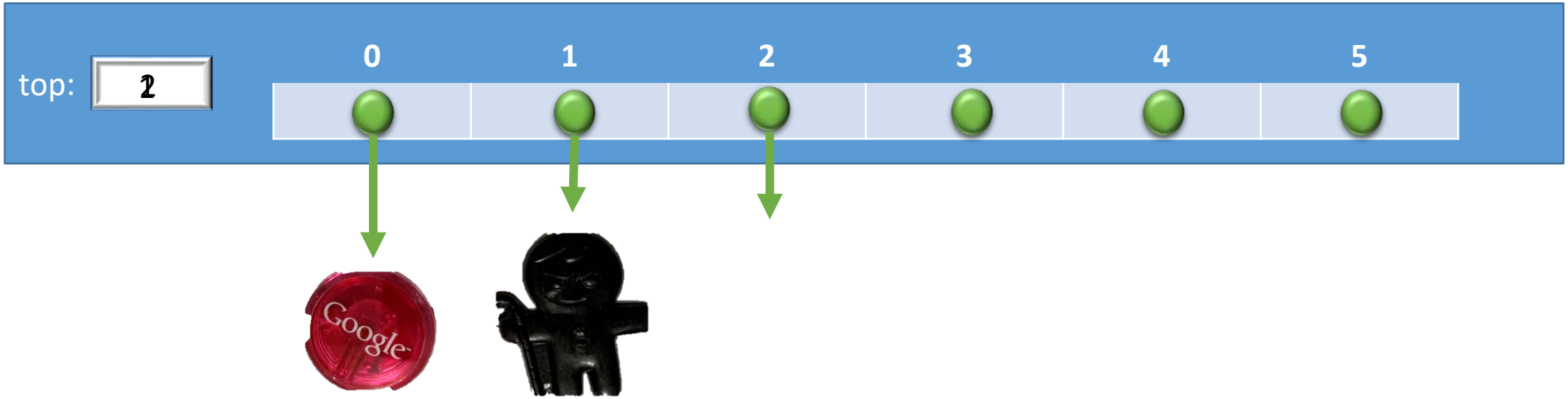
- Client program

```
toys.push("Red YOYO");
toys.push("Black COOKIE MAN");
toys.push("Blue NINJA");
```

- In class stack

```
public void push(T newEntry) {
    checkIntegrity();
    ensureCapacity();
    item[++top]=newEntry;
}
```

Usually O(1), if a stack is full, O(n)



Method peek and size

- Client program

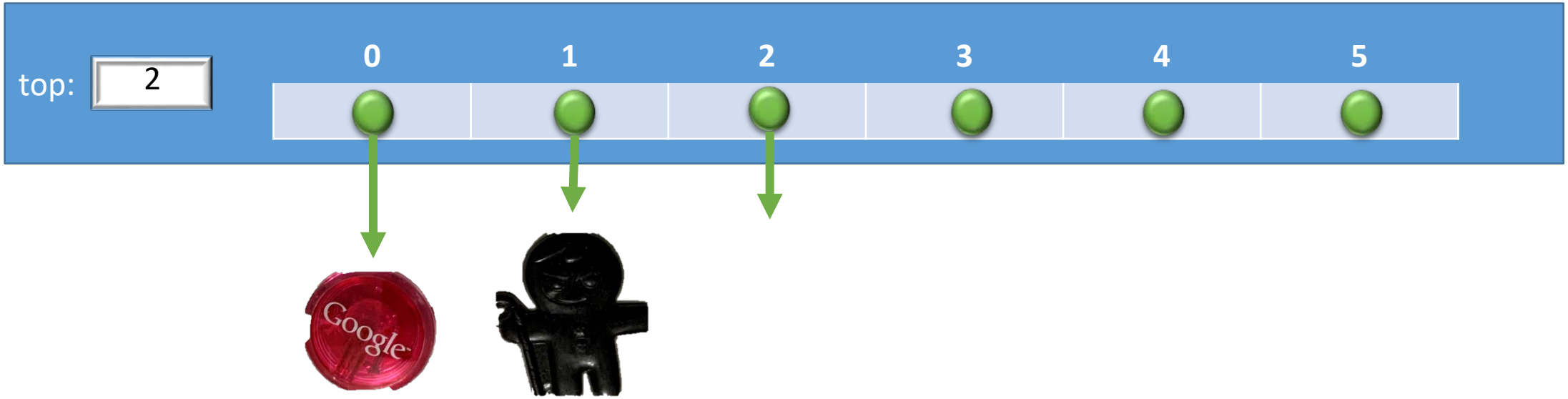
```
System.out.println("peek: "+ toys.peek());
System.out.println("size: "+ toys.size());
```

