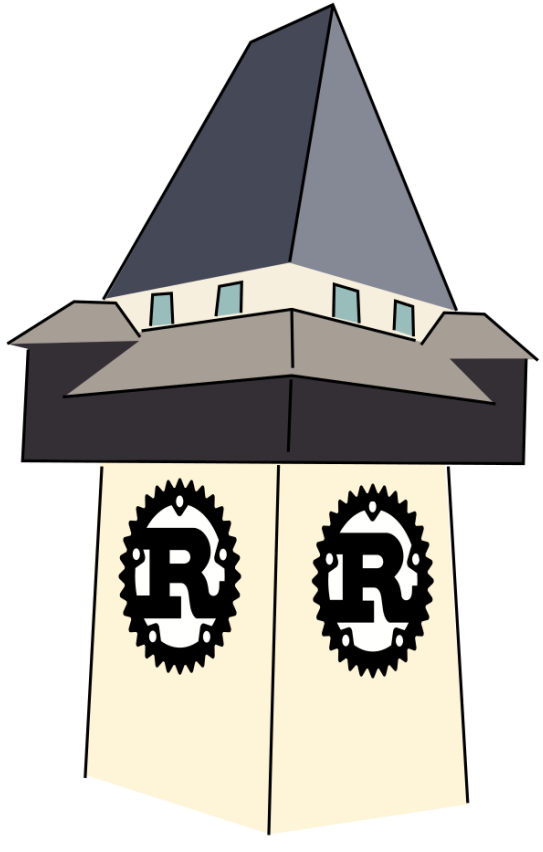
RUST GRAZ – 03 CONTROL STRUCTURES AND FUNCTIONS

Lukas Prokop

28th of August, 2019



Control structures and functions

28th of August 2019

Rust Graz, lab10


dost Geni
@eugen_yzeiri
Should I Rust or should I Go? @rustlang @golang
4:39 PM · Jul 25, 2019 · Twitter for Android
38 Retweets
193 Likes
Rust Language @rustlang · 22h
Replying to @eugen_yzeiri and @golang
Why not both?
8
47
457
Go @golang · 22h
Indeed!
9
37
276

NEW TALK STRUCTURE

- **Prologue:** Review of last talk & corrections
- **Dialogue:** Main topic with discussions and examples
- **Epilogue:** Definition of next talk topic

PROLOGUE

CORRECTION 1: ABOUT RISC-V

128 bit instructions are part of the *base* instruction set.
256 bit instructions occur as part of the Advanced Vector Extensions.

CLARIFICATION 2: INTEGER OVERFLOW IN RELEASE MODE

```rust
fn main() {
    let mut over = 255u8;
    over += 1;
    println!("{}", over);
}
```

```
root@unix ~ # rustc test.rs && ./test
thread 'main' panicked at 'attempt to add with overflow', test
note: run with `RUST_BACKTRACE=1` environment variable to disp
```

INTEGER OVERFLOW IN RELEASE MODE

```
fn main() {
    let mut over = 255u8;
    over += 1;
    println!("{}", over);
}
```

```
root@unix ~ # rustc -O test.rs && ./test
0
```

⇒ In release mode, integer overflows are not runtime errors.

CLARIFICATION 3: DENORMAL NUMBERS

Advanced IEEE 754 topic, I skipped last time.

Denormal numbers ensure: `x = y ⇔ x - y = 0`.

DENORMAL NUMBERS

IEEE 754 defines the concept of Denormal numbers.

> *In computer science,* ***denormal*** *numbers or* ***denormalized*** *numbers (now often called* ***subnormal*** *numbers) fill the underflow gap around zero in floating-point arithmetic. Any non-zero number with magnitude smaller than the smallest normal number is "subnormal".*

CLARIFICATION 4: F32::NAN AS U32

Result of last talk: `f32::NAN as u32` gives `0`.

Intentionally?

