CS1101S Studio Session Week 11: *Stream*

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Overview

1. Lazy evaluation
   - Computational model
   - Function application
2. Stream
   - Delayed evaluation
   - Stream programming

Lazy Evaluation

Computational model

- Computational model is a useful guideline for us to understand how the interpreter works.
- Computational model may vary depending on programming language and the runtime system used.
- In CS1101S, we introduce two computational models: ***substitution model*** and ***environment model***.

What to expect

- In the coming weeks, these two models will still be valid.

Lazy Evaluation

Substitution model

For *stateless* programming *only*:

- Evaluate all actual arguments;
- Replace all formal parameters with their actual arguments;
- Apply each statement in the function body (and get the return value);
- Repeat the first 3 steps until done.

Lazy Evaluation

Environment model

For *stateful* programming:

- Each frame contains a series of bindings of names and values.
- The value of a variable depends on its environment, a sequence of frames up to the global frame.
- Each function call will create a new frame and extend its enclosing environment.

Lazy Evaluation

Function in JavaScript

- Function in JavaScript is a first-class citizen (object).
- They have a `call` method.
- The `call` method is triggered when this function is applied.

Function application

- When a function is applied, "`this`" is prepanded to the list of parameters.

Lazy Evaluation

What does "evaluation" mean?

- JavaScript is a scripting language.
- The interpreter will only evaluate line-by-line sequentially.
- Thus, the value of a JavaScript program is always the value of the last statement (the last line).

Notice

- In other words, the other statements (except for the last one) do not affect the overall value of the program.
- However, they may have "side effects".

Lazy Evaluation

Function value & return value

- A function itself already represents a value, of "`function`" type.
- The return value of a function application is the value of the last statement, which is the `return` statement. It may be of "`number`", "`boolean`", "`string`", "`function`" type.

Thus...

- Function evaluation: evaluates one statement (the function object itself);
- Function application: evaluates all statements in the function body.

Lazy Evaluation

Exercise

- In the following slides, you are going to see a few short programs.
- Also, you will see a single line of comment.
- Identify the value of `x` at the point of that comment.
- Notice: *You may want to draw environment model diagram*.

Lazy Evaluation

Exercise 1

```
let x = 0;

function foo() {
    x = x + 1;
}

function bar(func) {
    // Here
    return func;
}

bar(foo());
```

Lazy Evaluation

Exercise 2

```
let x = 0;

function foo() {
    x = x + 1;
}

function bar(func) {
    // Here
    return func;
}

bar(foo);
```

Lazy Evaluation

Exercise 3

```
let x = 0;

function foo() {
    x = x + 1;
}

function bar(func) {
    return func;
}

bar(foo)();
// Here
```

Overview

1. Lazy evaluation
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Stream

Inspiration

In order to generate an infinite list of $\{1, 1, 1, ...\}$, you are given the two approaches as follows:

```
// 1st approach
const ones = pair(1, ones);

// 2nd approach
const ones = pair(1, () => ones);
```

Think about it...

- Which one is correct?
- What is the output?

Stream

The 1st approach

- It will give rize to an error.
- The right side of an assignment statement will be evaluated before the actual assignment is done.
- The `pair` function will evaluate the values of its arguments before the pair is constructed.
- Thus, the tail of the pair has not been defined yet.

Notice

- The following also does not work

```
const ones = pair(1, (() => ones)());
```

Stream

The 2nd approach

- There will not be any error.
- However, it is in fact not correct.
- It is not precise to say it is a list of $\{1, 1, 1, ...\}$.
- It is in fact a stream of $\{1, 1, 1, ...\}$.

Stream

JavaScript is not "*lazy*"

- For any assignment statement in JavaScript, the right side will always be evaluated before the actual assignment is done.
- Variable declaration and binding of function parameters to the values of actual arguments behave similar to assignment statements.
- Applicative order of reduction.

Delayed ~~lazy~~ evaluation

- Unlike some other languages like Haskell, JavaScript is not *lazy*.
- Thus, to **delay** the evaluation of some statements, we have to *wrap them into a function*.

Stream

Stream

- A stream is either an empty list, or a pair whose tail is a nullary function that returns a stream.
- A nullary function is a funcion with no parameters.

Revisit list library

Up to now, the list library supports different kinds of functions:

- List builder: `list`, `build_list`, `enum_list`;
- List getter: `head`, `tail`, `list_ref`, `member`, `is_member`;
- List information: `is_list`, `is_empty_list`, `length`, `equal`;
- List modifier: `append`, `reverse`, `remove`, `remove_all`, `filter`, `map`, `for_each`;
- List converter: `accumulate`, `list_to_string`.

Stream

Stream library

Up to now, the stream library supports different kinds of functions:

- Stream builder: `stream`, `build_stream`, `enum_stream`, `integers_from`;
- Stream getter: `stream_tail`, `stream_ref`, `stream_member`;
- List information: `is_stream`, `stream_length`;
- List modifier: `stream_append`, `stream_reverse`, `stream_map`, `stream_for_each`, `stream_remove`, `stream_remove_all`, `stream_filter`;
- List converter: `list_to_stream`, `stream_to_list`, `eval_stream`.

