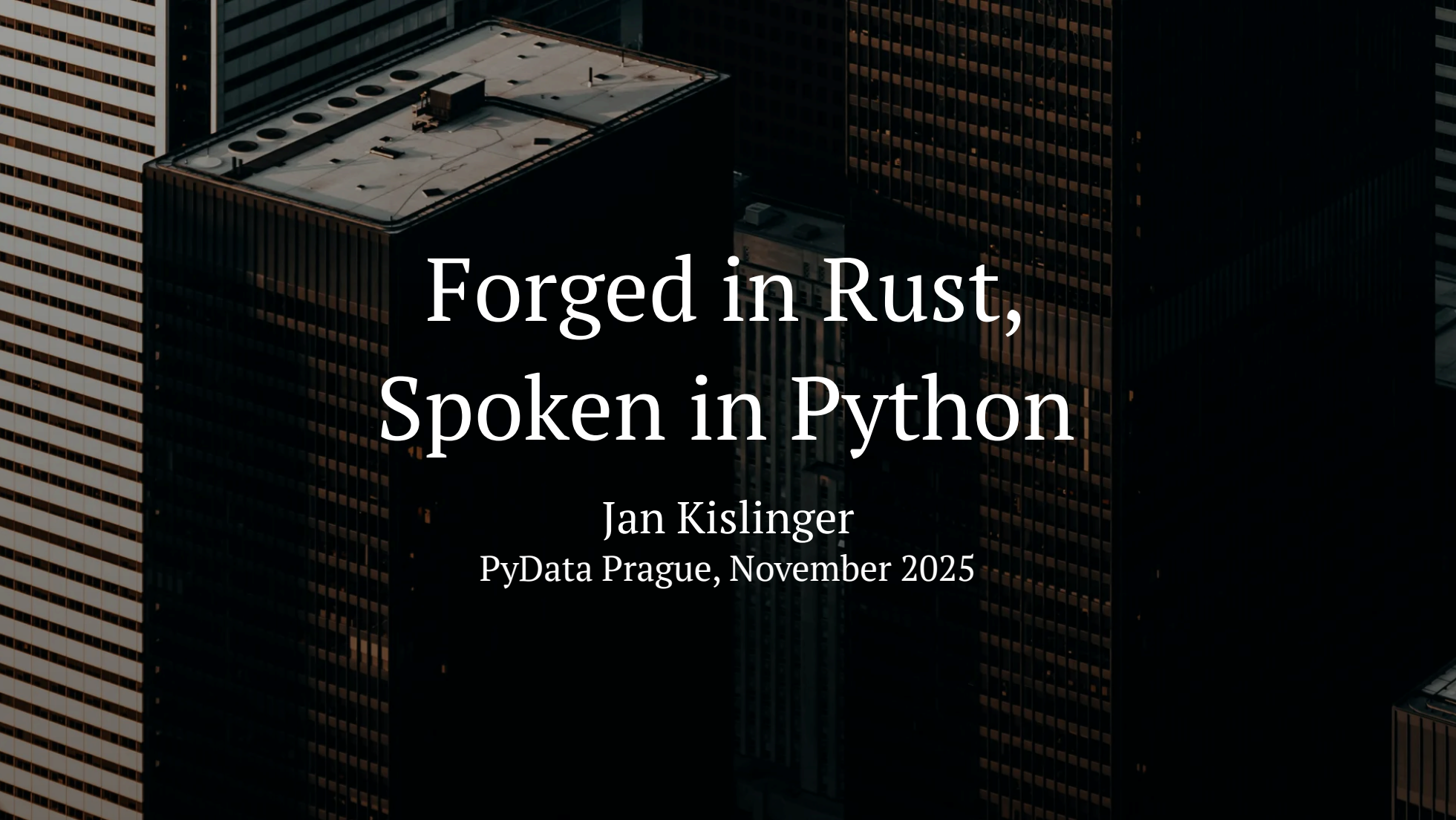

Forged in Rust, Spoken in Python

Jan Kislinger

PyData Prague, November 2025

2018: R ⇨ Python

- dplyr
- ggplot2
- Rcpp

2018: R ⇨ Python

- dplyr ⇨ Polars
- ggplot2
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2018: R ⇨ Python

- dplyr ⇨ Polars
- ggplot2 😔
- Rcpp ⇨ PyO3 + maturin

Why Rust

Why Rust

- Performance

Why Rust

- Performance
- Most admired language

Why Rust

- Performance
- Most admired language
- Effortless integration

You'll Learn Today

- Basic Rust concepts
- Call Rust from Python
- Popular projects
- Write Polars extension
- (+1 bonus tip)