F32::NAN AS U32

test/run-pass/numbers-arithmetic/float-int-invalid-const-cast.rs#L21

```rust
use std::{f32, f64};

// Forces evaluation of constants, triggering hard error
fn force<T>(_: T) {}

fn main() {
    // …
    { const X: u32 = f32::INFINITY as u32; force(X); }
    // …
}
```

IEEE 754-1985

The invalid operation exception is signaled if an operand is invalid for the operation on to be performed. The result, when the exception occurs without a trap, shall be a quiet NaN (6.2) provided the destination has a floating-point format. The invalid operations are …

IEEE 754-1985

Section 7.1 “Invalid Operation”

1. *Any operation on a signaling NaN (6.2)*
2. *Addition or subtraction—magnitude subtraction of infinites such as, (+∞) + (−∞)*
3. *Multiplication—0 × ∞*
4. *Division—0/0 or ∞/∞*
5. *Remainder— x REM y, where y is zero or x is infinite*
6. *Square root if the operand is less than zero*

IEEE 754-1985

IEEE 754-1985

7. **Conversion** of a binary floating-point number to an integer or decimal format when overflow, infinity, or **NaN** precludes a faithful representation in that format and this cannot otherwise be signaled

IEEE 754-1985

7. **Conversion** of a binary floating-point number to an integer or decimal format when overflow, infinity, or **NaN** precludes a faithful representation in that format and this cannot otherwise be signaled
8. Comparison by way of predicates involving < or >, without ?, when the operands are unordered (5.7, Table 4)

GAME: GUESS THE LANGUAGE

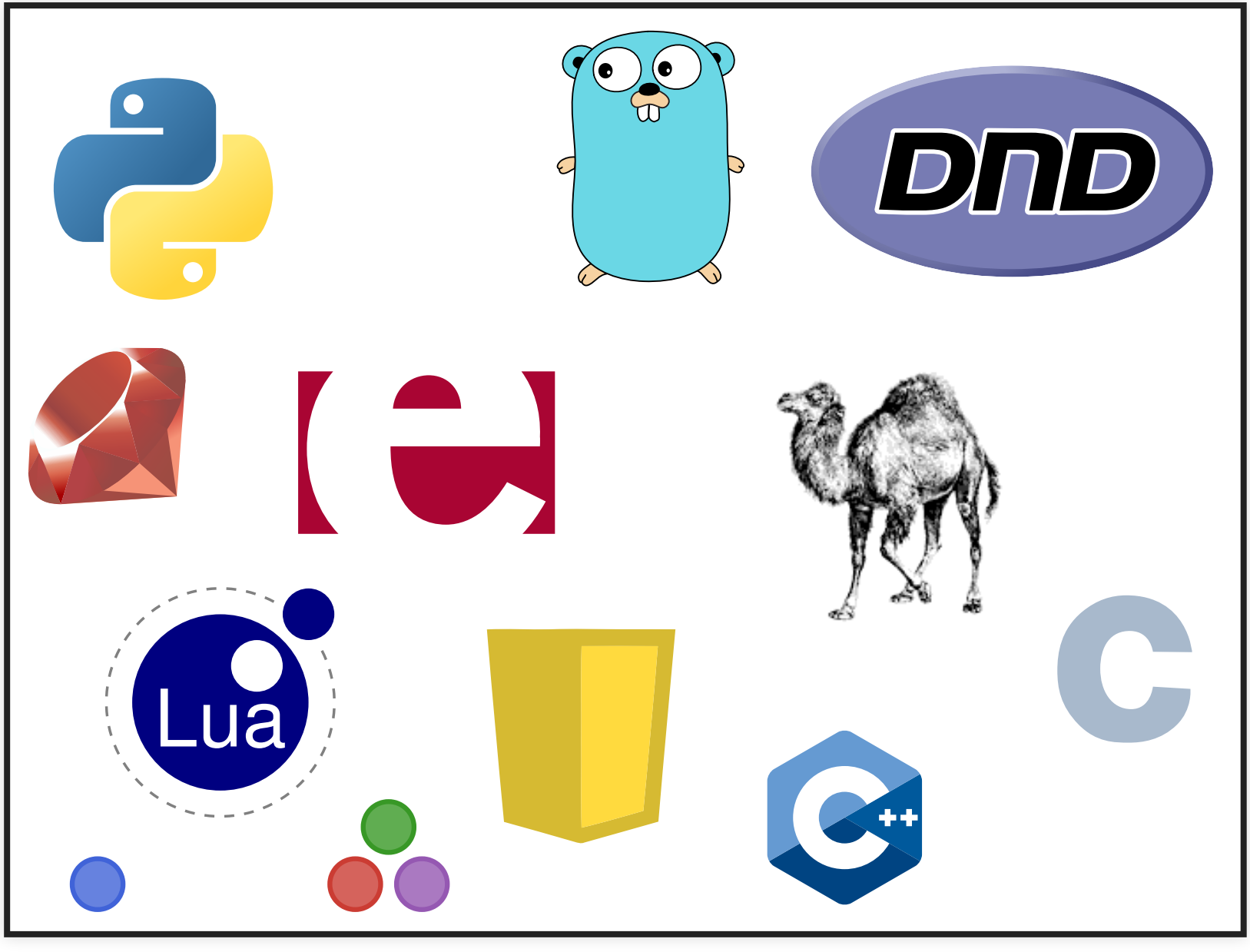
Guess the programming language by the following modified logos.

