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Putting a Roof over your Head

Object-Oriented Programming in Rust

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Rust: Safe and Efficient System-Level Programming

- **Safe:** memory-access interface defined via *ownership*
- **Efficient:** auto-deallocation (no garbage collector)
- **Modern and "in vogue":**
  - trying-to-be-helpful compiler & build system
  - active user community

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Rust: Beloved Features and Non-Features

Object-Oriented Programming

- **Objects:** struct instances, with encapsulated data and methods
- **Information hiding:** private data fields in structs

- **Inheritance:** one struct refines (specializes) data & methods of another
- **Exception handling:** errors/edge cases handled away from mainstream code

Absence of these features steepens the *already steep* learning curve specifically for C++/Java programmers.

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Goal of This Work

Roof: Rust with Object-Oriented Features

- Rust-like language with 1st-class support for exceptions and inheritance
- Transpilable into genuine Rust. (No extra runtime support!)

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SOME DETAILS

Exception Handling Primer: throw, try, catch!

A Roof program

```
fn f(x: u32) {
    if x > 100 { throw!("Too big!"); }
    ...;
}

fn g(x: u32) {
    f(x);
}

fn main() {
    try! {
        println!("Potentially throwing call");
        g(42);
    }
    catch! { e => { println!("{}", e); } }
}
```

Intended meaning:

- **`throw!`** : generate exception, to be passed up the call stack in search for handler
- **`try!`** + **`catch!`** :
  1. Execute `try` code.
  2. a) If exception is encountered, pass control to `catch` block.
     b) Otherwise skip `catch` block.

(C++ exception model)

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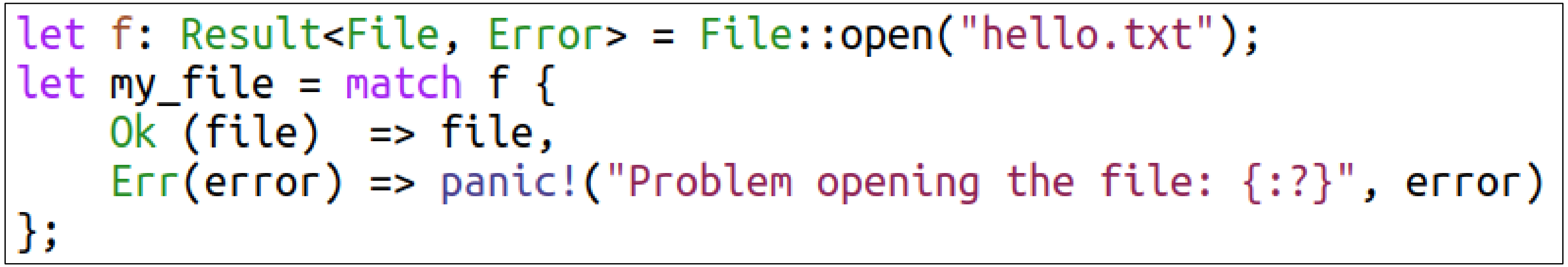
Existing Rust-Style Error Handling

Rust has a “union” type

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

= a two-variant type encapsulating “ok” and error results:



```
let f: Result<File, Error> = File::open("hello.txt");
let my_file = match f {
    Ok (file)  => file,
    Err(error) => panic!("Problem opening the file: {:?}", error)
};
```

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Throwing and Propagating Exceptions

Idea: Treat exceptions as part of a function's return value.

1.a Throwing:

- Perform *may-throw* analysis
- Change all functions that *may throw* to return `Result<T,str>`
- `return x` becomes `return Ok(x)`
  `throw!("Error!")` becomes `return Err("Error!")`

1.b Propagation: change calls to *may-throw* `f()` **outside** a `try` block:

`f()` →

```
match f() {
    Ok (s) => s,
    Err(t) => return Err(t)
}
```

Rust helps us out here:
`f()` → `f()?`

Trying and Catching Exceptions

Idea: Abstract try block into a function.

2.a Wrap try code into *helper function*.

2.b Call the helper.

2.c Pattern-match on the result.

```
try!   { stmts1; }
catch! { e => stmts2; }
```

```
let helper = || -> Result<(), str> {
    stmts1;
    Ok(())
};
match helper() {
    Ok (_) => (),
    Err(e) => stmts2
}
```

