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Rust/C++ Interop

Boulder Rust Meetup

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Tyler Weaver

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- Regular C++ Programmer
- Rust Cult Member
- Open-source Robotcist
- Wrote a Rust Library with C++ Bindings

Prefix

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- No AI generation tools were used
- Slides and more at tylerjw.dev

What Are We Going To Cover

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- Social Objections to Rust
- Details of Interop
- Examples of Useful Patterns
- Code Generation Tools

A Collective Craft

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Quality of your project has more to do with the people that build it than the tools selected. It is fine and good for the people to like their tools.

- C++ code that exists has value
- A little Rust is better than no Rust

Golden Gate Bridge

Before We Begin

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Code Generators

- cxx – Safe interop between Rust and C++
- bindgen – generate Rust FFI to C/C++ headers
- cbindgen – generate C headers for Rust FFI

Why Not

- Eigen C++ types <=> Nalgebra Rust types

Hourglass Language Bridge

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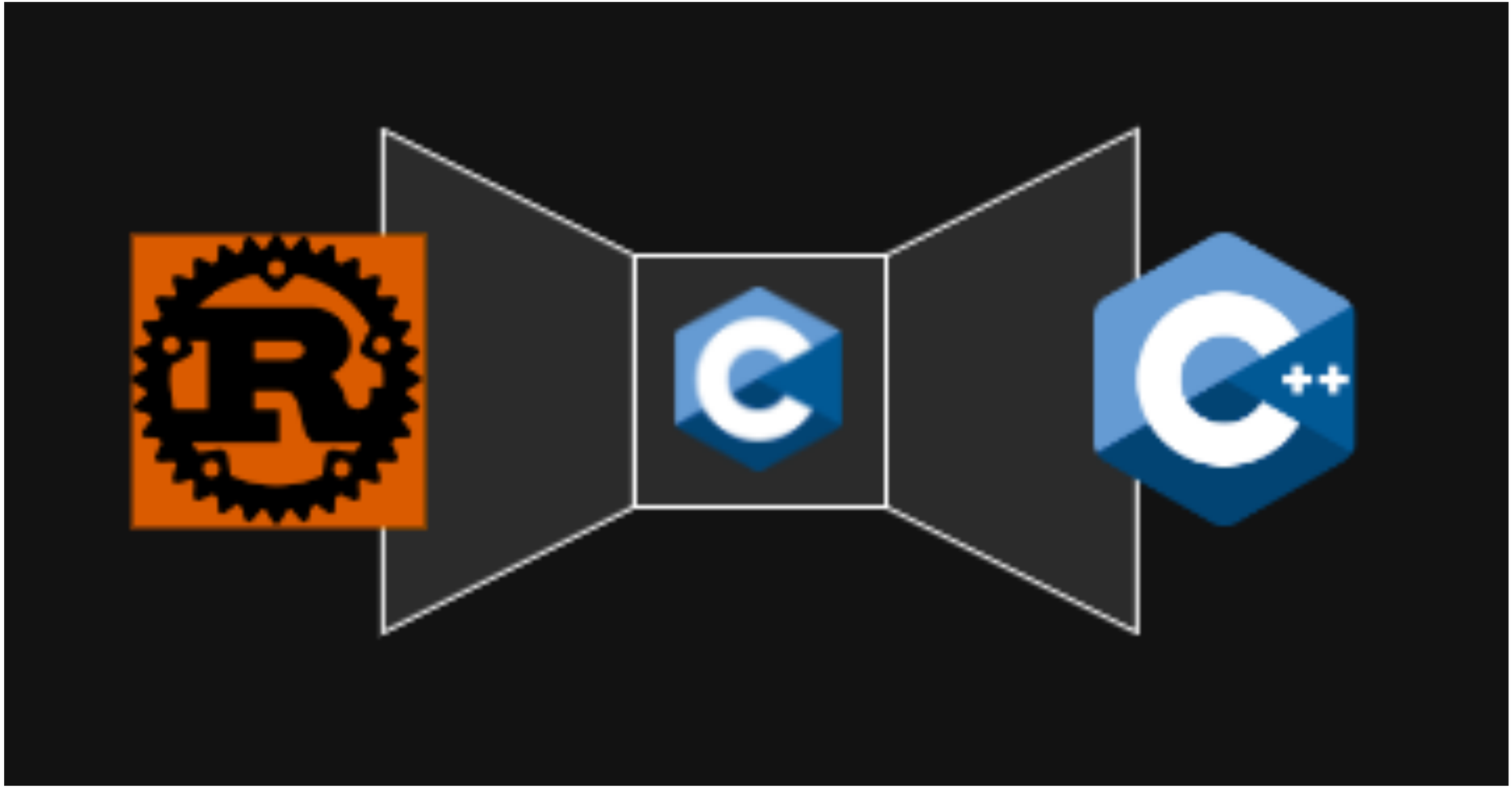