GAME: GUESS THE LANGUAGE

Guess the programming language by the following modified logos.

Legal:

- Gopher by Takuya Ueda (CC 3.0 BY).
- Javascript Badge by Nikotaf (CC BY-SA 4.0 Intl.).
- Removing “Lua” from the Lua logo would constitute copyright infringement.
- Original PHP logo by Colin Viebrock under CC BY-SA 4.0 Intl.
- The ruby logo was designed by Yukihiro Matsumoto under CC BY-SA 2.5.
- ISO/C++ → mod. requires permission → no reply after 1 month


DnD
Lua
C
C++

F32::NAN AS U32

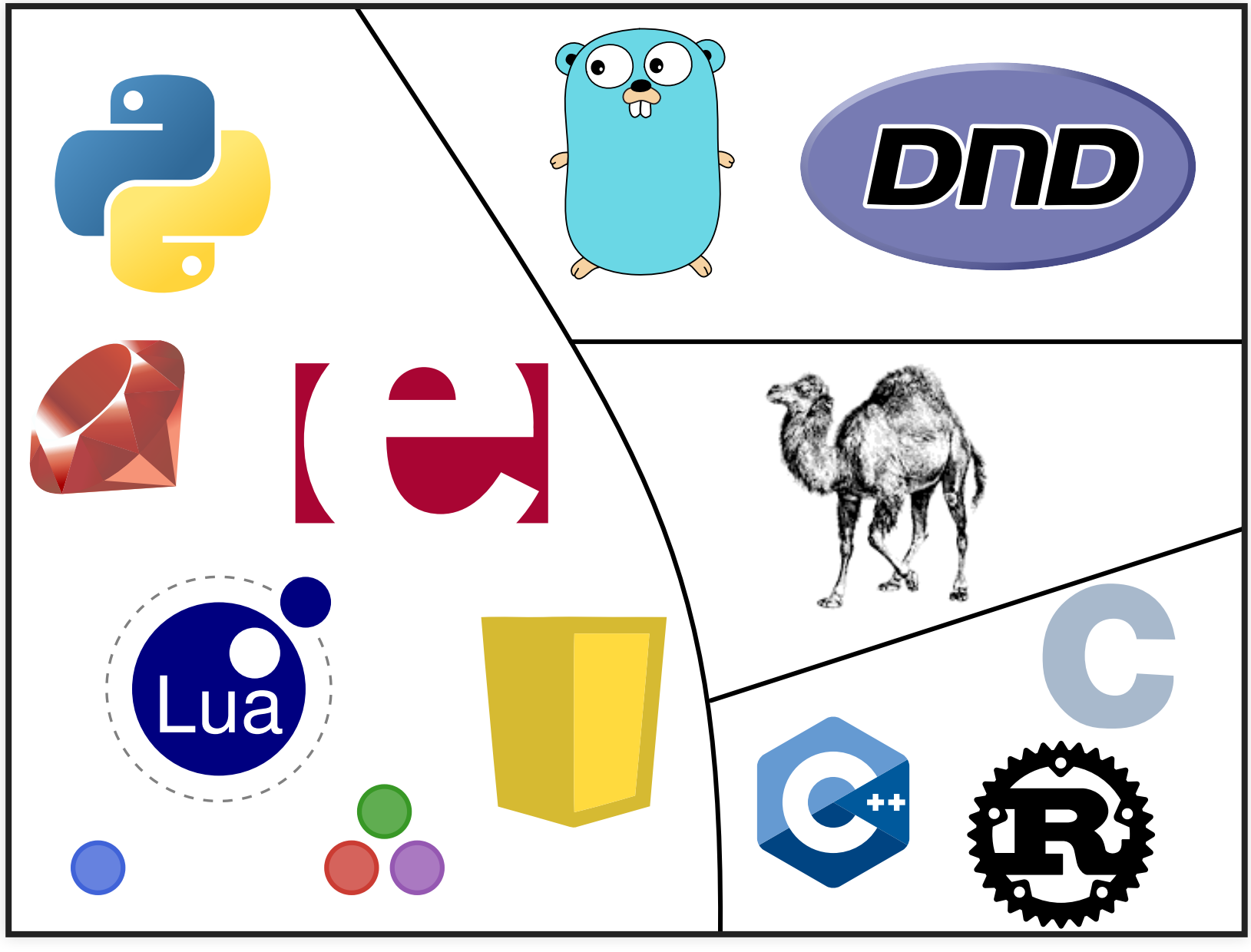
4 categories of behavior:

1. panic / exception / error
2. -9223372036854775808
3. NaN
4. 0

Which languages show which behavior?

F32::NAN AS U32

panic / exception / error	⇒	Python, Ruby, Erlang, Lua, JavaScript (w.r.t. `BigInt`), Julia
-9223372036854775808	⇒	Go, PHP
NaN	⇒	Perl
0	⇒	C, C++, *rust*


DnD
Lua
C
C++
R

L: panic, TR: -9223372036854775808, MR: NaN, BR: 0

PERL'S SPECIAL BEHAVIOR

```
#!/usr/bin/perl -l

my $value = 1.2;
print $value;
print int($value);

my $nan = "NaN" + 1;
#my $nan = -sin(9**9**9);
print $nan;
print int($nan);
```

PERL'S SPECIAL BEHAVIOR

```
1.2
1
NaN
NaN
```

PERL'S SPECIAL BEHAVIOR

Deep dive into perl internals:

```
use Devel::Peek;

$nan = "NaN" + 1;
$forced_nan = int($nan);

# SV = scalar value, UV = unsigned integer value, NV = double
Dump $nan;
Dump $forced_nan;
```

PERL'S SPECIAL BEHAVIOR

```
SV = PVNV(0x55a203d161b0) at 0x55a203db5970
  REFCNT = 1
  FLAGS = (NOK,pIOK,pNOK,IsUV)
  UV = 0
  NV = NaN
  PV = 0
SV = NV(0x55a203d64300) at 0x55a203d64318
  REFCNT = 1
  FLAGS = (NOK,pNOK)
  NV = NaN
```

NV = double value NaN ⇒ `int()` enforces integer representation but does not change value?!

DIALOGUE

CONTROL STRUCTURES

```c
#include <stdio.h>
int main() {
    int i;
    for (i = 0; i < 10; i++) {
        printf("%d\n", i);
    } while (i < 42);
}
```

BRANCHING

IF CONDITIONS

```
fn main() {
    let age = 28;
    if age > 25 {
        println!("I am old!");
    } else {
        println!("Still a youngster!");
    }
}
```

Syntactical remarks:

C-based	⇒	`if ( cond ) { then }`
TCL	⇒	`if { cond } { then }`
Dyalect, Go, rust	⇒	`if cond { then }`
Batch File	⇒	`if cond ( then )`

IF CONDITIONS

```
fn main() {
    let age = 28;
    println!("I am {}!",
        if age > 25 { "old" } else { "young" }
    );
}
```

IF CONDITIONS

⇒ no ternary operator `cond ? then : else`

```c
#include <stdio.h>

int main() {
    int age = 28;
    printf("I am %s\n", age <= 20 ? "young" : "old");
    return 0;
}
```

Bonus question: Do ruby or python have a ternary operator?