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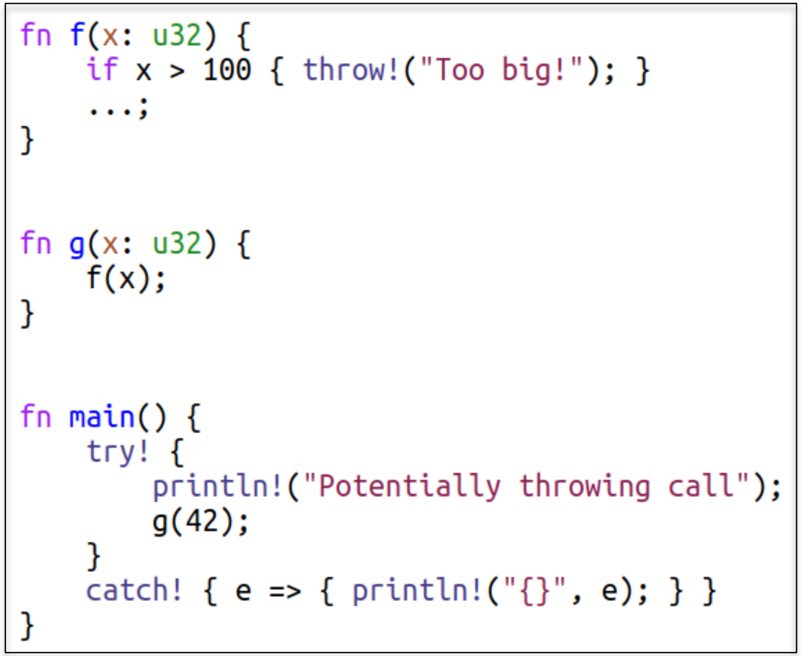
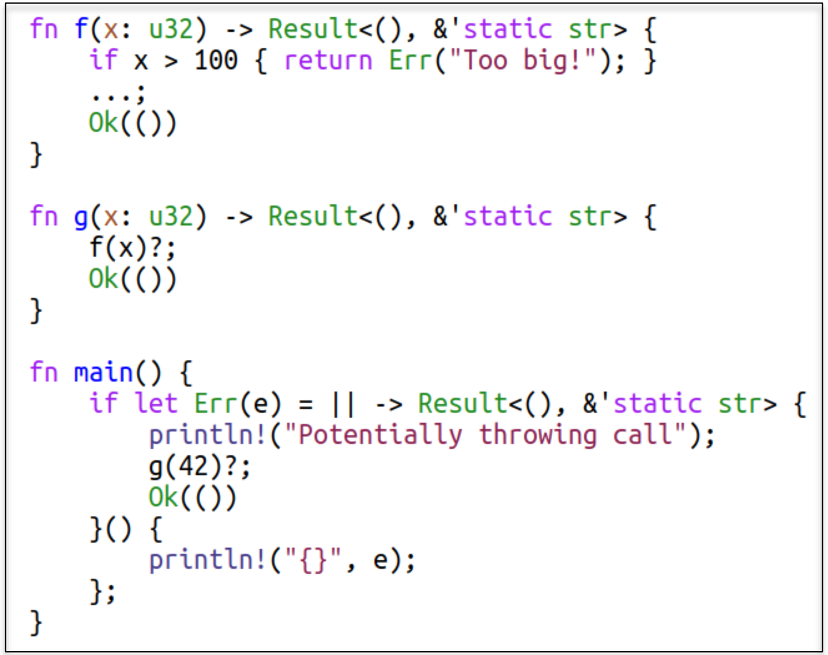
Roof to Rust Transpilation: Result



```
fn f(x: u32) {
    if x > 100 { throw!("Too big!"); }
    ...;
}


fn g(x: u32) {
    f(x);
}


fn main() {
    try! {
        println!("Potentially throwing call");
        g(42);
    }
    catch! { e => { println!("{}", e); } }
}
```



```
fn f(x: u32) -> Result<(), &'static str> {
    if x > 100 { return Err("Too big!"); }
    ...;
    Ok(())
}

fn g(x: u32) -> Result<(), &'static str> {
    f(x)?;
    Ok(())
}

fn main() {
    if let Err(e) = || -> Result<(), &'static str> {
        println!("Potentially throwing call");
        g(42)?;
        Ok(())
    }() {
        println!("{}", e);
    };
}
```

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DISCUSSION

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Trade-Offs of our Exception Handling

Our Exception system is currently binary:

A function either throws or it doesn't throw.

<u>In reality:</u>

- Exception types form hierarchies.
- Binary matching `Ok(_)` vs. `Err(e)` should really be (sub-)type checking

  → we need *inheritance*.

Inheritance in Rust

1. Simple data and method inheritance:

- Turn “is a" relationship into “has a”:

```
class Tree: public Plant → class Tree { Plant p; … }
```

- Works for multiple inheritance, too

2. Virtual methods: can be implemented using Rust’s *trait* mechanism:

- Capture virtual methods in a trait (function body = default implementation)
- Wrap a `Box` pointer around variables of base type: “dynamic dispatch”

```
Box<dyn Plant>
```

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Summary: OO Programming in Rust

1. Can we do it?
   - “OOP” means different things to different people
   - Core OOP concepts can be implemented fairly naturally in Rust

2. Do we need it?
   - Rust certainly has its own design patterns.
   - OOP comes with a baggage of 50+ years of history (“legacy concept”)
   - New Rust programmers with C++/Java background will appreciate

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