CS 476 – Programming Language Design

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Turing-Completeness

- Lambda calculus is Turing-complete
- C and OCaml can express all the same computations
- And so can a lot of other things:

Java Generics are T

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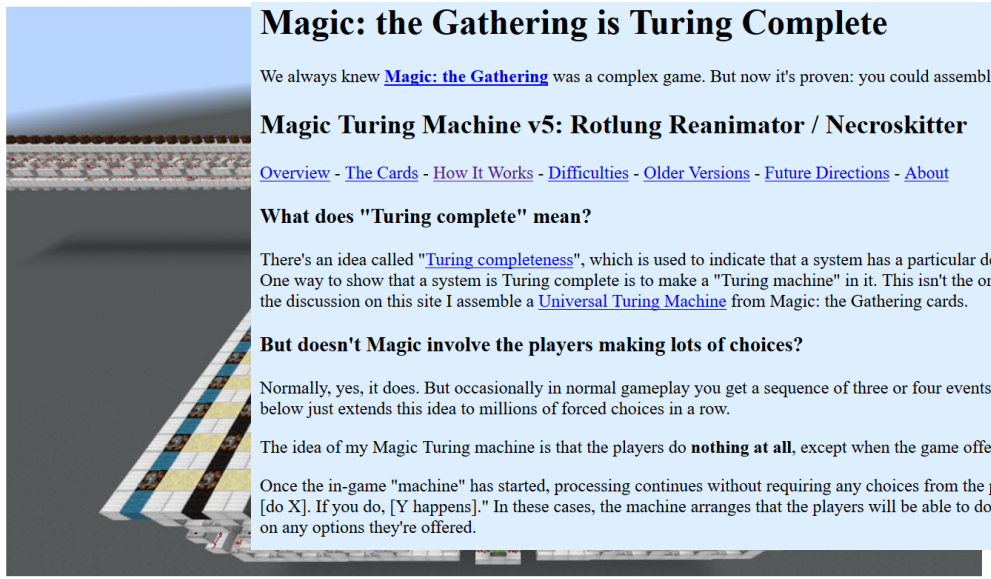
Abstract

This paper describes a reduction from the halting problem of Turing machines to subtype checking in Java. It follows that subtype checking in Java is undecidable, which answers a question posed by Kennedy and Pierce in 2007. It also follows that Java's type checker can recognize any recursive language, which improves a result of Gil and Levy from 2016. The latter point is illustrated by a parser generator for fluent interfaces.

Posted by u/_gigo 1 year ago

Turing machine in Minecraft



Magic: the Gathering is Turing Complete

We always knew **Magic: the Gathering** was a complex game. But now it's proven: you could assemble a computer out of Magic cards.

Magic Turing Machine v5: Rotlung Reanimator / Necroskitter

Overview - The Cards - How It Works - Difficulties - Older Versions - Future Directions - About

What does "Turing complete" mean?

There's an idea called "Turing completeness", which is used to indicate that a system has a particular degree of complexity. Any Turing-complete system is theoretically able to emulate any other. One way to show that a system is Turing complete is to make a "Turing machine" in it. This isn't the only way of demonstrating Turing completeness, but it is one of the more understandable. In the discussion on this site I assemble a Universal Turing Machine from Magic: the Gathering cards.

But doesn't Magic involve the players making lots of choices?

Normally, yes, it does. But occasionally in normal gameplay you get a sequence of three or four events in a row that are forced to happen by the cards and the rules of the game. The machine below just extends this idea to millions of forced choices in a row.

The idea of my Magic Turing machine is that the players do **nothing at all**, except when the game offers them a choice.

Once the in-game "machine" has started, processing continues without requiring any choices from the players, with one category of exceptions: Some of the cards in the machine say "You may [do X]. If you do, [Y happens]." In these cases, the machine arranges that the players will be able to do X, in precisely one way. It just requires the players to always choose to take the game up on any options they're offered.

Turing-Completeness: Representation

- Functional, imperative, etc. languages can all simulate each other
- We can define any language in OCaml (syntax, type system, semantics, interpreter)
  - Or in C, or in Java, or…

Choosing a Language

- We don’t have to choose a language based on what’s *possible* to compute
- Reasons for choosing a language:
  - Familiarity
  - Existing/legacy code
  - Library support
  - Tool support
  - Match between syntax/paradigm and thing we’re trying to describe
  - Level of abstraction

Turing-Incomplete Languages

- We don’t have to choose language based on what’s *possible* to compute
- And our languages don’t have to be able to compute everything!
- There are some useful Turing-incomplete *domain-specific* languages (DSLs):
  - Regular expressions
  - HTML
  - Some versions of SQL
  - Interactive theorem provers

Combining Language Features

- Lambda-expressions in Java, Python, …

```
f = lambda x : x + 1
(* f evaluates to a closure *)
print f(5)
```

- References in OCaml

Already exist, but require major changes to the semantics!

Combining Language Features

- Object orientation + universal polymorphism, as in F#
- There are now two “top” types: Object and ‘a
  - F# generic functions are defined with universal types
  - Other .NET methods (ToString, etc.) are defined on Object
  - Type inference may infer Object or ‘a as the type of an argument depending on how it’s used, unpredictably
  - *Reflection* makes this even worse: “generic” functions can case on the type of the input, turning polymorphism *ad-hoc*

Combining Language Features

- Pattern matching in imperative languages
  - Usually not done, because they don't have inductive datatypes
- Pattern matching in Rust:

```
enum Option<T> {
    Some(T),
    None,
}
```

```
match x {
        None => None,
        Some(i) => Some(i + 1),
}
```

Making a New Language

- Why make a new language?
  - To change the syntax
  - To make a design decision in the other direction
  - To make a common pattern easier to write
  - To combine features that can't easily be added on to an existing language
  - To make a language that *can't* express certain bad programs

Making a New Language: Swift

- Goal: a cleaner replacement for Apple's Objective-C
- Object-oriented, with Java-like syntax
- Can add an interface implementation to an existing class
- Functions (closures) as values
- Option type for possibly-null values
- Type inference
- Has libraries for iOS programming

Making a New Language: Kotlin

- Goal: a faster, more concise replacement for Java
- Object-oriented, with Java-like syntax
- Both member methods and top-level functions
- Can extend classes with new methods
- Functions (closures) as values, including higher-order functions
- Type inference
- Can deconstruct an object into the tuple of its fields
- Has libraries for Android programming

Making a New Language: Rust

- Goal: a safer replacement for C
- C-like syntax, but actually more like a functional language
- Inductive data types and pattern matching
- Type inference
- Type classes for ad-hoc polymorphism
- “Borrowing” type system for safe concurrency
- Used by Mozilla to implement Firefox

Making a New Language

- Swift: meant to replace Objective-C, cleaner and easier to use, combines OO and functional features, type system prevents null pointer references, pushed by Apple
- Kotlin: meant to replace Java, cleaner and easier to use, combines OO and functional features, type system prevents null pointer references, pushed by Google
- Rust: meant to replace C, safer, combines OO and functional features, type system prevents data races, pushed by Mozilla