Concepts of Rust

Concepts of Rust

- Compiled

```
   Compiling guessing_game v0.1.0 (...)
warning: unused `Result` that must be used
  --> src/main.rs:10:5
   |
10 |     io::stdin().read_line(&mut guess);
   |     ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
   |
   = note: this `Result` may be an `Err` variant,
       which should be handled
   = note: `#[warn(unused_must_use)]` on by default
help: use `let _ = ...` to ignore the resulting value
   |
10 |     let _ = io::stdin().read_line(&mut guess);
   |     +++++++
```

Concepts of Rust

- Compiled
- Strongly typed

```rust
fn add(a: i32, b: i32) -> i32 {
    a + b
}

fn main() {
    let x = 3;
    let s = add(x, 2);
}
```

Concepts of Rust

- Compiled
- Strongly typed
- Struct (no inheritance)

```rust
struct Rectangle {
    a: f32,
    b: f32,
}

impl Rectangle {
    fn new(a: f32, b: f32) -> Self {
        Self { a, b }
    }

    fn area(&self) -> f32 {
        self.a * self.b
    }
}
```

Concepts of Rust

- Compiled
- Strongly typed
- Struct (no inheritance)
- Trait, Generics

```
trait Shape {
    fn area(&self) -> f32;
}

struct Square { a: f32 };
impl Shape for Square {
    fn area(&self) -> f32 { self.a * self.a }
}

struct Circle { r: f32 };
impl Shape for Circle {
    fn area(&self) -> f32 { PI * self.r * self.r }
}

fn volume<T: Shape>(base: &T, height: f32) -> f32 {
    base.area() * height
}
```

Concepts of Rust

- Compiled
- Strongly typed
- Struct (no inheritance)
- Trait, Generics
- Enum

```
enum Shape {
    Square(f32),
    Rectangle(f32, f32),
    Circle(f32),
}

fn area(x: &Shape) -> f32 {
    match x {
        Shape::Square(a) => a * a,
        Shape::Rectangle(a, b) => a * b,
        Shape::Circle(r) => PI * r * r,
    }
}
```

Concepts of Rust

- Compiled
- Strongly typed
- Struct (no inheritance)
- Trait, Generics
- Enum
- Option, Result

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

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

Concepts of Rust

- Compiled
- Strongly typed
- Struct (no inheritance)
- Trait, Generics
- Enum
- Option, Result
- Error as value

```rust
fn parse_int_fallback(s: &str) -> i32 {
    match s.parse() {
        Ok(n) => n,
        Err(_) => i32::MIN,
    }
}

fn parse_int_option(s: &str) -> Option<i32> {
    s.parse().ok()
}

fn parse_int_panic(s: &str) -> i32 {
    s.parse().expect("Failed to parse")
}
```

Concepts of Rust

- Compiled
- Strongly typed
- Struct (no inheritance)
- Trait, Generics
- Enum
- Option, Result
- Error as value
- Borrow checker

```rust
fn print_first(vec: Vec<u32>) {
    println!("First element: {}", vec[0]);
}

fn main() {
    vec = vec![1, 2, 3];
    print_first(vec);
    print_first(vec);  // Error: Value used after being moved
}
```

Concepts of Rust

- Compiled
- Strongly typed
- Struct (no inheritance)
- Trait, Generics
- Enum
- Option, Result
- Error as value
- Borrow checker
- Macros

```rust
#[derive(Debug)]
struct Point {
    x: i32,
    y: i32,
}

fn main() {
    let point = Point { x: 1, y: 2 };
    println!("{:?}", point);
    // Point { x: 1, y: 2 }
}
```

