

Dynamic Languages - Past, Present and Future

David Chisnall

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What is a language?

- ▶ A means of communication.
- ▶ Something both parties can understand - the computer and the programmer.

A good (programming) language is easy for both parties to understand.

The Spair-Whorf Hypothesis

- ▶ Postulates a causal relationship between natural language and thought patterns.
- ▶ More relevant to computer languages than natural ones:
 - ▶ Natural languages can easily steal parts from others if they aren't expressive enough.
 - ▶ "Notation as a tool of thought" - Kenneth E. Iverson, 1980 Turing Award Lecture.

Language semantics affect the kind of programs we write.

Examples

- ▶ C++ has no GC, which encourages copying rather than aliasing.
- ▶ Tail-recursion optimisations in languages encourage recursive algorithms.

Consider widely different languages, like Prolog and Erlang—the capabilities of the language have significant impact on the structure of the code.

What is a 'Dynamic' Language

- ▶ The core language is very small.
- ▶ Anything outside the core language can be *replaced* by the user.
- ▶ If a static type system is present, it does not affect run time semantics.

In a dynamic language, customisation of the language is not just possible, but *encouraged*.

The Smalltalk Family

- ▶ Smalltalk - first dynamic, object-oriented, language.
- ▶ Self - Smalltalk without classes.
- ▶ JavaScript - Self with Java syntax.

A Quick Introduction to Smalltalk

Assignment:

```
1 | aVariable := anExpression.
```

Message Sending:

```
1 | 'Unary message'  
2 receiver run.  
3 | 'Message with one parameter'  
4 receiver doSomethingTo: anObject.  
5 | 'Message with two parameters'  
6 receiver doSomethingWith: a and:b.
```

Smalltalk Flow Control

- ▶ No flow control other than message sending in the language.
- ▶ If statements implemented with *blocks* (closures).
- ▶ Block literals are defined with square brackets.

```
1 | aBoolean ifTrue: [ obj message. ]  
2 |     ifFalse: [ obj2 message. ].
```

True and False are subclasses of Boolean with different implementations.

```
1 | whileTrue: body  
2 |     ^self value ifTrue:[  
3 |         body value.  
4 |         self whileTrue: body  
5 |     ].
```


Why is this important?

- ▶ User can add new flow control structures (e.g. for-each loops, map, select).
- ▶ User-defined and system-defined versions are indistinguishable.
- ▶ Encourages users to define new ones where convenient.

How does message sending work?

Example in Objective-C - set of Smalltalk-like extensions to C

```
1 [aDictionary setObject:anObject forKey:aKey];
```

Becomes:

```
1 // This would really be cached
2 SEL selector = sel_get_uid("setObject:forKey");
3 IMP method = objc_msg_lookup(aDictionary,
    selector);
4 method(aDictionary, selector, anObject, aKey);
```

This is slow

- ▶ Looking up a method dynamically is slower than calling a function directly.
- ▶ The compiler can't inline functions called indirectly.
- ▶ The compiler can't perform interprocedural analyses on indirect calls.

How do we make it fast?

- ▶ Cache the results of the lookup.
 - ▶ *Polymorphic Inline Caching* caches a set of (class, method) pairs at each call site.
- ▶ Heuristic optimisations (guess-and-test):
 - ▶ Use static analysis to work out what the class *might* be.
 - ▶ Optimise as if it is.
 - ▶ Add a branch in case it isn't.

Do we actually need to?

- ▶ Often 'fast' and 'flexible' are not needed in the same bit of code.
- ▶ Why write them both in the same language?

The Pragmatic Smalltalk Compiler

- ▶ Initial release as part of Étoilé 0.4.
- ▶ ABI-compatible with Objective-C.
- ▶ JIT compiler based on LLVM.
 - ▶ Also does static compilation (as of Monday).
 - ▶ Produces .o files that can be linked with C/ObjC code.

What does this mean?

- ▶ Objective-C is a pure superset of C.
 - ▶ Calling C from Objective-C has no overhead.
 - ▶ C or Objective-C can have inline assembly (if you really need it).
- ▶ Objective-C objects and Smalltalk objects use the same structure.
- ▶ An object can have methods in Objective-C and Smalltalk.
- ▶ No virtual machine, just a small runtime library.

Can we make it even more flexible?

- ▶ $class \times selector \rightarrow method$ - class-based dispatch.
- ▶ $object \times selector \rightarrow method$ - prototype-based dispatch.
- ▶ $sender \times object \times selector \times type \rightarrow$
 $type \times context \times method \times object$ - Étoilé runtime's multidimensional dispatch.

Context Oriented Programming and other buzzwords use multidimensional dispatch.

What can we do with this?

- ▶ Change behaviour based on sender, e.g. enforce runtime visibility constraints.
- ▶ Use the *type* modification for interaction between typed and untyped languages.
- ▶ Embed arbitrary information with the context.

And that's useful because...?

We can...

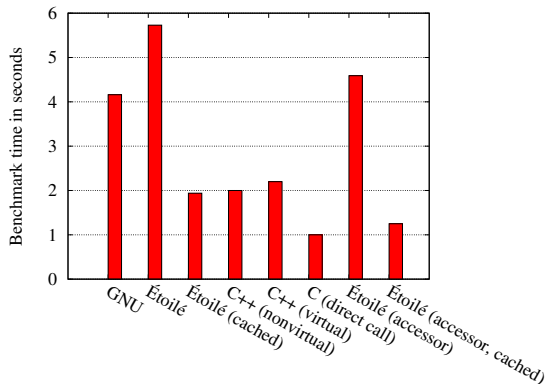
- ▶ ...track messages going in to a group of objects, record them, and log the entire history of an object.
- ▶ ...isolate less-trusted portions of a program.
- ▶ ...track messages travelling between threads for safe concurrency.

Real example:

```
1 MKMusicPlayer *player = [[MKMusicPlayer alloc]
   initWithDefaultDevice];
2 // Move the player into a new thread.
3 player = [player inNewThread];
```

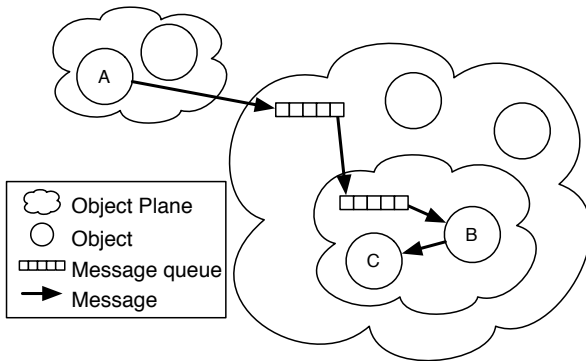
All messages sent to player are sent to the other thread, all replies are futures.

Performance



Old performance data - Étoilé runtime gives much better performance with the new sparse array implementation (equivalent to GNU).

Object Planes



- ▶ Associate a grouping of objects with a mediator object.
- ▶ Intercept messages flowing between planes.

Work conducted in collaboration with Dr. Damien Pollet at INRIA Lille



Closing Remarks

- ▶ Dynamic languages encourage loose-coupling, which makes code less fragile.
- ▶ They make reasoning about code harder (but we're working on that).
- ▶ They make programming more fun!

Obligatory Étoilé plug:



<http://etoileos.com>