IF CONDITIONS

Quiz: What will the output show?

```c
#include <stdio.h>

int main() {
    int age = 28;
    printf("I am in my %ds\n",
        age <= 20 ? 10 : age > 30 ? 30 : 20
    );
    return 0;
}
```

IF CONDITIONS

Quiz: What will the output show?

```php
<?php
$age = 28;
echo "I am in my "
    . (age <= 20 ? 10 : age > 30 ? 30 : 20)
    . "s\n";
```

C	⇒	20s, left-associative evaluation
PHP	⇒	30s, right-associative evaluation

IF CONDITIONS

Back to rust.

RFC 1362 “Rust Needs The Ternary Conditional Operator (-?-:-)” [Closed]

via dscorbett, 2015/11/10

> *Rust already has this:* `return if value == 5 { success } else { failure }`.

IF CONDITIONS

via tolkanabroski, 2017/05/09

5 minutes into rust first thing that i look up was Ternary operator. Im back to C. RIP.

MATCH-CASE

via The Rust Book

```
let number = 19;
match number {
    // Match a single value
    1 => println!("One!"),
    // Match several values
    2 | 3 | 5 | 7 | 11 => println!("This is a prime"),
    // Match an inclusive range [13, 19]
    13...19 => println!("A teen"),
    // Handle the rest of cases
    _ => println!("Ain't special"),
}
```

⇒ fancy pattern matching can be done, we will discuss it with the type system / traits.

MATCH-CASE

```
warning: `...` range patterns are deprecated
 --> test.rs:9:7
  |
9 |     13...19 => println!("A teen"),
  |       ^^^ help: use `..=` for an inclusive range
  |
  = note: `#[warn(ellipsis_inclusive_range_patterns)]` on by d
```

13 . . . 19 ⇔ [13, 19] … deprecated

13 . . =19 ⇔ [13, 19] … inclusive range

13 . . 19 ⇔ [13, 19) … exclusive range

⇒ RFC 37854

MATCH-CASE

Works with strings too (to be discussed).

```
// What's your name?
let name = "Lukas";
match name {
    "Lukas" => println!("Access granted!"),
    _ => println!("How bad …")
}
```

MATCH-CASE

All branches must have the same datatype.

```
fn main() {
    let eggs_required = 4;
    println!("We need {} eggs",
        match eggs_required {
            0 => "no",
            1 => 1,
            _ => "more"
        }
    );
}
```

MATCH-CASE

```
error[E0308]: match arms have incompatible types
 --> test.rs:6:9
  |
4 |           match eggs_required {
  |  _________-
5 | |             0 => "no",
  | |                  ---- this is found to be
  | |                     of type `&'static str`
6 | |             1 => 1,
  | |                  ^ expected &str, found integer
7 | |             _ => "more"
8 | |         }
  | |_________- `match` arms have incompatible types
  |
  = note: expected type `&str`
```

MATCH-CASE

```rust
fn main() {
    let eggs_required = 4;
    println!("We need {} eggs",
        match eggs_required {
            0 => "no",
            0 => "one",
            _ => "more"
        }
    );
}
```

```
warning: unreachable pattern
 --> test.rs:6:4
  |
6 |             0 => "one",
  |             ^
  |
  = note: `#[warn(unreachable_patterns)]` on by default

We need more eggs
```

MATCH-CASE

You need to cover **all** branches!

```
error[E0004]: non-exhaustive patterns: `-2147483648i32..=0i32`
              `4i32`, `6i32` and 3 more not covered
 --> test.rs:3:7
  |
3 | match number {
  |       ^^^^^^ patterns `-2147483648i32..=0i32`, `4i32`,
  |                       `6i32` and 3 more not covered
  |
  = help: ensure that all possible cases are being handled,
          possibly by adding wildcards or more match arms

error: aborting due to previous error

For more information about this error, try `rustc --explain E0
```

MATCH-CASE

… which the compiler does not always recognize.

```
let num = 5;
println!("The number is {}!",
    match num % 2 {
        1 => "odd",
        0 => "even",
    }
);
```

⇒ error[E0004]: non-exhaustive patterns: `-2147483648i32..=-1i32` and `2i32..=2147483647i32` not covered

EXPRESSIONS

Conclusio: rust is *expression*-oriented.