Development Tools

Python

Development Tools

Python

- Environment: `pip`, `virtualenv`, `pipx`, `poetry`, `uv`

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Rust

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Rust

- `cargo`

Development Tools

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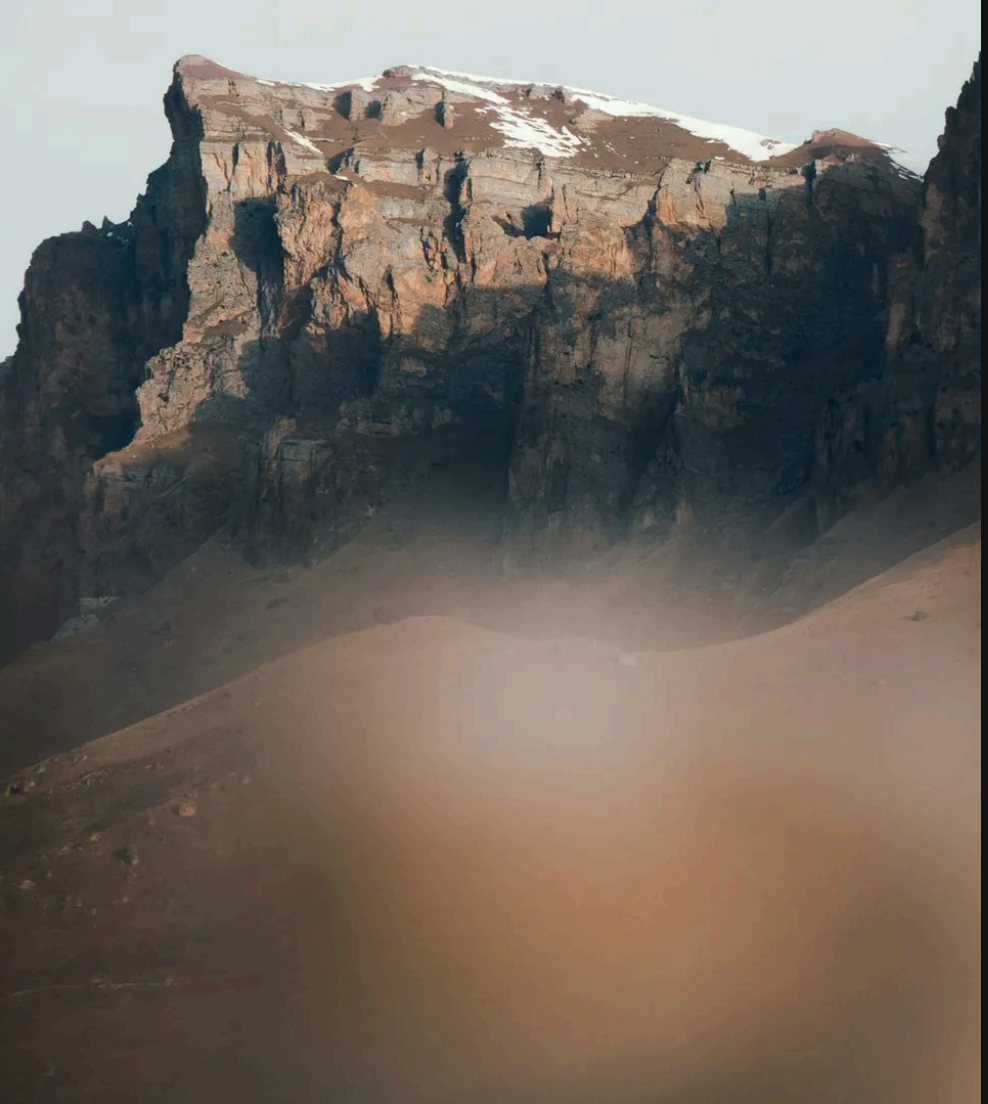
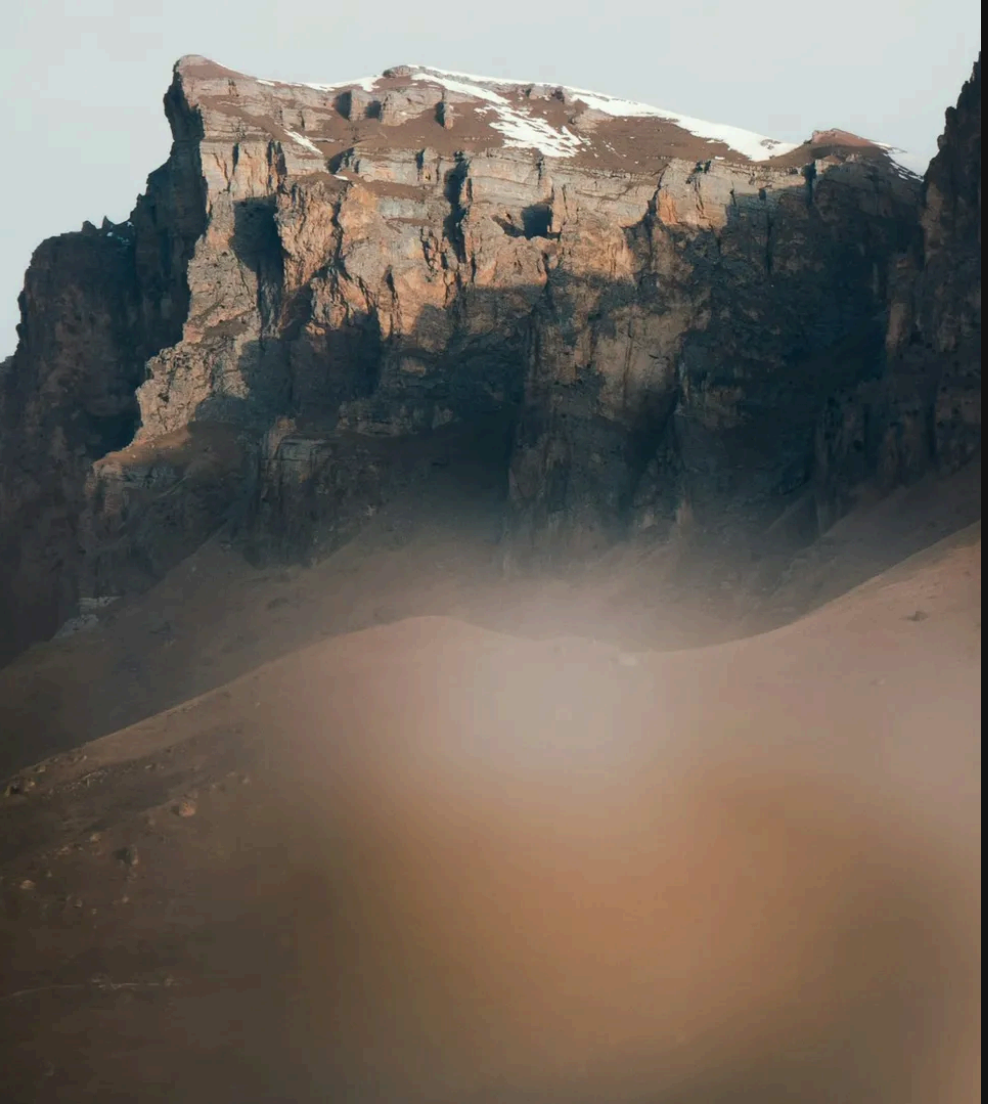
Rust

