Gradual Verification
Stack

1. Creating struct for Node

```c0
≡ stack.c0
1    #use <conio>
2
3
4    struct Node {
5        int val;
6        struct Node *next;
7        struct Node *prev;
8    };
9
10   typedef struct Node Node;
11
12   int main () {
13       return 0;
14   }
```

Output:

```
[sbt:gvc0> run -x stack.c0
[info] running (fork) gvc.Main -x stack.c0
[info] [*] — Fri Feb 17 16:45:05 EST 2023
[info] 450
[success] Total time: 3 s, completed Feb 17, 2023, 4:45:07 PM
[sbt:gvc0> run -x stack.c0
[info] running (fork) gvc.Main -x stack.c0
[info] [*] — Fri Feb 17 16:55:13 EST 2023
[info] 0
[success] Total time: 3 s, completed Feb 17, 2023, 4:55:15 PM
sbt:gvc0>  ▮
```

2. Creating a push function

```c
void push (Node *head, int val)
{
    Node *y = head;
    while (y->next != NULL)
    {
        y = y->next;
    }
    y->next = alloc(struct Node);
    y->next->val = val;
    y->next->next = NULL;
}
```

Output:
```
[sbt:gvc0> run -x stack.c0
 [info] running (fork) gvc.Main -x stack.c0
 [info] [*] — Fri Feb 17 17:38:46 EST 2023
 [info] 0
 [success] Total time: 3 s, completed Feb 17, 2023, 5:38:48 PM
```

3. Creating a pop function

```c
void pop (Node *head) {

    Node *y = head;
    y = y -> next;

    if (y == NULL) {
        head = NULL;
    } else {
        while (y -> next -> next != NULL) {
            y = y->next;
        }


        y -> next = NULL;
    }
}
```

Output:

```
[error] Exception in thread "main" gvc.VerificationException: Assignment might fail. There might be insufficient permission to access y.Node$next. (<no position>)
[error]         at gvc.Main$.verifySiliconProvided(main.scala:299)
[error]         at gvc.Main$.verify(main.scala:259)
[error]         at gvc.Main$.$anonfun$run$4(main.scala:153)
[error]         at gvc.benchmarking.Output$.printTiming(Output.scala:47)
[error]         at gvc.Main$.run(main.scala:152)
[error]         at gvc.Main$.delayedEndpoint$gvc$Main$1(main.scala:72)
[error]         at gvc.Main$delayedInit$body.apply(main.scala:41)
[error]         at scala.Function0.apply$mcV$sp(Function0.scala:39)
[error]         at scala.Function0.apply$mcV$sp$(Function0.scala:39)
[error]         at scala.runtime.AbstractFunction0.apply$mcV$sp(AbstractFunction0.scala:17)
[error]         at scala.App.$anonfun$main$1$adapted(App.scala:80)
[error]         at scala.collection.immutable.List.foreach(List.scala:431)
[error]         at scala.App.main(App.scala:80)
[error]         at scala.App.main$(App.scala:78)
[error]         at gvc.Main$.main(main.scala:41)
[error]         at gvc.Main.main(main.scala)
[error] Nonzero exit code returned from runner: 1
[error] (Compile / run) Nonzero exit code returned from runner: 1
[error] Total time: 2 s, completed Feb 17, 2023, 5:39:48 PM
```

Fix:

```c
void pop (Node *head)
    //@ requires ? && head != NULL;
{

    Node *y = head;
    y = y -> next;


    if (y == NULL) {
        head = NULL;
    } else {
        while (y -> next -> next != NULL) {
            y = y->next;
        }



        y -> next = NULL;
    }
}
```

4. Main code:

```c
int main () {

    Node* head = alloc(struct Node);
    head->val = 5;
    head->next = NULL;
    push(head, 10);
    push(head, 34);
    push(head, 32);
    pop(head);
    push(head, 12);
    pop(head);
    return 0;
}
```

Error:

```
sbt:gvc0> run -x stack.c0
[info] running (fork) gvc.Main -x stack.c0
[info] [*] — Fri Feb 17 17:52:30 EST 2023
[error] Error: Field access runtime check failed for struct Node.next
[error] Nonzero exit code returned from runner: 1
[error] (Compile / run) Nonzero exit code returned from runner: 1
[error] Total time: 4 s, completed Feb 17, 2023, 5:52:33 PM
```

Fix try 1:

```
void push (Node *head, int val)
{
    Node *y = head;
    while (y->next != NULL)
    //@ loop_invariant ? && y != NULL;
    {
        y = y->next;
    }
    y->next = alloc(struct Node);
    y->next->val = val;
    y->next->next = NULL;
}

void pop (Node *head)
    //@ requires ? && head != NULL;
{
    Node *y = head;
    y = y -> next;

    if (y == NULL) {
        printint(head->val);
        head = NULL;
    } else {
        while (y -> next -> next != NULL)
        //@ loop_invariant ? && y != NULL;
        {
            y = y->next;
        }
        printint(y->next->val);
        y -> next = NULL;
    }
}
```

Error:

```
[error] Exception in thread "main" gvc.VerificationException: Loop invariant y != null might not hold on entry. Assertion y != null might not hold. (<no position>)
[error]          at gvc.Main$.verifySiliconProvided(main.scala:299)
[error]          at gvc.Main$.verify(main.scala:259)
[error]          at gvc.Main$.$anonfun$run$4(main.scala:153)
[error]          at gvc.benchmarking.Output$.printTiming(Output.scala:47)
[error]          at gvc.Main$.run(main.scala:152)
[error]          at gvc.Main$.delayedEndpoint$gvc$Main$1(main.scala:72)
[error]          at gvc.Main$delayedInit$body.apply(main.scala:41)
[error]          at scala.Function0.apply$mcV$sp(Function0.scala:39)
[error]          at scala.Function0.apply$mcV$sp$(Function0.scala:39)
[error]          at scala.runtime.AbstractFunction0.apply$mcV$sp(AbstractFunction0.scala:17)
[error]          at scala.App.$anonfun$main$1$adapted(App.scala:80)
[error]          at scala.collection.immutable.List.foreach(List.scala:431)
[error]          at scala.App.main(App.scala:80)
[error]          at scala.App.main$(App.scala:78)
[error]          at gvc.Main$.main(main.scala:41)
[error]          at gvc.Main.main(main.scala)
[error] Nonzero exit code returned from runner: 1
[error] (Compile / run) Nonzero exit code returned from runner: 1
[error] Total time: 2 s, completed Feb 17, 2023, 6:01:47 PM
```

Fix try 2:

```c
void push (Node *head, int val)
//@ requires ? && head != NULL;
{
    Node *y = head;
    while (y->next != NULL)
    {
        y = y->next;
    }
    y->next = alloc(struct Node);
    y->next->val = val;
    y->next->next = NULL;
}
```

Output:

```
[sbt:gvc0> run -x stack.c0
[info] running (fork) gvc.Main -x stack.c0
[info] [*] - Fri Feb 17 18:06:30 EST 2023
[info] 32120
[success] Total time: 3 s, completed Feb 17, 2023, 6:06:32 PM
```