

Using MLIR from C and Python

Alex Zinenko

A dark blue diagonal gradient bar that starts from the bottom left corner and extends towards the top right corner, covering the bottom half of the slide.

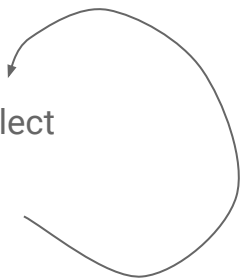
Agenda

- API design and basics
- Traversing IR
- Creating operations
- Creating attributes/types from a custom dialect
- Build system support
- Running passes

In C

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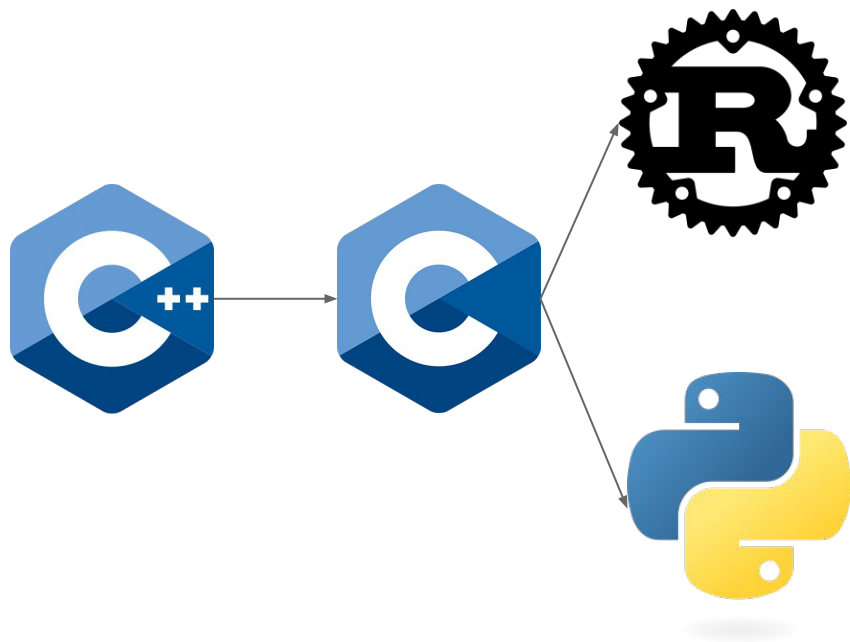
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- Traversing IR
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In Python

C API Design Goals

- Primarily an interoperability layer with other languages.
- Bias towards minimalism at expense of usability.
- Weak stability guarantee.



Naming Conventions

General:

- Everything prefixed with mlir
- Types are capitalized:
 - MlirOperation
 - MlirAttribute
- Functions are not:
 - mlirOperationCreate
 - mlirAttributeGet

Functions:

- “Method” functions are prefixed with type:
 - mlirOperationCreate(MlirOperaiton, ...)
 - mlirAttributeGet(MlirAttribute, ...)
- Constructor/Destructor
 - MlirTypeNameCreate/Destroy
- Context-owned unique object
 - MlirTypeNameGet
- Accessor
 - MlirOperationGetContext

Type Model

Types are opaque structs typically holding a pointer:

- `MlirOperation (mlir::Operation *)`
- `MlirAttribute (mlir::Attribute -> Impl *)`
- `MlirType (mlir::Type -> Impl *)`
- ...

Instances of every type are nullable:

- `bool mlir<Type>IsNull(Mlir<Type> x)`

Inheritance trees are not materialized. Functions always use the base type, but specify in the name if they expect a derived type:

- `mlirShapedTypeGetRank(MlirType type)`
- `mlirMemRefTypeGetLayout(MlirType type)`

and assert (`llvm::cast`) the expected type is given.

The user can check if an object is of a type:

```
bool mlirTypeIsAShapedType(MlirType type)
```

Traversing IR

Reminder: MLIR consists of:

- a top-level operation (module)
- with an attached list of regions
- that are linked lists of blocks
- that are linked lists of operations
 - with attached regions...

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intptr_t mlirOperationGetNumRegions(MlirOperation op);  
MlirRegion mlirOperationGetRegion(  
    MlirOperation op, intptr_t pos);
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intptr_t mlirOperationGetNumRegions(MlirOperation op);  
MlirRegion mlirOperationGetRegion(  
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```

```
MlirBlock mlirRegionGetFirstBlock(MlirRegion region);  
MlirBlock mlirBlockGetNextInRegion(MlirBlock block);
```

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```

```
MlirBlock mlirRegionGetFirstBlock(MlirRegion region);  
MlirBlock mlirBlockGetNextInRegion(MlirBlock block);
```

```
MlirOperation mlirBlockGetFirstOperation(MlirBlock block);  
MlirOperation mlirOperationGetNextInBlock(  
    MlirOperation op);
```

Simple Example

```
MlirContext context = mlirContextCreate();
```

Simple Example

```
MlirContext context = mlirContextCreate();
MlirOperation module =                                     // Parse from source
    mlirOperationCreateParse(context, mlirStringRefCreateFromCString("."),
                              mlirStringRefCreateFromCString("input.mlir")); // File name of the source
```