- `cargo`



Just in Python

Hidden features



Just in Python

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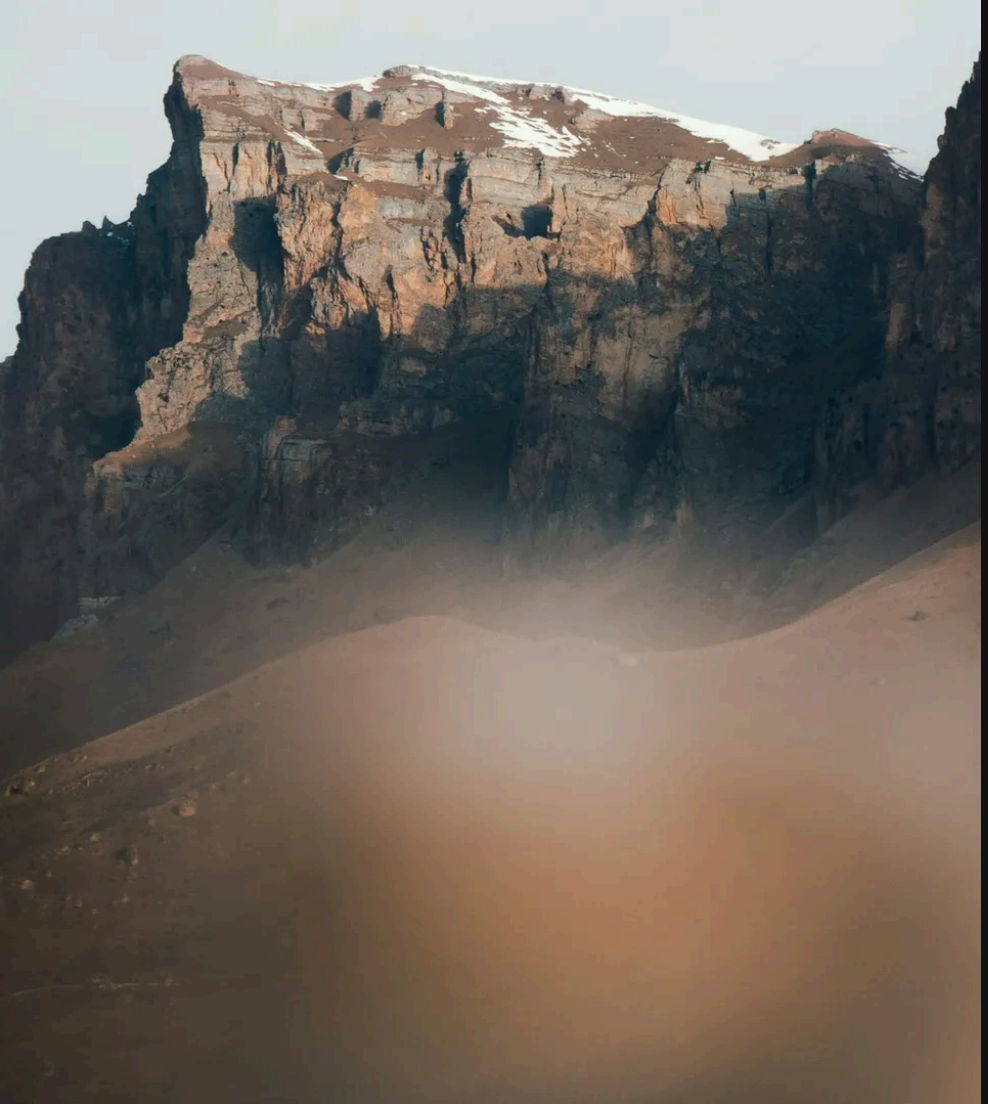
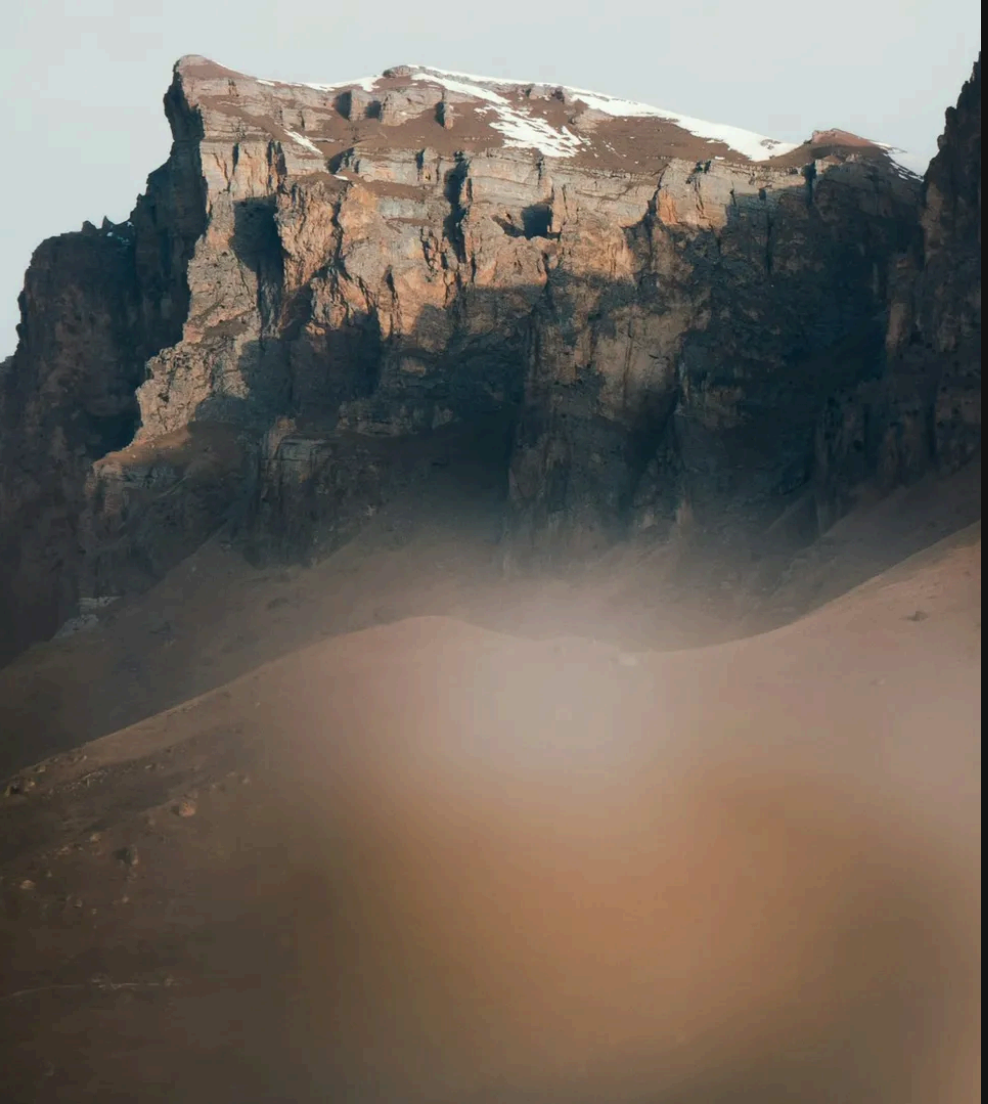
- `int` (unbounded)



