Hochschule **RheinMain**
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Rust

(SELECTED TOPIC IN COMPUTER ENGINEERING)

LV 7281

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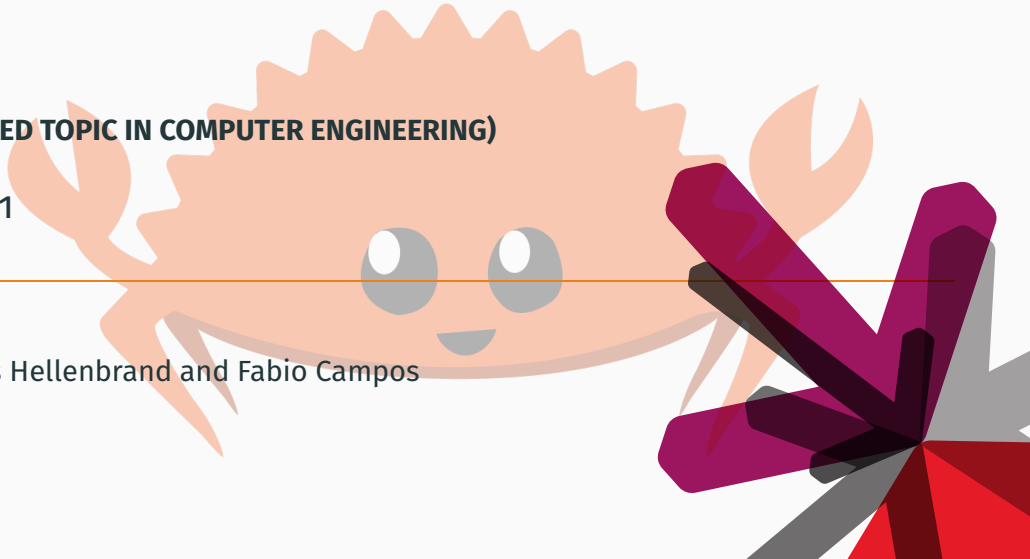

Agenda

- Error Handling
- Lifetimes

Error Handling

Different types of errors[1] 1/2

1. dereferencing null pointer
2. server does not respond
3. (function) contract violation
4. config file has invalid format
5. division by zero
6. array out of bounds
7. file not found
8. user entered letters as phone number

[1] stronlgy based on *https://github.com/LukasKalbertodt/programmieren-in-rust*

Different types of errors 2/2

Unrecoverable Errors $\approx$ Bugs

- dereferencing null pointer
- (function) contract violation
- division by zero
- array out of bounds

Recoverable errors

- config file has invalid format
- file not found
- server does not respond
- user entered letters as phone number

Bugs

- unexpected and usually not treatable
- lead to unpredictable status
- **Solution:** abort
- in Rust: *panic!()* $\rightarrow$ abort thread

```
1  fn main() {
2      let x = 101;
3      println!("Hello world of panic!");
4      panic!("goodbye, x = {}", x);
5  }
```

```
1  thread 'main' panicked at src/main.rs:4:5:
2  goodbye, x = 101
3  note: run with 'RUST_BACKTRACE=1' environment variable to display a backtrace
```

Panic

```rust
#[allow(unconditional_panic)]
fn main() {
    let vec = vec![1, 2];
    vec[101];
}
```

```
$ rustc panic.rs
$ ./panic
thread 'main' panicked at panic.rs:4:5:
index out of bounds: the len is 2 but the index is 101
note: run with 'RUST_BACKTRACE=1' environment variable to display a backtrace
```

```
$  RUST_BACKTRACE=1 ./panic
thread 'main' panicked at panic.rs:4:5:
index out of bounds: the len is 2 but the index is 101
stack backtrace:
   0: rust_begin_unwind
             at /rustc/7cf61ebde7b22796c69757901dd346d0fe70bd97/library/std/src/panicking.rs:647:5
   1: core::panicking::panic_fmt
             at /rustc/7cf61ebde7b22796c69757901dd346d0fe70bd97/library/core/src/panicking.rs:72:14
   2: core::panicking::panic_bounds_check
             at /rustc/7cf61ebde7b22796c69757901dd346d0fe70bd97/library/core/src/panicking.rs:208:5
   3: panic::main
   4: core::ops::function::FnOnce::call_once
note: Some details are omitted, run with 'RUST_BACKTRACE=full' for a verbose backtrace.
```

Where to panic?