Simple Example

```
MlirContext context = mlirContextCreate();
MlirOperation module =                                     // Parse from source
    mlirOperationCreateParse(context, mlirStringRefCreateFromCString("..."),
                              mlirStringRefCreateFromCString("input.mlir")); // File name of the source
MlirRegion body = mlirOperationGetFirstRegion(module);    // First region of the module
```

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MlirRegion body = mlirOperationGetFirstRegion(module);   // First region of the module
MlirBlock bodyBlock = mlirRegionGetFirstBlock(body);    // First block of the region
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MlirStringRef publicVisibility = mlirStringRefCreateFromCString("public");
```

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MlirBlock bodyBlock = mlirRegionGetFirstBlock(body);     // First block of the region
MlirStringRef visibility = mlirSymbolTableGetVisibilityAttributeName();
MlirStringRef publicVisibility = mlirStringRefCreateFromCString("public");
for (MlirOperation op = mlirBlockGetFirstOperation(bodyBlock); // Iterate over the linked list
     !mlirOperationIsNull(op); // of operations in the block
     op = mlirOperationGetNextInBlock(op)) {

}
```


Simple Example

```
MlirContext context = mlirContextCreate();
MlirOperation module =                                     // Parse from source
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for (MlirOperation op = mlirBlockGetFirstOperation(bodyBlock); // Iterate over the linked list
     !mlirOperationIsNull(op); // of operations in the block
     op = mlirOperationGetNextInBlock(op)) {
    MlirAttribute visibilityAttr =                          // Assuming top-level ops are
        mlirOperationGetAttributeByName(op, visibility); // symbols, find those with
    MlirStringRef visibilityStr = mlirStringAttrGetValue(visibilityAttr); // public visibility
}
}
```

Simple Example

```
MlirContext context = mlirContextCreate();
MlirOperation module =                                     // Parse from source
    mlirOperationCreateParse(context, mlirStringRefCreateFromCString("..."),
                              mlirStringRefCreateFromCString("input.mlir")); // File name of the source
MlirRegion body = mlirOperationGetFirstRegion(module);   // First region of the module
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MlirStringRef visibility = mlirSymbolTableGetVisibilityAttributeName();
MlirStringRef publicVisibility = mlirStringRefCreateFromCString("public");
for (MlirOperation op = mlirBlockGetFirstOperation(bodyBlock); // Iterate over the linked list
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     op = mlirOperationGetNextInBlock(op)) {
    MlirAttribute visibilityAttr =                          // Assuming top-level ops are
        mlirOperationGetAttributeByName(op, visibility); // symbols, find those with
    MlirStringRef visibilityStr = mlirStringRefGetValue(visibilityAttr); // public visibility
    if (mlirStringRefEqual(visibilityStr, publicVisibility))
        do something
}
```

Creating IR from C

Aka the “stable” API to MLIR

Ownership Model

By default, no ownership transfer.

`Mlir<Type> mlir<Type>Create(...)` -> the caller owns the result and *must destroy it* or transfer ownership.

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`Mlir<Type> mlir<Type>Create(...)` -> the caller owns the result and *must destroy it* or transfer ownership.

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... `mlir<something>Owned<Type>(..., Mlir<Type>)` -> the caller transfers ownership to the callee.

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`Mlir<Type> mlir<Type>Create(...)` -> the caller owns the result and *must destroy it* or transfer ownership.

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... `mlir<something>Owned<Type>(..., Mlir<Type>)` -> the caller transfers ownership to the callee.

`Mlir<Type> mlir<Type>Get(MlirContext)` -> the context owns the object.

Trivial Example

```
#include "mlir-c/IR.h"
```

```
MlirContext context = mlirContextCreate(); // Create an owned context
```


Trivial Example

```
#include "mlir-c/IR.h"

MlirContext context = mlirContextCreate();
MlirOperationState state = mlirOperationStateGet(
    mlirStringRefCreateFromCString("builtin.module"),
    mlirLocationUnknownGet(context));

// Create an owned context
// Create operation state to prepare
// Non-owning string reference
// Locations are owned by context
```

Trivial Example

```
#include "mlir-c/IR.h"

MlirContext context = mlirContextCreate();
MlirOperationState state = mlirOperationStateGet(
    mlirStringRefCreateFromCString("builtin.module"),
    mlirLocationUnknownGet(context));
MlirRegion region = mlirRegionCreate();

// Create an owned context
// Create operation state to prepare
// Non-owning string reference
// Locations are owned by context
// Create owned region
```

Trivial Example

```
#include "mlir-c/IR.h"

MlirContext context = mlirContextCreate();
MlirOperationState state = mlirOperationStateGet(
    mlirStringRefCreateFromCString("builtin.module"),
    mlirLocationUnknownGet(context));
MlirRegion region = mlirRegionCreate();
MlirRegion regions[] = {region};
mlirOperationStateAddOwnedRegions(
    &state, sizeof(regions) / sizeof(MlirRegion), regions);

// Create an owned context
// Create operation state to prepare
// Non-owning string reference
// Locations are owned by context
// Create owned region
// Make a list of regions
// Transfer owned regions to the operation
// state
```