Just in Python

Hidden features

- `int` (unbounded)
- `str` (cached)



Just in Python

Hidden features

- `int` (unbounded)
- `str` (cached)
- `dict` (sorted)

Popular Projects

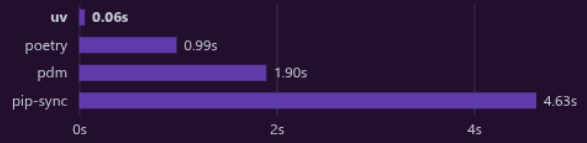
Written in Rust; Used by Python developers

Python Tooling

astral.sh

uv

An extremely fast Python package and project manager, written in Rust.



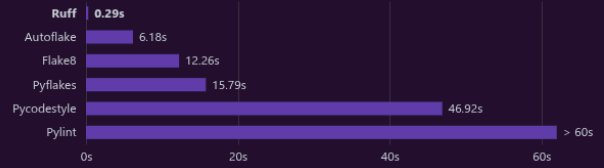
Installing Trio's dependencies with a warm cache.

Ruff

Ruff | pypi v0.14.6 | license MIT | python 3.7 | 3.8 | 3.9 | 3.10 | 3.11 | 3.12 | 3.13 | CI failing | Discord

Docs | Playground

An extremely fast Python linter and code formatter, written in Rust.



Linting the CPython codebase from scratch.


Polars

- Data frame library

- Data frame library
- Backend written in Rust

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- Backend written in Rust
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- Lazy expressions 🤗
- Consistent syntax
- No (multi-) indices

```python
# Polars
result = (
    pl.scan_csv("data.csv")
    .filter(pl.col("value") > 10)
    .with_columns(double=pl.col("value") * 2)
    .group_by("category")
    .agg(double_mean=pl.col("double").mean())
    .collect()
)
```

```python
# Pandas
result = (
    pd.read_csv("data.csv")
    .iloc[lambda d: d["value"] > 10]
    .assign(double=lambda d: d["value"] * 2)
    .groupby("category")
    .agg(double_mean=("double", "mean"))
    .reset_index()
)
```

```r
# R::dplyr
result <- read_csv("data.csv") |>
  filter(value > 10) |>
  mutate(double = value * 2) |>
  group_by(category) |>
  summarise(double_mean = mean(double, na.rm = TRUE))
```

```python
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result = (
    pl.scan_csv("data.csv")
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```

Other Examples

orjson

Fast, correct JSON library for Python.

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Fast, correct JSON library for Python.

Pydantic

Data validation using Python type hints.

Other Examples

orjson

Fast, correct JSON library for Python.

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Robyn

High-Performance [...] Web Framework with a Rust runtime.

PyO3 + maturin

Call Rust from Python

- Create new project

```
> maturin init my-lib
✔ 🤷 Which kind of bindings to use? · pyo3
  ✨ Done! Initialized project my-lib
> tree my-lib
my-lib
├── Cargo.toml
├── pyproject.toml
└── src
    └── lib.rs

1 directory, 3 files
```

Call Rust from Python

- Create new project
- Write Rust code

```rust
// src/lib.rs
fn fibo(n: u32) -> u32 {
    match n {
        ..2 => 1,  // range(2)
        _ => fibo(n-1) + fibo(n-2)
    }
}
```

Call Rust from Python

- Create new project
- Write Rust code
- Decorate using `pyo3` macros

```rust
// src/lib.rs
use pyo3::prelude::*;

#[pyfunction]
fn fibo(n: u32) -> u32 {
    match n {
        ..2 => 1,
        _ => fibo(n-1) + fibo(n-2)
    }
}
```

Call Rust from Python

- Create new project
- Write Rust code
- Decorate using `pyo3` macros
- Export as Python module