- C and many other languages distinguish between statements (e.g. `int a = 5;`) and expressions (e.g. `5`).
- Functional languages commonly only define expressions.

Thus, the following is a valid program:

```
fn main() {
    5;
}
```

EXPRESSIONS

Wait! What about the following program?

```
fn main() {
    let whoami = println!("Hello World!");
    println!("{}", whoami);
}
```

EXPRESSIONS

```
error[E0277]: `()` doesn't implement `std::fmt::Display`
 --> test.rs:3:20
  |
3 |     println!("{}", whoami);
  |                    ^^^^^^ `()` cannot be formatted
  |                           with the default formatter
  |
  = help: the trait `std::fmt::Display` is not
          implemented for `()`
  = note: in format strings you may be able to
          use `{:?}` (or {:#?} for pretty-print) instead
  = note: required by `std::fmt::Display::fmt`

error: aborting due to previous error
```

EXPRESSIONS

- There are expressions that return “nothing”
- We just discovered the datatype `unit`
- `unit` is represented as `()`
- `num += 1` also returns `()`

LOOPS

FOR LOOP

```
fn main() {
    for i in 1..35 {
        if i % 3 == 0 && i % 5 == 0 {
            println!("Fizz Buzz")
        } else if i % 5 == 0 {
            println!("Buzz")
        } else if i % 3 == 0 {
            println!("Fizz")
        } else {
            println!("{}", i)
        }
    }
}
```

1 2 Fizz 4 Buzz Fizz 7 8 Fizz Buzz 11 Fizz 13 14 Fizz Buzz 16 17 Fizz 19 Buzz Fizz 22 23 Fizz Buzz 26 Fizz 28 29 Fizz Buzz 31 32 Fizz 34

FOR LOOP

Syntactical remarks:

via Pascal:

```
type
  digit = 0..9;
  letter = 'A'..'Z';
var
  num: digit;
  alpha: letter;
```

FOR LOOP

```rust
fn main() {
    for i in 1..5 {
        println!("Hello?");
    }
}
```

```
warning: unused variable: `i`
 --> test.rs:2:9
  |
2 |     for i in 1..5 {
  |         ^ help: consider prefixing with
  |                 an underscore: `_i`
  |
  = note: `#[warn(unused_variables)]` on by default

Hello?
Hello?
Hello?
Hello?
```

UNUSED VARIABLES

- Sometimes we need to assign a name to some value, which we won't use
- Use _ if you want to ignore the value
- In rust, _ is a reserved identifier

This idiom exists in many languages. What about Clojure, Python, C#, Javascript and Go?

```
fn main() {
    for _ in 1..5 {
        println!("Hello?");
    }
}
```

FOR LOOP

Question: What is the expression value of a loop?

FOR LOOP

```rust
fn main() {
    let hello = "hello";
    let expr_value = for i in 1..=5 {
        println!("{}", &hello[0..i]);
    };
    println!("{}", expr_value);
}
```

```
error[E0277]: `()` doesn't implement `std::fmt::Display`
 --> test.rs:6:20
  |
6 |     println!("{}", expr_value);
  |                    ^^^^^^^^^^ `()` cannot be
  |         formatted with the default formatter
…
```

WHILE LOOP

Question: When do we use for loops?
when do we use while loops?

via The Rust Book

```
let mut x = 5;
let mut done = false;

while !done {
    x += x - 3;

    println!("{}", x);

    if x % 5 == 0 {
        done = true;
    }
}
```

INFINITE LOOP

```
loop {
    let message = read_from_some(socket);
    match message.command {
        "STOP" => break,
        "IGNORE" => continue,
        "PRINT" => println!("received: {}\n", message),
    };
}
```

- `break` terminates any loop immediately
- `continue` skips the remaining loop body