Project Layout

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```
├── Cargo.toml
├── crates
│   ├── robot_joint
│   │   ├── Cargo.toml
│   │   └── src
│   │       └── lib.rs
│   └── robot_joint-cpp
│       ├── Cargo.toml
│       ├── CMakeLists.txt
│       ├── cmake
│       │   └── robot_jointConfig.cmake.in
│       ├── include
│       │   └── robot_joint.hpp
│       └── src
│           ├── lib.cpp
│           └── lib.rs
└── README.md
```

Zakim Bridge

robot_joint/src/lib.rs

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```rust
pub struct Joint {
    name: String,
    parent_link_to_joint_origin: Isometry3<f64>,
}

impl Joint {
    pub fn new() -> Self;
}
```

robot_joint-cpp/src/lib.rs

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```rust
use robot_joint::Joint;

#[no_mangle]
extern "C" fn robot_joint_new() -> *mut Joint {
    Box::into_raw(Box::new(Joint::new()))
}

#[no_mangle]
extern "C" fn robot_joint_free(joint: *mut Joint) {
    unsafe {
        drop(Box::from_raw(joint));
    }
}
```

robot_joint-cpp/include/robot_joint.hpp

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```cpp
struct RustJoint;

class Joint {
  public:
    Joint();
    ~Joint();

    // Disable copy as we cannot safely copy opaque pointers to rust objects.
    Joint(Joint& other) = delete;
    Joint& operator=(Joint& other) = delete;

    // Explicit move.
    Joint(Joint&& other);
    Joint& operator=(Joint&& other);

  private:
    RustJoint* joint_ = nullptr;
};
```

robot_joint-cpp/src/lib.cpp

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```cpp
#include "robot_joint.hpp"

extern "C" {
extern RustJoint* robot_joint_new();
extern void robot_joint_free(RustJoint*);
}
```

robot_joint-cpp/src/lib.cpp

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```cpp
Joint::Joint() : joint_(robot_joint_new()) {}

Joint::~Joint() {
  if (joint_ != nullptr) {
    robot_joint_free(joint_);
  }
}

Joint::Joint(Joint&& other) : joint_(other.joint_) {
  other.joint_ = nullptr;
}

Joint& Joint::operator=(Joint&& other) {
  joint_ = other.joint_;
  other.joint_ = nullptr;
  return *this;
}
```

Build System Integration

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See My Blog for a link to CMake example

tylerjw.dev

Fremont Bridge

First-class Types

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robot_joint/src/lib.rs

```rust
impl Joint {
    pub fn calculate_transform(&self, variables: &[f64]) -> Isometry3<f64>;
}
```

robot_joint-cpp/include/robot_joint.hpp

```cpp
class Joint {
  public:
    Eigen::Isometry3d calculate_transform(const Eigen::VectorXd& variables);
};
```

robot_joint-cpp/src/lib.rs

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```rust
#[repr(C)]
struct Mat4d {
    data: [c_double; 16],
}

#[no_mangle]
extern "C" fn robot_joint_calculate_transform(
    joint: *const Joint,
    variables: *const c_double,
    size: c_uint,
) -> Mat4d {
    unsafe {
        let joint = joint.as_ref().expect("Invalid pointer to Joint");
        let variables = std::slice::from_raw_parts(variables, size as usize);
        let transform = joint.calculate_transform(variables);
        Mat4d {
            data: transform.to_matrix().as_slice().try_into().unwrap(),
        }
    }
}
```

robot_joint-cpp/src/lib.cpp

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```cpp
struct Mat4d {
  double data[16];
};

extern "C" {
extern struct Mat4d robot_joint_calculate_transform(
  const RustJoint*, const double*, unsigned int);
}

Eigen::Isometry3d Joint::calculate_transform(const Eigen::VectorXd& variables)
{
  const auto rust_isometry = robot_joint_calculate_transform(
    joint_, variables.data(), variables.size());
  Eigen::Isometry3d transform;
  transform.matrix() = Eigen::Map<Eigen::Matrix4d>(rust_isometry.data);
  return transform;
}
```

Red Cliff Bridge

So What?

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Rust / C++ Interop is Straightforward
Don’t Listen to the Naysayers

Attribution

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Kyle Cesare's OptIk
github.com/kylc/optik