```rust
// src/lib.rs
use pyo3::prelude::*;

#[pyfunction]
fn fibo(n: u32) -> u32 {
    match n {
        ..2 => 1,
        _ => fibo(n-1) + fibo(n-2)
    }
}

#[pymodule]
mod my_lib {
    #[pymodule_export]
    use super::fibo;
}
```

Call Rust from Python

- Create new project
- Write Rust code
- Decorate using `pyo3` macros
- Export as Python module
- Compile & install

```
> maturin develop
🍹 Building a mixed python/rust project
🔗 Found pyo3 bindings
🐍 Found CPython 3.13 at .venv/bin/python
📦 Built wheel for CPython 3.13 to <...>.whl
✏️ Setting installed package as editable
🛠️ Installed my-lib-0.1.0
```

Call Rust from Python

- Create new project
- Write Rust code
- Decorate using `pyo3` macros
- Export as Python module
- Compile & install
- Run Python

```python
# main.py
from my_lib import fibo

print(fibo(12))
```

Binding Structs to Classes

```rust
#[pyclass]
struct Accumulator {
    value: i64,
}

#[pymethods]
impl Accumulator {
    fn add(&mut self, x: i64) {
        self.value += x;
    }

    fn get(&self) -> i64 {
        self.value
    }
}

#[pymodule]
mod my_lib {
    #[pymodule_export]
    use super::Accumulator;
}
```

```python
from my_lib import Accumulator

x = Accumulator()
x.add(1)
x.add(2)

print(x.get())
# 3

print(x)
# <builtins.Accumulator object at 0x7dfc89505c50>
```

Binding Structs to Classes

```rust
#[pyclass]
struct Accumulator {
    value: i64,
}

#[pymethods]
impl Accumulator {
    #[new]
    fn new() -> Self {
        Self { value: 0 }
    }

    fn add(&mut self, x: i64) {
        self.value += x;
    }

    fn get(&self) -> i64 {
        self.value
    }
}
```

```python
from my_lib import Accumulator

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struct Accumulator {
    value: i64,
}

#[pymethods]
impl Accumulator {
    #[new]
    fn new() -> Self {
        Self { value: 0 }
    }

    fn add(&mut self, x: i64) { ... }
    fn get(&self) -> i64 { ... }

    fn __str__(&self) -> String {
        format!("{:?}", &self)
    }
}
```

```python
from my_lib import Accumulator

x = Accumulator()
x.add(1)
x.add(2)

print(x.get())
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print(x)
# <builtins.Accumulator object at 0x7dfc89505c50>
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    }

    fn add(&mut self, x: i64) { ... }
    fn get(&self) -> i64 { ... }

    fn __str__(&self) -> String {
        format!("{:?}", &self)
    }
}
```

```python
from my_lib import Accumulator

x = Accumulator()
x.add(1)
x.add(2)

print(x.get())
# 3

print(x)
# Accumulator { value: 3 }
```

Python Exceptions

```rust
use pyo3::prelude::*;

#[pyfunction]
fn parse_int(text: String) -> PyResult<i64> {
    match text.trim().parse::<i64>() {
        Ok(v) => Ok(v),
        Err(e) => {
            let msg = format!("cannot parse integer: {e}");
            Err(PyValueError::new_err(msg))
        }
    }
}

#[pymodule]
mod my_lib {
    #[pymodule_export]
    use super::parse_int;
}
```

```python
from my_lib import parse_int

assert parse_int("  123 ") == 123

try:
    parse_int("foo")
except ValueError as e:
    print(e)
    # invalid digit found in string
```

Python Exceptions

```rust
use pyo3::prelude::*;

#[pyfunction]
fn parse_int(text: String) -> PyResult<i64> {
    text.trim().parse()
        .map_err(PyValueError::new_err)
}

#[pymodule]
mod my_lib {
    #[pymodule_export]
    use super::parse_int;
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```

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from my_lib import parse_int

assert parse_int("  123 ") == 123

try:
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```

Good Case for Rust

Stay in Python

Good Case for Rust

- Performance-critical code

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- Performance-critical code
- Tight loops over large arrays

Stay in Python

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- Parsing / validation

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- Wrapping an existing Rust crate

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Stay in Python

- I/O-bound tasks

Good Case for Rust

- Performance-critical code
- Tight loops over large arrays
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Stay in Python

