Strux

Data Structure Visualization Language

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Strux

- Strux is a general-purpose language that allows for the visualization of data structures
- Using a familiar Java-like syntax, it helps programmers become familiar with the different ways data is stored
- Easy to use: data structures are built in

Motivation

Learning data structures is difficult

- It can be hard to relate code to data structure concepts
- Textbook drawings of data structures are static
  - Difficult to see how they relate to code after each operation

Solution: Visualizations

Visualizations

- ASCII art rendering of a stack, queue, linked list, binary tree, or array
- Dynamic
- Help programmers:
  - Become familiar with the key features of each structure
  - Expose the data their objects currently contain

Features

Standard Language Elements

- Strictly typed
- Operators
  - Increment and decrement
- Control flow
  - if/elif/else
  - Loops
  - Statements
- Program entry point: `main()`
  - Must return `int`

Strux Specialties

- Built-in data structures
  - Array
  - Tree
  - Stack
  - Queue
  - LinkedList
- `.show()`
  - Data structures are printed in ASCII format
- Quick Sort arrays: step-by-step visualization
- Unified function calls for data structures
  - `enqueue`/`push` → `add()`
  - `dequeue`/`pop` → `remove()`
  - `quicksort()`/tree can take in `num[]`, string[], or `int[]`

Software Technologies Used

GitHub

LLVM

OCaml

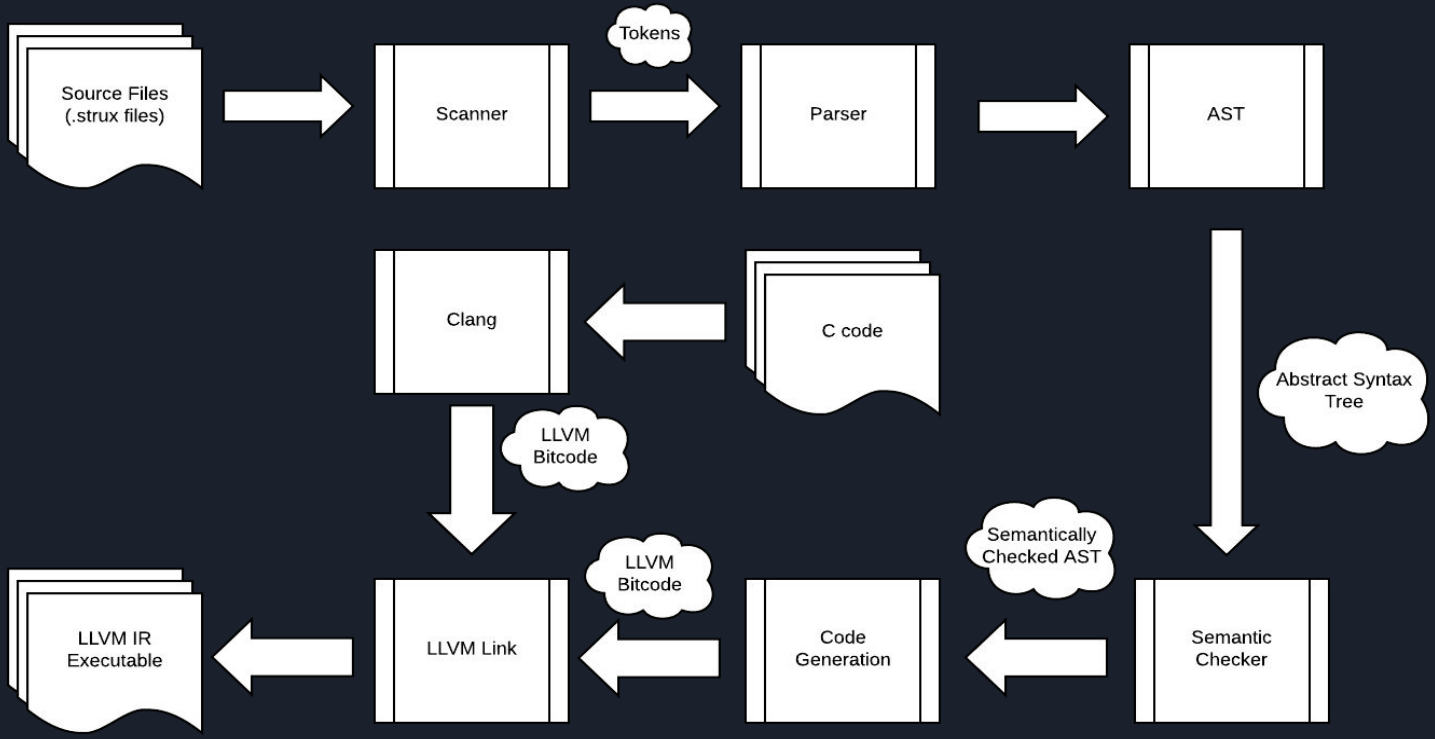
Ubuntu

Atom

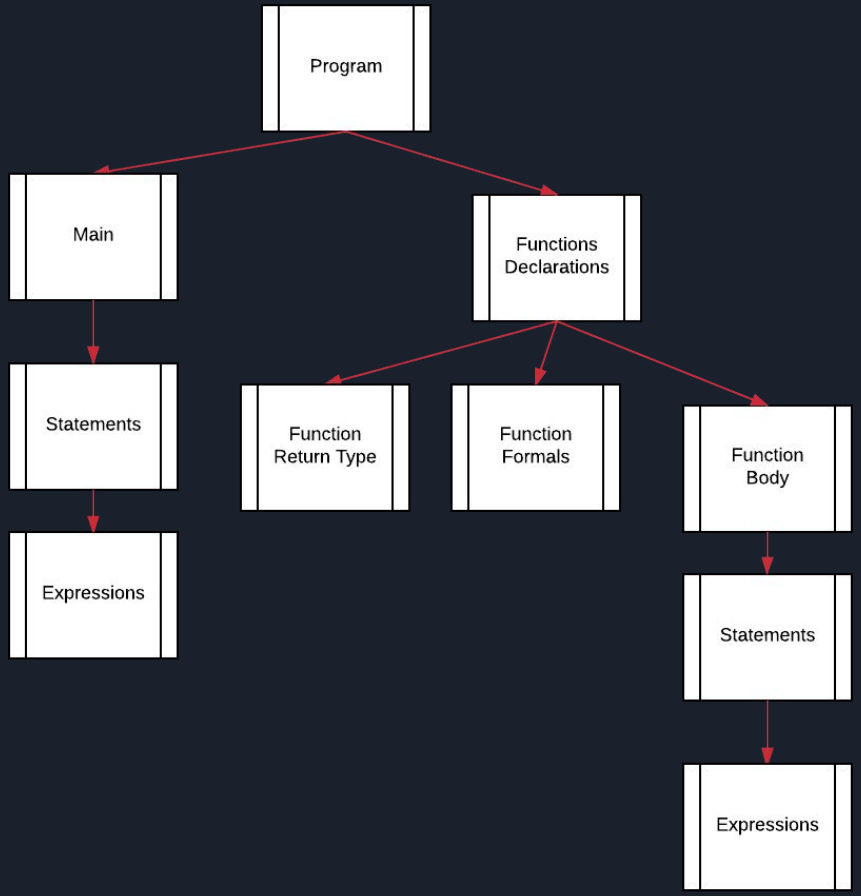
C

DigitalOcean

Architecture



AST


Program
Main
Functions Declarations
Statements
Function Return Type
Function Formals
Function Body
Expressions
Statements
Expressions

Running Strux

```
$ make
$ ./linkStrux.sh
$ ./testall.sh
```

Running Strux

`linkStrux.sh`

- Stack, Queue, LinkedList, Tree, showQuickSort written in C
- `linkStrux.sh` converts C to bytecode

`testall.sh`

- MicroC test script
- Runs all `.strux` files in `tests/` directory and compares output to `.out` or `.err` file