BONUS: CONTROL STRUCTURES IN ACTION

```
fn main() {
    let squares = vec![1, 2, 4, 9];

    for (i, square) in squares.iter().enumerate() {
        println!("{} ⇒ {}  ", i, square);
    }

    println!("");

    let skip_iter = squares.iter().skip(1);
    for (prev, next) in squares.iter().zip(skip_iter) {
        println!("diff = {}", next - prev);
    }
}
```

BONUS: CONTROL STRUCTURES IN ACTION

```
0 ⇒ 1
1 ⇒ 2
2 ⇒ 4
3 ⇒ 9

diff = 1
diff = 2
diff = 5
```

BONUS: CONTROL STRUCTURES IN ACTION

```
use std::collections::HashMap;

fn main() {
    let text = "Hello World";

    let mut freq: HashMap<u8, u8> = HashMap::new();
    for chr in text.bytes() {
        *freq.entry(chr).or_insert(0) += 1
    }

    for (c, f) in freq.iter() {
        println!("{} (ASCII {:>3}) ⇒ {:>2}",
            (*c as char), c, f);
    }
}
```

BONUS: CONTROL STRUCTURES IN ACTION

```
'l' (ASCII 108) ⇒  3
'W' (ASCII  87) ⇒  1
' ' (ASCII  32) ⇒  1
'd' (ASCII 100) ⇒  1
'e' (ASCII 101) ⇒  1
'r' (ASCII 114) ⇒  1
'H' (ASCII  72) ⇒  1
'o' (ASCII 111) ⇒  2
```

FUNCTIONS

NAMED FUNCTIONS

- We already know one function: `main`
- We can define custom functions

```
fn add(a: u32, b: u32) -> u32 {
    return a + b;
}

fn main() {
    println!("23 + 19 = {}", add(23, 19));
}
```

```
23 + 19 = 42
```

NAMED FUNCTIONS

- The last expression is the return value
- Pay attention to any semicolon

```
fn add(a: u32, b: u32) -> u32 {
    a + b
}

fn main() {
    println!("23 + 19 = {}", add(23, 19));
}
```

NAMED FUNCTIONS

```
fn add(a: u32, b: u32) -> u32 {
    a + b;
}

fn main() {
    println!("23 + 19 = {}", add(23, 19));
}
```

NAMED FUNCTIONS

```
error[E0308]: mismatched types
 --> test.rs:1:27
  |
1 | fn add(a: u32, b: u32) -> u32 {
  |    ---                    ^^^ expected u32, found ()
  |    |
  |    this function's body doesn't return
2 |     a + b;
  |           - help: consider removing this semicolon
  |
  = note: expected type `u32`
             found type `()`

error: aborting due to previous error
```

NAMED FUNCTIONS

```
fn main() {
    println!("23 + 19 = {}",
        (fn add(a: u32, b: u32) -> u32 { a + b })
        (23, 19)
    );
}
```

Guess: Does this work?

NAMED FUNCTIONS

```
error: expected expression, found keyword `fn`
 --> test.rs:3:10
  |
3 |         (fn add(a: u32, b: u32) -> u32 { a + b })
  |          ^^ expected expression

error: aborting due to previous error
```

NAMED FUNCTIONS

```
fn main() {
    fn add(a: u32, b: u32) -> u32 {
        a + b
    }
    println!("23 + 19 = {}", add(23, 19));
}
```

Guess: Does this work?

NAMED FUNCTIONS

```
fn main() {
    fn add(a: u32, b: u32) -> u32 {
        a + b
    }
    println!("23 + 19 = {}", add(23, 19));
}
```

Guess: Does this work? Yes.

