snek-compiler

An x86_64 compiler for snek language.

The Snek Language

Concrete Syntax

```
<prog> := <defn>* <expr>
<defn> := (fun (<name> <name>*) <expr>)
<expr> :=
    | <number>
    | true
    | false
    | input
    | <identifier>
    | (let (<binding>+) <expr>)
    | (<op1> <expr>)
    | (<op2> <expr> <expr>)
    | (set! <name> <expr>)
    | (if <expr> <expr> <expr>)
    | (block <expr>+)
    | (loop <expr>)
    | (break <expr>)
    | (<name> <expr>*)
    | (tuple <expr>+) (new)
    | (index <expr> <expr>) (new)
    | nil (new)

<op1> := add1 | sub1 | isnum | isbool | print
<op2> := + | - | * | < | > | >= | <= | =

<binding> := (<identifier> <expr>)
```

Syntax Descriptions (Examples)

Simple operators

```
(add1 x) => x + 1
(sub1 x) => x - 1
(+ x y) => x + y
(- x y) => x - y
...
```

Let binding

```
(
    let
    ((x 10) (y (add1 x)))
    (
        block
        (print x) => 10
        (print y) => 11
    )
)
```

If statement

```
(
    if
    cond_expr
    true_branch_expr
    false_branch_expr
)
```

Loop and block

```
(
    loop
    (
        block
        expr1
        expr2
        ...
        (break break_result)
    )
)
```

Function

```
(
    fun
    (fname arg1 arg2)
    (+ arg1 arg2)
)

(fname 2 3) => 5
```

Tuple and index (new)

Tuple expressions are in the form as follows:

```
(tuple expr1 expr2 expr3 ...)
```

The index expression retrieves an element from a tuple:

```
(index t idx)
```

Where `t` should be a tuple and `idx` should be a number. The program checks the type dynamically. Tuples are 0-indexed.

Both C and Python support heap-allocated data while C does not check the index bound of arrays. The design of tuple in this language is more like Python than C.

Example using tuple and index:

```
(
    let
    ((t (tuple 0 (tuple 1 2) (tuple 3 4) nil)))
    (
        block
        (print (index t 0)) => 0
        (print (index t 1)) => (tuple 1 2)
        (print (index t 2)) => (tuple 3 4)
        (print (index t 3)) => nil
    )
)
```

Abstract Syntax (in Rust)

```
enum Op1 {
    Add1,
    Sub1,
    // Neg,
    IsNum,
    IsBool,
}

enum Op2 {
    Plus,
    Minus,
    Times,
    Equal,
    Greater,
    GreaterEqual,
    Less,
    LessEqual,
}

enum Expr {
    Number(i64),
    True,
    False,
    Input,
    Id(String),
    Let(Vec<(String, Expr)>, Box<Expr>),
    UnOp(Op1, Box<Expr>),
    BinOp(Op2, Box<Expr>, Box<Expr>),
    If(Box<Expr>, Box<Expr>, Box<Expr>),
    Loop(Box<Expr>),
    Break(Box<Expr>),
    Set(String, Box<Expr>),
    Block(Vec<Expr>),
    Print(Box<Expr>),
    Call(String, Vec<Expr>),

    Tuple(Vec<Expr>), // (new)
    Index(Box<Expr>, Box<Expr>), // (new)
    Nil, // (new)
}

enum Def {
    Fun(String, Vec<String>, Expr),
}

struct Prog {
    defs: Vec<Def>,
    main: Expr,
```

```
}
```

Data Representations

`[....]` represents the last hex digit in binary.

Data	Representation
Numbers	`0x........ .......[...0]`
True	`0x00000000 0000000[0111]`
False	`0x00000000 0000000[0011]`
Tuple	`0x........ .......[..01]`
nil	`0x00000000 0000000[0001]`

Tuple structure in heap

Tuple definition:

```
(tuple val1 val2 ...)
```

Heap structure:

```
[size, val1, val2, ...]
```

The size and elements in the tuple take 8 bytes each. `QWORD [base_addr]` retrieves the size of the tuple, `QWORD [base_addr + 8]` retrieves the first element of the tuple (index 0), etc.

Example:

```
(
    let
    ((t (tuple 0 1 2 3)))
    (
        block
        (index t -1) => out of bound
        (index t 0) => 0
        (index t 1) => 1
        (index t 2) => 2
        (index t 3) => 3
        (index t 4) => out of bound
    )
)
```

Usage

Create a `.snek` file in the folder `tests`, e.g., `tests/example.snek`.

```
(fun (fact sofar n) (
    if
    (= n 1)
    sofar
    (fact (* sofar n) (+ n -1))
))

(fact 1 input)
```

This sample code computes `input!`, where `3!=3*2*1=6`.