Test

- Edge Cases
  - Visualization of large numbers or large data structures
  - Calling methods on empty data structures
  - Handling null exceptions
- Incompatible Types
  - Initialization, typos
- Static vs. dynamic scoping
- Pass by value vs. by reference
- Duplicate initialization
- Calling methods that do not exist

Test - Unit and Integration Tests

Unit Test

```
int main() {
      int i = 2;
      print(i--);
      return 0;
}
```

Integration Test

```
int main() {
  print(gcd(81, 153));
  return 0;
}

int gcd(int n1, int n2) {
  int gcd = 1;

  for (int i = 1; i <= n1 and i <= n2; i++) {
    if (n1 % i == 0 and n2 % i == 0) {
      gcd = i;
    }
  }
  return gcd;
}
```

Test - Incompatible Types/Error Checks

Fail Test:

```
int main() {
    LinkedList::string l = new LinkedList::string();
    l.add(3);
    return 0;
}
```

Terminates Gracefully:

```
Fatal error: exception Failure("illegal actual add argument found int
expected string in 3")
```

Stack

```
int main() {
    Stack::int s = new Stack::int(2,3,4);
    s.show();

    s.remove();
    s.show();

    s.add(5);
    s.show();
    return 0;
}
```

Console Output

```
+---+ <- Top
| 4 |
+---+
| 3 |
+---+
| 2 |
+---+
```

```
+---+ <- Top
| 3 |
+---+
| 2 |
+---+
```

```
+---+ <- Top
| 5 |
+---+
| 3 |
+---+
| 2 |
+---+
```

Queue

```
int main() {
    Queue::string struxers = new Queue::string("Josh", "Kofi", "Millie", "Sophie");
    struxers.show();

    struxers.add("Edwards");
    struxers.show();

    struxers.remove();
    struxers.show();
}
```

```
+------+--------+--------+---------+
| Josh | Kofi | Millie | Sophie |
+------+--------+--------+---------+
Head                        Tail
```

```
+------+--------+--------+---------+
| Kofi | Millie | Sophie | Edwards |
+------+--------+--------+---------+
Head                        Tail
```

```
+------+------+--------+--------+---------+
| Josh | Kofi | Millie | Sophie | Edwards |
+------+------+--------+--------+---------+
Head                               Tail
```