- out of bounds
- overflows and underflows
- *unimplemented!()*
- *unreachable!()*
- Asserts $\rightarrow$ e.g. function contracts
- Deadlocks (if detected)
- ...

Unwinding

- clears stack before terminating $\rightarrow$ unwinding
- by climbing up the stack
- *drops* all local objects ($\approx$ destructor, more in 2 weeks)
- can take quite a lot of time
- to deactivate (panic='abort' @cargo profile or *crate panic_abort*)

Recoverable errors

- expected
- due to invalid state of the environment
- can be handled
- in Rust: no exceptions, done using return values:
  - *Result<T, E>*
  - *Option<T>*
- error cannot be ignored $\rightarrow$ safer
- correct result must first be ”unpacked”

Result<T, E> example

```rust
use std::fs::File;

fn main() {
    let file_result = File::open("hello.txt");
    match file_result {
        Ok(file) => {
            // do something with the file
        },
        Err(error) => {
            panic!("Error: {}", error);
        }
    }
}
```

```rust
enum Result<T, E> {
    Ok(T),
    Err(E),
}

impl File { // fake impl of File
    fn open(name: &str) -> Result<Self, String>
    { ... }
    ...
}
```

Propagating Errors

```
fn copy_file(from: &str, to: &str) -> Result<(), String> {
    match File::open(from) {
        Ok(file) => {
            ...
            Ok(())
        }
        Err(e) => {
            // not my beer!
            Err(e)
        }
    }
}
```

Which type of error?

- String … a good choice?
- enums significantly better!
  - defining error cases
  - methods for output
- error type *() → Option<T>*

```
fn copy_file(from: &str, to: &str) -> Result<(), FileError> {
    ...
}
enum FileError {
    NoFile,
    NoPermission,
    MaxDescriptors,
}
impl FileError {
    fn description(&self) -> String {
        ...
    }
}
```

Option

Option<T> has two variants:

- *None*: failure or lack of value
- *Some(value)*: tuple struct wraps value

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

```rust
fn take_101th(vec: Vec<i32>) -> Option<i32> {
    if vec.len() < 101 {
        None
    } else {
        Some(vec[4])
    }
}

fn main() {
    let vec = vec![1, 2];
    let big_vec = vec![0; 200];
    println!("{:?}, {:?}", take_101th(vec), take_101th(big_vec));
}
```

Shortcuts for Panic on Error

It converts recoverable error into bug

```
fn take_101th(vec: Vec<i32>) -> Option<i32> {
    if vec.len() < 101 {
        None
    } else {
        Some(vec[4])
    }
}
fn main() {
    let vec = vec![1, 2];
    let big_vec = vec![42; 200];
    println!("{:?}, {:?}", take_101th(big_vec.clone()), take_101th(big_vec).unwrap());
    println!("{:?}", take_101th(vec.clone()).unwrap()); // fine?
    println!("{:?}", take_101th(vec).expect("length of vector should be >= 101")); // fine?
}
```

Open topics

- *try!()* and the *?* operator → see next exercise
- the bottom type *!*
- ...

Lifetimes

Working with references

Reference always points to valid object

- no use after drop/free
- scope of reference < scope of referenced value
- scope of variables $\rightarrow$ stack (LIFO)

```
1  fn return_smt() -> &u32 {
2      let x = 101u32;
3      &x  // fine?
4  }
5
6  let r = {
7      let x = 101u32;
8      &x  // fine?
9  };
```

Rust compiler

the rust compiler ensures:

- no reference longer than referenced value
- aliasing xor mutability
- analysis based on
  - own function body
  - own signature
  - signature of called functions

```
fn foo(i: &u8) -> &u8 { ... }

let r = {
    let x = 3;
    foo(&x) // fine?
}
```

Rust compiler

the rust compiler ensures:

- no reference longer than referenced value
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```rust
fn foo(i: &u8) -> &u8 {
    i
}
```

```rust
static STATIC_X: u8 = 101;

fn foo(i: &u8) -> &u8 {
    println!("{}", i);
    &STATIC_X
}
```

```rust
fn foo(i: &u8) -> &u8 { ... }

let r = {
    let x = 3;
    foo(&x) // fine?
}
```

Rust compiler

- full analysis impossible without function body
- rust aims for safety
- $\rightsquigarrow$ necessary information required in signature