Stream

Apart from them - interleave

```
function interleave(s1, s2) {
    if (is_empty_list(s1)) {
        return s2;
    } else {
        return pair(head(s1),
                    () => interleave(s2, stream_tail(s1)));
    }
}
```

Use interleave - pairs

```
function pairs(s, t) {
    return pair(pair(head(s), head(t)), function () {
        const part1 = stream_map(x => pair(head(s), x),
                                 stream_tail(t));
        const part2 = pairs(stream_tail(s), stream_tail(t));

        return interleave(part1, part2);
    });
}
```

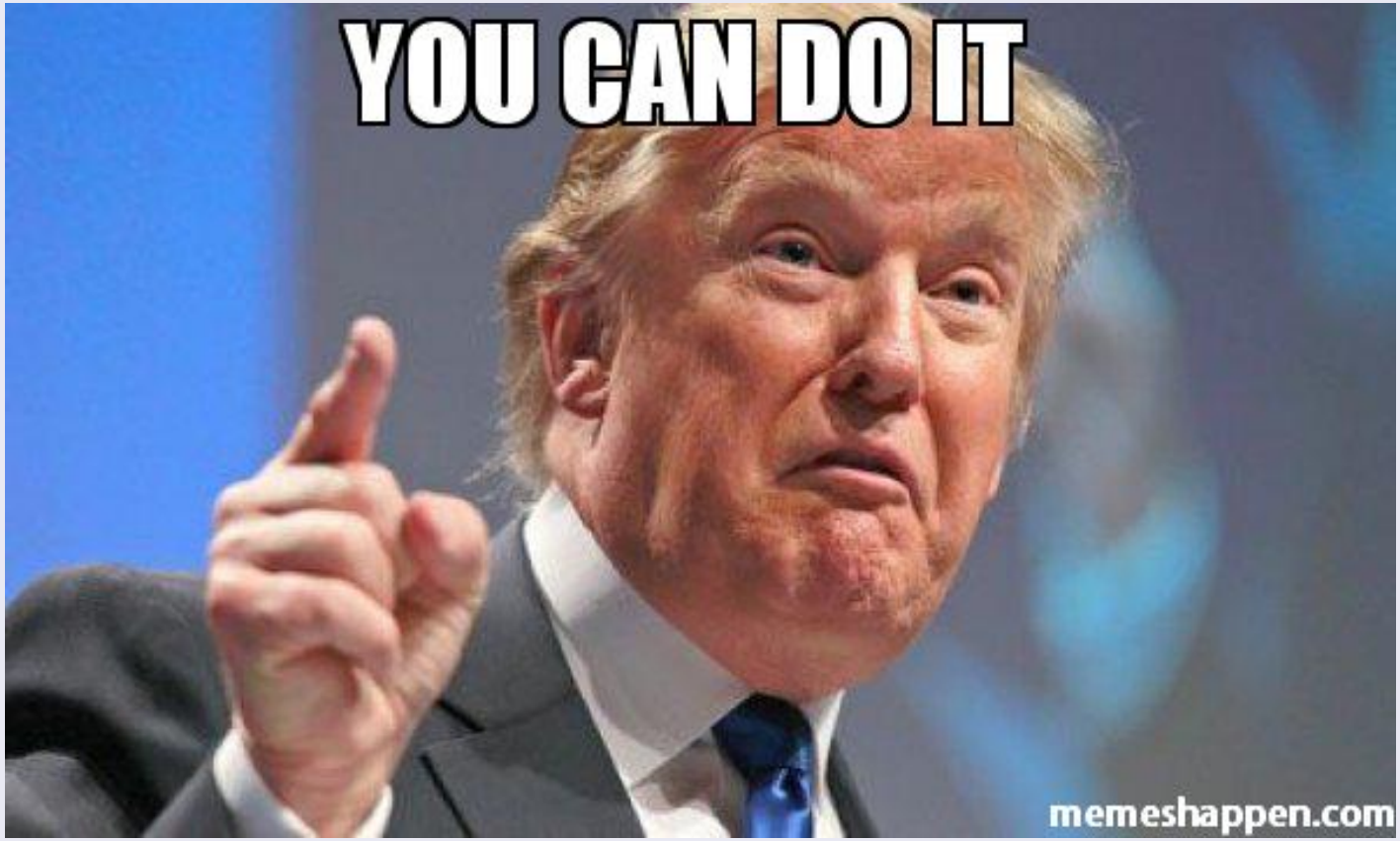
Stream

To become good at stream

- Do not forget the pair/list;
- Understand higher-order programming well;
- Always do wishful thinking!

Stream

Try your best...



Let's discuss them now.

End

The End

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