- I/O-bound tasks
- Leverage existing library

Good Case for Rust

- Performance-critical code
- Tight loops over large arrays
- Parsing / validation
- Specific algorithm
- Wrapping an existing Rust crate

Stay in Python

- I/O-bound tasks
- Leverage existing library
- Rapid prototyping

Good Case for Rust

- Performance-critical code
- Tight loops over large arrays
- Parsing / validation
- Specific algorithm
- Wrapping an existing Rust crate

Stay in Python

- I/O-bound tasks
- Leverage existing library
- Rapid prototyping
- Interactive data exploration

(Not) Calling Python from Rust

```python
import polars as pl

df = (
    pl.DataFrame({"x": [1, 2, 3]})
    .with_columns(y=pl.col("x").map_elements(lambda x: x+1))
)

# Expr.map_elements is significantly slower than the native expressions API.
# Only use if you absolutely CANNOT implement your logic otherwise.
# Replace this expression...
#   - pl.col("x").map_elements(lambda x: ...)
# with this one instead:
#   + pl.col("x") + 1
#
#   .with_columns(y=pl.col("x").map_elements(lambda x: x+1))
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(Not) Calling Python from Rust

```python
import polars as pl

df = (
    pl.DataFrame({"x": [1, 2, 3]})
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Polars Extension

```python
import polars as pl
from farmhash import hash64

(
    pl.DataFrame({"text": ["hello", "world"]})
    .with_columns(
        hash=pl.col("text").map_elements(
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        )
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)

# ┌─────────┬──────────────────────┐
# | text    ¦ hash                 |
# | ---     ¦ ---                  |
# | str     ¦ u64                  |
# ╞═════════╪══════════════════════╡
# | hello   ¦ 13009744463427800296 |
# | world   ¦ 16436542438370751598 |
# └─────────┴──────────────────────┘
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```rust
use polars::prelude::*;
use pyo3_polars::derive::polars_expr;

#[polars_expr(output_type=UInt64)]
fn farm64(inputs: &[Series]) -> PolarsResult<Series> {
    let strings: &StringChunked = inputs[0].str()?;
    let hashes: UInt64Chunked = strings.iter()
        .map(|x| x.map(farm::fingerprint64))
        .collect();
    Ok(hashes.into_series())
}

#[pymodule]
mod my_lib {}
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Polars Extension

```python
import polars as pl
from polars.plugins import register_plugin_function

LIB = Path(__file__).parent / "my_lib.abi3.so"

def farm64(col_name: str) -> pl.Expr:
    return register_plugin_function(
        plugin_path=LIB,
        args=[pl.col(col_name)],
        function_name="farm64",
        is_elementwise=True,
    )


(
    pl.DataFrame({"text": ["hello", "world"]})
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Docker Image Optimization

```python
# pipeline.py
(
    pl.scan_csv("data.csv")
    .filter(pl.col("value") > 10)
    .with_columns(double=pl.col("value") * 2)
    .group_by("category")
    .agg(double_mean=pl.col("double").mean())
    .sink_csv("result.csv")
)
```

```dockerfile
FROM python

COPY . /app
RUN --mount=uv uv sync
```

Docker Image Optimization

```python
# pipeline.py
(
    pl.scan_csv("data.csv")
    .filter(pl.col("value").gt(10))
    .with_columns(
        pl.col("value").mul(2).alias("double"),
    )
    .group_by(pl.col("category"))
    .agg(
        pl.col("double").mean().alias("double_mean"),
    )
    .sink_csv("result.csv")
)
```

```dockerfile
FROM python

COPY . /app
RUN --mount=uv uv sync
```

Docker Image Optimization

```rust
// pipeline.rs
let lf = LazyCsvReader::new("data.csv")
    .has_header(true)
    .finish()?
    .filter(col("value").gt(lit(10)))
    .with_columns([
        col("value").mul(lit(2)).alias("double"),
    ])
    .groupby([col("category")])
    .agg([
        col("double").mean().alias("double_mean"),
    ]);

lf.sink(
    SinkDestination::File("result.csv".into()),
    FileType::Csv.into(),
    Default::default(),
)?;
```

```dockerfile
FROM python

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```
FROM rust as builder

COPY . /build
RUN cargo install

FROM debian
COPY --from builder cargo/bin/myapp /bin/myapp
```

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Q & A

Jan Kislinger

- ML Engineer
- Personalization

- PhD student
- Full-page recommendations