LISP

A Programmable Programming Language

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Offenes Kolloquium für Informatik

Agenda

1. Why Lisp?
2. The Basics of Lisp
3. Macros in Action
4. Tools and Platforms
5. Literature and more obscure Lisp dialects
6. Why it never (really) caught on
7. Bonus - A bit of History

Why Lisp?

Timeless

- When we talk about Lisp we talk about a language family
- One of the oldest ($\sim$ 1958) language families still in use today (only Fortran is older)
- The Syntax is by its very nature timeless

Timeline of Lisp dialects(edit)

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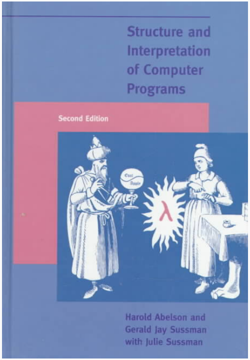
Innovator

- Garbage Collection
- Homoiconicity (Code is Data)
- Higher Order Functions
- Dynamic Typing
- Read Evaluate Print Loop (REPL)
- Multiple Dispatch
- And many more …

Scheme - A Language for Teaching

- Scheme was used as an introductory Language in famous Universities like MIT (6.001)
- Extremely small language core
- Great for learning to build your own abstractions



Picking a Language for this Talk

Lets look at the most popular Lisp dialects on GitHub (provided by GitHut):

GitHub Popuplarity Rank	Language
20	Emacs Lisp
23	**Clojure**
40	**Scheme**
42	Common Lisp
48	Racket

Clojure with its JVM heritage and Scheme with its focus on a small core will be used throughout this talk.

The Basics of Lisp

The name giving lists

- The basis of lisp is the s(ymbolic)-expression
- Either a atom or a list
- Atoms are either symbols or literals
- Every element of a list is either an atom or another list
- Elements are separated by whitespace
- The first element of a (to be evaluated) list has to be what we will call a *verb* in this talk

```
;atoms
x
12
;lists
(+ 1 2 3)
(+ (* 2 3) 3)
```

What is a verb?

- A verb is either a
    - A function
    - A macro
    - A special form
- Special forms include *if, fn, loop, recur etc.*
- They are built into the language and cannot be user defined
- On the other hand functions and macros can be
- Since functions are familiar to most people we will start with them

Calling Functions

- The arguments of functions are evaluated before they are passed to the function
- This is an important distinction from macros/special forms
- Calling functions in a prefix manner might feel strange in the beginning

```
;the + function called as a
;prefix and not as an infix
(+ 1 2 3)
;the infamous
(println "hello world")
```

Calling Java Methods – Clojure Only

- Since Clojure runs on the JVM, interop with Java is necessary to make use of existing libraries
- Java Methods are called like (.instanceMember instance args*)

```
(.toUpperCase "Hello World")
-> "HELLO WORLD"
```

- Creating a new Instance will be very familiar to Java Developers
- There is however a short form for creating new instances

```
(new String "hello world")
-> "hello world"
(String. "hello world")
-> "hello world"
```

Just a bit more Syntax

- Before we will learn how to create our own functions a bit more syntastic sugar
- Vectors are the data structure in Clojure that are used to define the arguments of a function

```
[1 2 3]
-> [1 2 3]
(vector 1 2 3)
-> [1 2 3]
```

- Maps/Dictionaries are created via the curly brace literal

```
{"a" 1 "b" 2 "c" 3}; or (hash-map ...)
-> {"a" 1, "b" 2, "c" 3}
; note the comma, comma is whitespace in Clojure
```

- These are implemented via so called reader macros we will learn about them in the macro section

Define your own Functions - 1

- The special form *fn* is used to create functions

```
(fn [x] (* x x))
-> #function[user/eval10725/fn--10726]
((fn [x] (* x x)) 12)
-> 144
```

- An optional name can be given to the function to make non tail calls

```
((fn foo [x] (if (< x 1) x (foo (dec x)))) 10)
-> 0
```

Define your own Functions - 2

- to make a tail recursive call the *recur* special form is used

```
((fn [x] (if (< x 1) x (recur (dec x)))) 10)
```

- Since functions will often be bound to a global variable (inside a namespace) the following syntax will be seen often

```
(defn foo "doc string here" [x]
  (if (< x 1)
    x
    (foo (dec x))))
-> #'user/foo
(foo 10)
-> 0
```