- In class stack

```
public T peek() {
     if(isEmpty()) return null;
     else return item[top];
}
public int size() {
          return top+1;
}
```

O(1)

O(1)



Method pop

- Client program

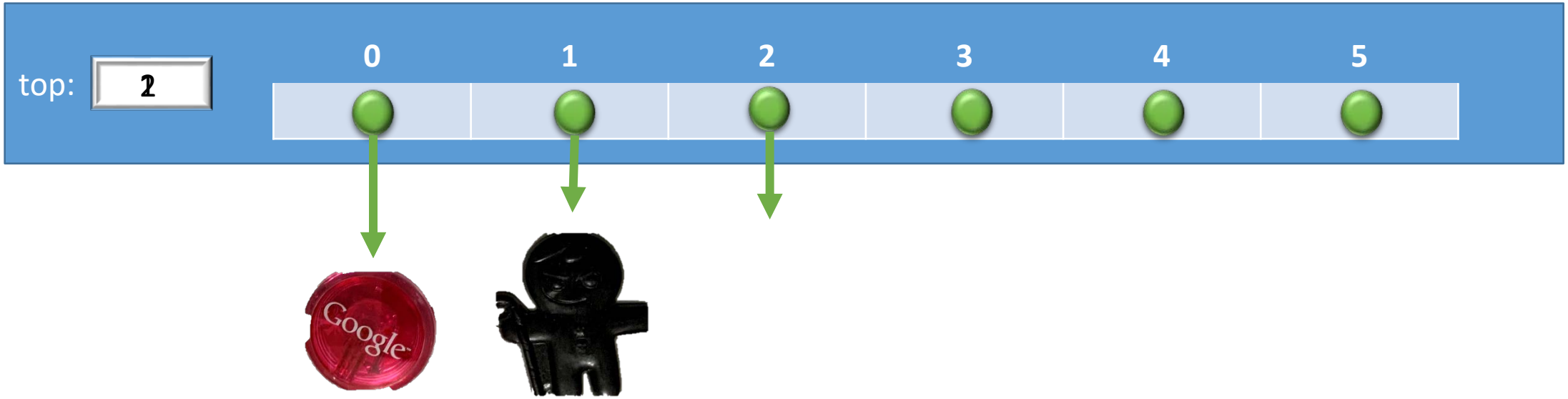
```
System.out.println("pop: "+ toys.pop());
```

Result:

- In class stack

```
public T pop() {
     if(isEmpty()) return null;
     else {
          T result = item[top];
          item[top] = null;
          top--;
          return result;
     }
}
```

O(1)