Compile to assembly

```
make tests/example.s
```

The assembly code is generated in `tests/example.s`.

Compile to executable binary

```
make tests/example.run
```

The executable is generated in `tests/example.run`.

Run the executable

```
# 10 is the input value, default is "false"
./tests/example.run 10
# output: 3628800
```

Testing

Write test files (`.snek` files) in the `tests` directory, add entries in `tests/all_tests.rs` , and then run:

```
make test
```

Examples

Constructing and accessing heap-allocated data

Test file: `tests/index_print.snek`

```
(
    let
    ((t (tuple 0 1 2 3)))
    (
        block
        (print t)
        (print (index t 0))
        (print (index t 1))
        (print (index t 2))
        (print (index t 3))
        t
    )
)
```

Index into a tuple.

Program output:

```
$ ./tests/index_print.run
(tuple 0 1 2 3)
0
1
2
3
(tuple 0 1 2 3)
```

Tag-checking for heap-allocated data

Test file: `tests/index_not_tuple.snek`

```
(
    index
    input
    0
)
```

Since `input` is a number or boolean (not a tuple), the program should throw a dynamic type error.

Program output:

```
$ ./tests/index_not_tuple.run
Error: invalid argument (type error)
$ ./tests/index_not_tuple.run 1
Error: invalid argument (type error)
$ ./tests/index_not_tuple.run true
Error: invalid argument (type error)
```

The program catches the error at runtime.

Index out of bound

Test file: `tests/index_out_of_bound.snek`

```
(
    index
    (tuple 1 2 3)
    input
)
```

If `input < 0` or `input > 2`, the program throws an error with message `index out of bound`.

Program output:

```
$ ./tests/index_out_of_bound.run -1
Error: index out of bound
$ ./tests/index_out_of_bound.run 2
3
$ ./tests/index_out_of_bound.run 3
Error: index out of bound
```

The program catches the error at runtime.

Index not a number

Test file: `tests/index_not_num.snek`

```
(
    index
    (tuple 1 2 3)
    (tuple 2)
)
```

The index into a tuple should be a number, the program throws a dynamic type error.

Program output:

```
$ ./tests/index_not_num.run
Error: invalid argument (type error)
```

The program catches the error at runtime.

Index wrong args

Test file: `tests/index_wrong_args.snek`

```
(index (tuple 1 2) 0 1)
```

The index expression accepts 2 args while the test case has 3. The program should throw a parse error.

Compiling output:

```
$ make tests/index_wrong_args.run
cargo run -- tests/index_wrong_args.snek tests/index_wrong_args.s
    Finished dev [unoptimized + debuginfo] target(s) in 0.25s
     Running `target/debug/snek-compiler tests/index_wrong_args.snek tests/index_wrong_a
parse prog: ((index (tuple 1 2) 0 1))
parse expr: (index (tuple 1 2) 0 1)
thread 'main' panicked at 'Invalid: parse error', src/main.rs:275:22
note: run with `RUST_BACKTRACE=1` environment variable to display a backtrace
make: *** [tests/index_wrong_args.s] Error 101
```

The error is captured during the parsing procedure.

Functions with tuples

Test file: `tests/tuple_points.snek`

```
(
    fun
    (point x y)
    (tuple x y)
)

(
    fun
    (sump p1 p2)
    (
        tuple
        (+ (index p1 0) (index p2 0))
        (+ (index p1 1) (index p2 1))
    )
)

(
    let
    ((x (point 1 2)) (y (point 3 4)))
    (
        block
        (print x)
        (print y)
        (print (sump x y))
    )
)
```

Create 2 points and calculate the sum of coordinates with functions.

Program output:

```
$ ./tests/tuple_points.run
(tuple 1 2)
(tuple 3 4)
(tuple 4 6)
(tuple 4 6)
```

Binary search tree (insert & search)