Define your own Functions - 3

- For short lambda functions there is an even more compact notation
- inside the lambda function % is used to for arguments
- % and %1 are used for the first argument, %2 … for the rest

```
#(* % %)
-> #function[user/eval10725/fn--10726]
(map #(* % %) (range 10))
-> (0 1 4 9 16 25 36 49 64 81)
```

Branch with *if*

- We have already seen the *if* special form
- It consists of a test, a then expression and an optional else expression
- *if* can be used like a ternary expression in Java

```
(println (if (< 4 3) "hello" "world"))
-> world
```

```
System.out.println(4 < 3 ? "hello" : "world")
```

do multiple things

- Evaluates multiple expressions and returns the value of the last one (or nil)

```
(if (< 3 4)
    (do
        (println "hello world")
        (println "and again")))
-> hello world
   and again
```

Bind with let

- Of course we also need to bind local variables inside expressions
- The *let* special form is used for that
- It uses pairs inside a vector for that purpose
- Has support for Destructering

```
(let [x 1] x)
-> 1
;basic Destructering
(let [[x y] [1 2]] (+ x y))
-> 3
```

Loop with ... well ... loop

- We have seen recursion, now we will cover iteration with the *loop* special form
- The *loop* form is very similiar to a *let* binding
- To repeat we use *recur* just like when working with tail recursion earlier

```
(loop [x 10]
  (if (> x 1)
    (recur (- x 2))))
```

- There are other types of loops in clojure, like *for* and *while*, but they are implemented as macros
- *loop* and *recur* is therefore all we need!

Your new best friends *doc* and *source*

- *doc* will show you the docstring of a given function, macro or special form

```
(doc +)
-> ([] [x] [x y] [x y & more])
   Returns the sum of nums. (+) returns 0.
   Does not auto-promote longs,
   will throw on overflow. See also +'
```

- *source* will show you the source code of a given function or macro

```
(source when)
-> (defmacro when
     ".. doc string ..."
     [test & body]
     (list 'if test (cons 'do body)))
```

Macros in Action

Kinds of Macros

Macros can be grouped in different Categories

- Syntactic Sugar Macros - Using simple pattern matching and templates
- Complex Transformations - The most demanding and the most rewarding
- Reader Macros - Syntactic sugar on the reader level, not to be confused with the other two

Yes Code really is Data

- Code really is nothing more than a linked list

```
(type '(+ 1 2 3))
-> clojure.lang.PersistentList
```

- The ' is used to **prevent** evaluation, it is equivalent to *(quote ...)*
- The function *eval* (may be familiar from a lot of scripting languages) takes a s-expression, not a string!

```
(eval '(+ 1 2 3))
-> 6
```

Reader Macros

- To get s-expression from a string, the *read-string* function can be used

```
(eval (read-string "(+ 1 2 3)"))
-> 6
```

- The reader uses read macros to parse special syntax like [], the ’ or the lambda #() syntax
- Clojure has a set of predefined reader macros, they can not be user defined
- Some lisps (e.g. Common Lisp or Racket) don’t suffer from this restriction
- That means that theses lisp dialects have compile time + parse time macros

The syntax quote

- Before we will look at macros, we will introduce the syntax-quote
- It helps us evaluating things in nested quoted structeres

```
; ` is a syntax quote
; ~ evaluates inside such quote
`(foo ~(+ 1 2 3))
-> (user/foo 6)
```

- Everything that is not evaluated through the tilde character will be left alone (only the current namespace is added)

Macros

- Macros are arbitrary lisp code executed at compile time
- Normally only code transformation is done, but it is not limited to transformations
- One could for instance query a database or perform computation of all sorts

```
(defmacro foo [] (+ 1 2))
-> 3
```

A bit of sugar

- Let's look at the simple *when* macro with *(source when)*

```
(defmacro when
  ...
  [test & body]
  (list 'if test (cons 'do body)))
```

- The ampersand just stands for the rest, so body are all expressions after test.
- Here we create code by creating a list
- Using the list function is basically the inverse of a syntax quote, everything is evaluated except quoted expressions

The *while* loop

- The *while* loop ships with Clojure, here is the source

```
(defmacro while
  ...
  [test & body]
  `(loop []
     (when ~test
       ~@body
       (recur))))
```