Method isEmpty

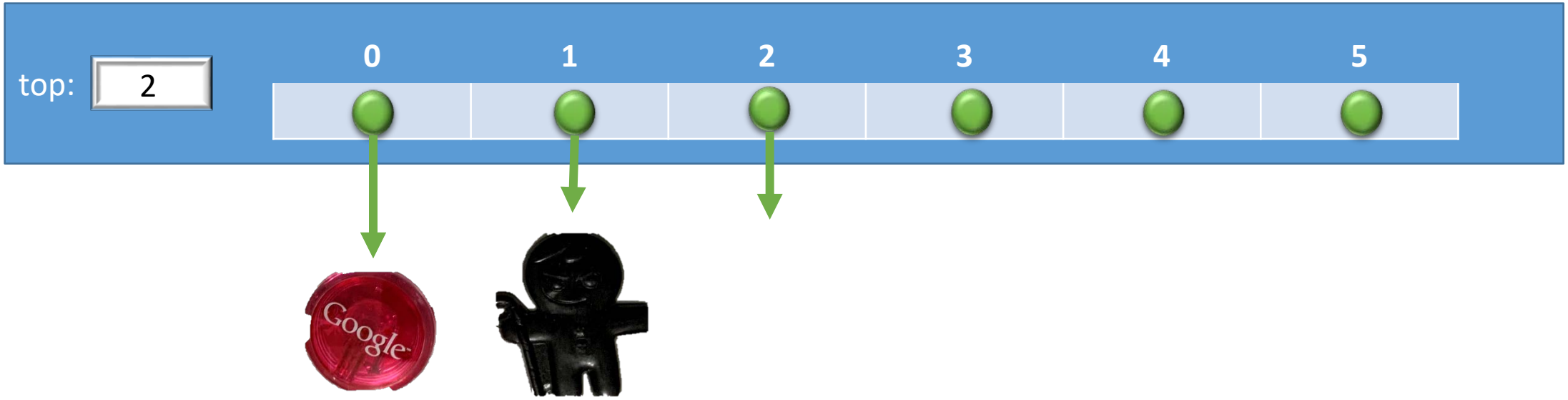
- Client program

```
System.out.println("isEmpty: "+
                        toys.isEmpty());
```

- In class stack

```
public boolean isEmpty() {
        return top<0;
}
```

O(1)



Method clear

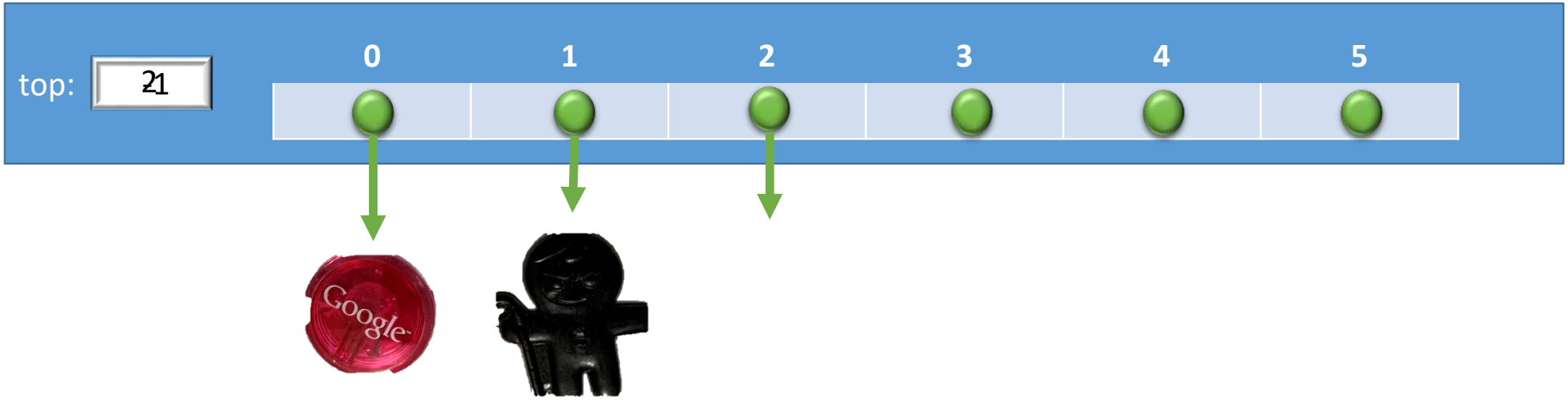
- Client program

```
toys.clear()
```

- In class stack

```
public void clear() {
    @SuppressWarnings("unchecked")
    T[] tempItem = (T[]) new Object[item.length];
    item = tempItem;
    top = -1;
}
```

O(1)



Thank you