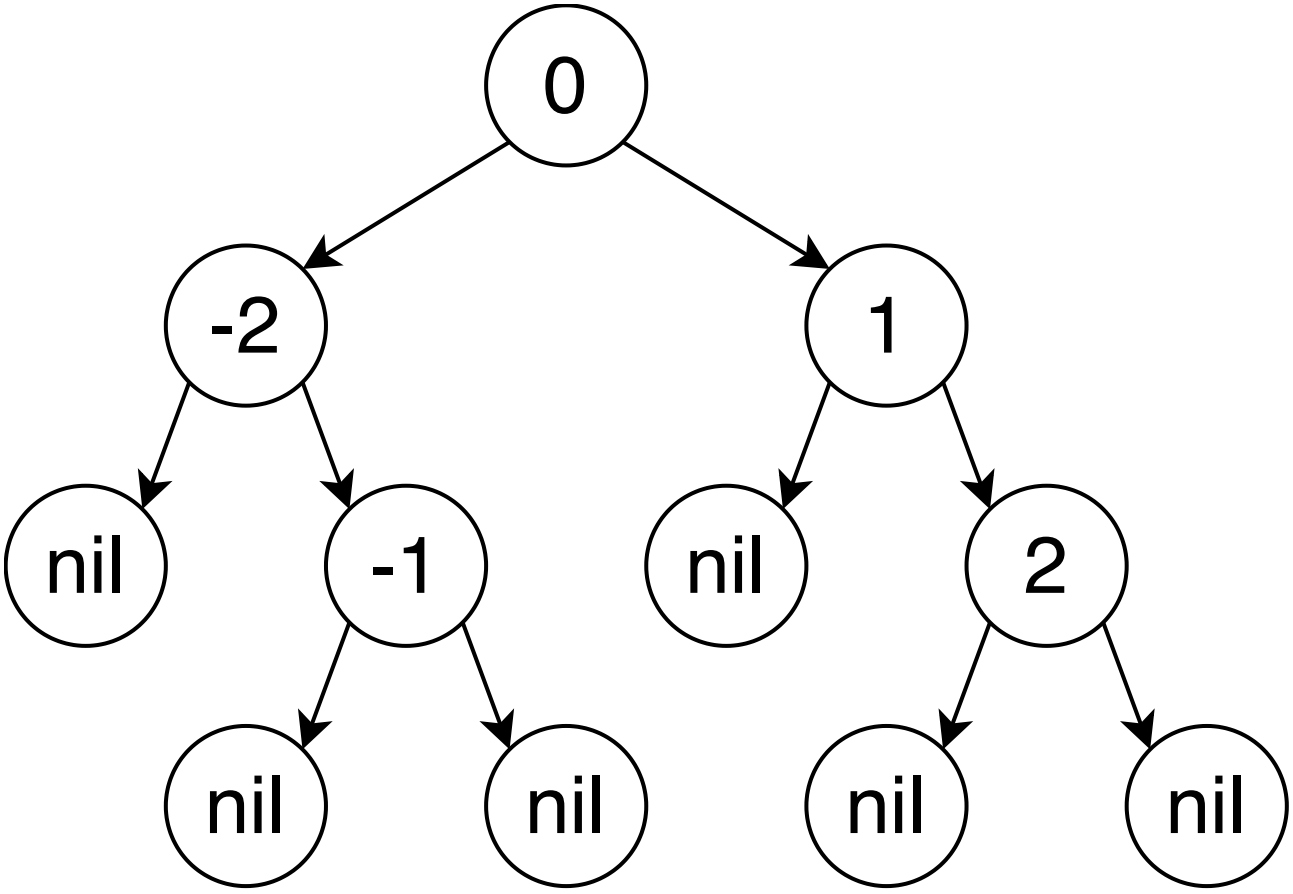
Test file: `tests/tuple_bst.snek`

```
(
    fun
    (insert bst val)
    (
        if
        (= bst nil)
        (tuple nil val nil)
        (
            if
            (< (index bst 1) val)
            (
                tuple
                (index bst 0)
                (index bst 1)
                (insert (index bst 2) val)
            )
            (
                tuple
                (insert (index bst 0) val)
                (index bst 1)
                (index bst 2)
            )
        )
    )
)

(
    fun
    (search bst val)
    (
        if
        (= bst nil)
        false
        (
            if
            (= (index bst 1) val)
            true
            (
                if
                (< (index bst 1) val)
                (search (index bst 2) val)
                (search (index bst 0) val)
            )
        )
    )
)

(
    let
    ((bst (tuple nil 0 nil)))
```

```
    (
        block
        (set! bst (insert bst 1))
        (set! bst (insert bst 2))
        (set! bst (insert bst -2))
        (set! bst (insert bst -1))
        (print (search bst -1))
        (print (search bst 2))
        (print (search bst 3))
        (print (search bst -3))
        bst
    )
)
```

Implements a binary search tree with `insert` and `search` methods.

The binary search tree in the example is shown in the following image.



Program output:

```
$ ./tests/tuple_bst.run
true
true
false
false
(tuple (tuple nil -2 (tuple nil -1 nil)) 0 (tuple nil 1 (tuple nil 2 nil)))
```

References & Credits

- Discussions on binary search tree