ANONYMOUS FUNCTIONS

- Anonymous functions in general have no name
- Reduces the synactic overhead of named functions
- Commonly used only used once for `map` or alike

```
fn main() {
    let vals = vec![0, 0, 1, 2, 4, 7];
    for digit in vals.iter().map(|item| { item + 1 }) {
        println!("{}", digit);
    }
}
```

ANONYMOUS FUNCTIONS

- Functions can be assigned …
- … multiple times

```
fn main() {
    let i_am_a_function = |a: u32, b: u32| {
        a + b
    };
    let add = i_am_a_function;

    println!("23 + 19 = {}", add(23, 19));
}
```

ANONYMOUS FUNCTIONS

In an anonymous manner, our guess-example from before works.

```
fn main() {
    println!("23 + 19 = {}",
        (|a: u32, b: u32| { a + b })
        (23, 19)
    );
}
```

ANONYMOUS FUNCTIONS

Syntactical remarks - claim:

ruby introduced this syntax

```
irb(main):001:0> my_array = [1, 3, 4, 6];
=> [1, 3, 4, 6]
irb(main):002:0> my_array.each{ |item| puts item }
1
3
4
6
=> [1, 3, 4, 6]
irb(main):003:0>
```

ANONYMOUS FUNCTIONS

Ruby:	`|a, b| { a + b }`
Python:	`lambda a, b: a + b`
Clojure:	`#(+ %1 %2)`
Groovy:	`{ int a, int b -> a + b }`
Haskell:	`(\x y -> x + y)`
C++11:	`[](int a, int b) { return a + b`

CLOSURES

A function accesses values outside the scope it constitutes.

```
fn main() {
    let c = 1;
    let add = |a: u32, b: u32| { a + b + c };
    println!("23 + 18 + 1 = {}", add(23, 18));
}
```

```
23 + 18 + 1 = 42
```

CLOSURES

```
fn main() {
    let mut c = 1;
    let add = |a: u32, b: u32| { a + b + c };
    println!("23 + 18 + 1 = {}", add(23, 18));
}
```

⇒ warning: variable does not need to be mutable

```
23 + 18 + 1 = 42
```

CLOSURES

```rust
fn main() {
    let mut c = 1;
    let add = |a: u32, b: u32| { c += 1; a + b + c };
    println!("23 + 18 + 1 = {}", add(23, 18));
}
```

```
error[E0596]: cannot borrow `add` as mutable,
              as it is not declared as mutable
 --> test2.rs:4:34
  |
3 | let add = |a: u32, b: u32| { c += 1; a + b + c };
  |     --- help: consider changing this to be mutable: `mut a
4 | println!("23 + 18 + 1 = {}", add(23, 18));
  |                              ^^^ cannot borrow as mutable

error: aborting due to previous error

For more information about this error, try `rustc --explain E0
```

CLOSURES

Compiler messages are often very helpful. So, let's just do it. `add` is now mutable:

```
fn main() {
    let mut c = 1;
    let mut add = |a: u32, b: u32| { c += 1; a + b + c };
    println!("23 + 18 + 1 = {}", add(23, 18));
}
```

```
23 + 18 + 1 = 43
```

BLOCKS {} DEFINE SCOPES

```
fn add(a: u32, b: u32) {
    let c = 1;
    a + b
}

fn main() {
    println!("23 + 18 + 1 = {}", add(23, 18 + c));
}
```

```
error[E0425]: cannot find value `c` in this scope
 --> test2.rs:7:47
  |
7 |     println!("23 + 18 + 1 = {}", add(23, 18 + c));
  |                                   not found in this scope ^
```

…

BLOCKS {} DEFINE SCOPES

```rust
fn main() {
    {
        let b = 6;
    }
    println!("{}", b);
}
```

```
error[E0425]: cannot find value `b` in this scope
 --> test.rs:5:20
  |
6 |     println!("{}", b);
  |                    ^ help: a local variable with a
  |                      similar name exists: `a`

error: aborting due to previous error

For more information about this error, try `rustc --explain E0
```

FUNCTIONS: TO BE CONTINUED

Advanced topics:

- Functions are types implementing traits
- Borrowing
- Methods and traits
- Visibility of functions and modules
- Functions and control structures in LLVM IR

EPILOGUE

QUIZ

Which three loop constructs do we have in rust?

Which identifier is used for unused variables?

What is an anonymous function?

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NEXT SESSION

Wed, 2019/09/25 19:00

Show of hands:

- **Topic 1:** Strings, string types and UTF-8
- **Topic 2:** References, borrowing & borrow checker

⇒ majority voted in favor of topic 2.