LinkedList

```
int main() {
    LinkedList::num ll = new LinkedList::num(8.6, 6.0);
    ll.show();

    ll.delete(1);
    ll.show();
}
```

```
+----------+  +----------+  +------+      +----------+  +------+
| 8.600000 |->| 6.000000 |->| NULL |      | 8.600000 |->| NULL |
+----------+  +----------+  +------+      +----------+  +------+
0             1             <- Index      0             <- Index
```

Array and Quick Sort

```
int main() {
    int[4] myArr = [0, 1, 2, 3];
    myArr.show();

    myArr[2] = 8;
    myArr.show();
}

[0, 1, 2, 3]
[0, 1, 8, 3]
```

Array and Quick Sort

```
int main() {
    int[9] myArr = [1, 4, 3, 6, 7, 2, 99, 23, 37];
    myArr.quickSort();
    myArr.show();

    num[9] a = [1.2, 4.4, 3.5, 6.5, 7.5, 2.3, 23.9, 99.5, 37.9];
    a.quickSort();
    a.show();
}

[1, 2, 3, 4, 6, 7, 23, 37, 99]
[1.200000, 2.300000, 3.500000, 4.400000, 6.500000, 7.500000, 23.900000, 37.900000, 99.500000]
```

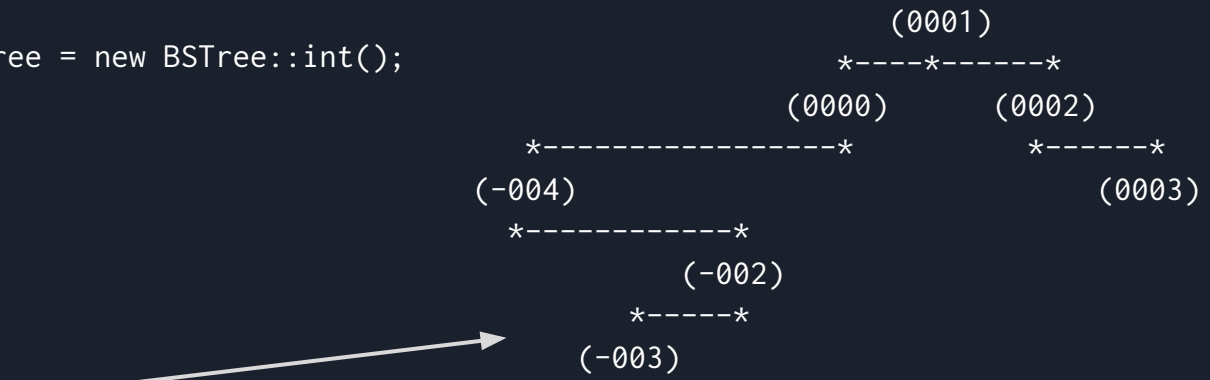
Array and Quick Sort

```
int main() {
    int[4] myArr = [3, 4, 1, 6];
    myArr.showQuickSort();
}
```

```
================================================
At this step:
current array: [3 4 1 6 ]
numbers swapped: 1,4
array after swap: [3 1 4 6 ]
pivot is 4
================================================
At this step:
current array:  [3 1 4 6 ]
pivot swapped: 3,1
array after swap: [1 3 4 6 ]
pivot is 3
================================================
At this step:
current array: [1 3 4 6 ]
pivot is 1
================================================
QuickSort complete! Final Result: [1 3 4 6 ]
```

BSTree

```
int main() {
    BSTree::int tree = new BSTree::int();
    tree.add(1);
    tree.add(2);
    tree.add(3);
    tree.add(0);
    tree.add(-4);
    tree.add(-2);
    tree.add(-3);
    tree.show();
    return 0;
}
```



Challenges

macOS High Sierra

- On the new macOS, some previous architectural systems are not being supported
  - LLVM.Bitreader would throw a bitreader error
- Because we need to translate our C code into bitcode, we decided to develop on an Ubuntu instance hosted on DigitalOcean to introduce a level of abstraction and make it easier for members on the team with High Sierra
- Older macOS systems still work perfectly with Strux code

Limitations of ASCII

- Very large data structures appear distorted when `show()` is called due to the way they are printed
- For `LinkedList` and `Queue`, we introduce compact visualizations when structures are too long

LinkedList

```
+---+  +---+  +------+
| 0 |->| 1 |->| NULL | vs. [0]->[1]->[NULL]
+---+  +---+  +------+
0      1
```

Queue

```
+---+---+---+
| 0 | 1 | 2 |   vs.  Head->[0][1][2]<-Tail
+---+---+---+
Head     Tail
```

NOW TIME FOR THE DEMO!