- The loop does not need bindings, since were ware dealing with a while and not a for loop
- The @-sign in front of body unpacks the body list into its elements
- So 1 2 3 4 …instead of (1 2 3 4 …)

Pattern Matching in Scheme

- Scheme provides an even more elegant syntax for simple macros with *syntax-rules*

```
(define-syntax for
  (syntax-rules (in as)
     (
      ;pattern
      (for element in list body ...)
      ;template
      (map (lambda (element) body ...) list)
     )
     ((for list as element body ...)
      (for element in list body ...))))

(for i in '(1 2 3) (display i))
```

Complex Macros

- For time reasons we can't look at more complex macros in detail
- We will look at an example at a higher level
- As an example I have picked the async/await statement from languages like C# or JS (ECMAScript 2017 draft)
- This is usally done by creating a state machine
- The CSharp code was decompiled to retrieve the state machine

Async in C# - Before

```
static async Task<int> TestAsync()
{
    Console.WriteLine("Init test method");

    var firstResult = await GetNumberAsync(1);
    Console.WriteLine(firstResult);

    var secondResult = await GetNumberAsync(2);
    Console.WriteLine(secondResult + firstResult);

    var thirdResult = await GetNumberAsync(4);

    Console.WriteLine("I'm done");
    return firstResult - secondResult + thirdResult;
}

public static async Task<int> GetNumberAsync(int number)
    => await Task.Run(() => number);
```

Async in C# - After

The CLR has no extra byte code instructions for async/await, everything is handled by the compiler

```
[CompilerGenerated] // shortend
void IAsyncStateMachine.MoveNext()
{
    try
    {
        switch (num)
        {
        case 0:
            taskAwaiter = this.<>u__1;
            this.<>u__1 = default(TaskAwaiter<int>);
            this.<>1__state = -1;
            break;
        case 1:
            taskAwaiter2 = this.<>u__1;
            this.<>u__1 = default(TaskAwaiter<int>);
            this.<>1__state = -1;
            goto IL_117;
```

Async in Clojure with core.async

- In Clojure we don’t need dont to wait until a standard comittee adds the feature
- We just use the core.async library implemented purely in Clojure
- core.async uses channels in a technique known as Communicating Sequential Processes
- The syntax will be more familiar to users of the go language

```clojure
(defn fake-search [kind]
  (fn [c query]
    (go
      (<! (timeout (rand-int 100)))
      (>! c [kind query]))))
```

The *macroexpand* function helps us to examine the macro code

```
(fn state-machine
  ([state_3730]
    (loop []
      (let
        [result
          (case (int (ioc/aget-object state_3730 1))
           3 (let [inst_3728 (ioc/aget-object state_3730 2)
                   state_3730 state_3730]
               (ioc/return-chan state_3730 inst_3728))
           2 (let [inst_3725 (ioc/aget-object state_3730 2)
                   inst_3726 (vector kind query)
                   state_3730 (ioc/aset-all! state_3730 5 inst_3725)]
               (ioc/put! state_3730 3 c inst_3726))
           1 (let [inst_3722 (rand-int 100)
                   inst_3723 (timeout inst_3722)
                   state_3730 state_3730]
               (ioc/take! state_3730 2 inst_3723)))]
```

Deep Understanding

Clojure provides a deep understanding of the language through macros and functions like *doc*, *source* and *macroexpand*. This should not be taken for granted, especially when compared to languages like e.g. C++.

C++ - The worst Offender

> *Help me sort out the meaning of "{}" as a constructor argument*
>
> – Scott Meyers, Author of *Effective C++*

```
class Widget{
    public:
        // default ctor
        Widget();
        // std::initializer_list ctor
        Widget(std::initializer_list<int> il);
};

Widget w1;      // calls default ctor
Widget w2{};    // also calls default ctor
Widget w3();    // most vexing parse! declares a function!

Widget w4({});  // calls std::initializer_list ctor with empty list
Widget w5{{}};  // ditto  -- ... not so fast Dr. Meyers
```

C++ - The worst Offender

- The specific example can be looked up on Scott Meyers Blog
- The last call does *not* create an empty list
- Even a seasoned C++ expert and book author can’t figure out seemingly simple examples
- -> Please don’t take the tools Clojure provides for granted

Tools and Platforms

Literature and more obscure Lisp dialects

Why it never (really) caught on

Questions?

Bonus - A bit of History