Trivial Example

```
#include "mlir-c/IR.h"

MlirContext context = mlirContextCreate();
MlirOperationState state = mlirOperationStateGet(
    mlirStringRefCreateFromCString("builtin.module"),
    mlirLocationUnknownGet(context));
MlirRegion region = mlirRegionCreate();
MlirRegion regions[] = {region};
mlirOperationStateAddOwnedRegions(
    &state, sizeof(regions) / sizeof(MlirRegion), regions);
MlirOperation module = mlirOperationCreate(state);
...
```

```
// Create an owned context
// Create operation state to prepare
// Non-owning string reference
// Locations are owned by context
// Create owned region
// Make a list of regions
// Transfer owned regions to the operation
// state
// Create owned operation
```

Trivial Example

```
#include "mlir-c/IR.h"

MlirContext context = mlirContextCreate();
MlirOperationState state = mlirOperationStateGet(
    mlirStringRefCreateFromCString("builtin.module"),
    mlirLocationUnknownGet(context));
MlirRegion region = mlirRegionCreate();
MlirRegion regions[] = {region};
mlirOperationStateAddOwnedRegions(
    &state, sizeof(regions) / sizeof(MlirRegion), regions);
MlirOperation module = mlirOperationCreate(state);
...
mlirOperationDestroy(module);
mlirContextDestroy(context);

// Create an owned context
// Create operation state to prepare
// Non-owning string reference
// Locations are owned by context
// Create owned region
// Make a list of regions
// Transfer owned regions to the operation
// state
// Create owned operation
// Free owned operation recursively
// Free owned context
```

Creating Operations

Using the generic state object:

- Name as StringRef
- Location
- List of operands
- List of result types
- List of attributes (also properties)
- List of *owned* regions
- List of successors

```
mliroperationStateGet(MlirStringRef name,  
                      MlirLocation loc);  
mliroperationStateAddOperands(...);  
mliroperationStateAddResults(...);  
mliroperationStateAddAttributes(...);  
mliroperationStateAddOwnedRegions(...);  
mliroperationStateAddSuccessors(...);
```

Works for any dialect, but may be slow because of string name lookup.

Creating Operations

Common signature:

```
mliroperationstateadd<...>(
    Mliroperationstate *state,
    intptr_t n,
    Mliroperationstate *elements)
```

```
mliroperationstateget(Mliroperationstate name,
                      Mliroperationstate loc);
mliroperationstateaddoperands(...);
mliroperationstateaddresults(...);
mliroperationstateaddattributes(...);
mliroperationstateaddownedregions(...);
mliroperationstateaddsuccessors(...);
```

Creating Operations

- Works for any dialect out of the box
- Does *not* call the build function, leading to duplication.
- Does *not* verify.

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- Does *not* call the build function, leading to duplication.
- Does *not* verify.

Creating Types

- No generic format unlike operations.
- Requires defining additional functions.

Creating Types

Declaration

```
#include "mlir-c/IR.h"  
#include "mlir-c/Support.h"
```

```
#ifdef __cplusplus  
extern "C" {  
#endif
```

```
MLIR_DECLARE_CAPI_DIALECT_REGISTRATION(  
    Transform, transform);
```

Creating Types

Declaration

```
#include "mlir-c/IR.h"
#include "mlir-c/Support.h"

#ifdef __cplusplus
extern "C" {
#endif

MLIR_DECLARE_CAPI_DIALECT_REGISTRATION(
    Transform, transform);
```

Definition

```
#include "mlir-c/Support.h"
#include "mlir/CAPI/Registration.h"

MLIR_DEFINE_CAPI_DIALECT_REGISTRATION(
    Transform, transform,
    transform::TransformDialect)
```

Creating Types (cont'd)

Declaration

```
MLIR_CAPI_EXPORTED bool
```

```
mlirTypeIsATransformOperationType(MlirType type);
```

```
MLIR_CAPI_EXPORTED MlirTypeID
```

```
mlirTransformOperationTypeGetTypeID(void);
```

```
MLIR_CAPI_EXPORTED MlirType
```

```
mlirTransformOperationTypeGet(MlirContext ctx,
```

```
    MlirStringRef operationName);
```

Creating Types (cont'd)

Declaration

```
MLIR_CAPI_EXPORTED bool
```

```
mmlirTypeIsATransformOperationType(MlirType type);
```

```
MLIR_CAPI_EXPORTED MlirTypeID
```

```
mmlirTransformOperationTypeGetTypeID(void);
```

```
MLIR_CAPI_EXPORTED MlirType
```

```
mmlirTransformOperationTypeGet(MlirContext ctx,
```

```
    MlirStringRef operationName);
```

Definition

```
bool mmlirTypeIsATransformOperationType(  
    MlirType type) {  
    return isa<transform::OperationType>(unwrap(type)); }  
}
```

```
MlirTypeID
```

```
mmlirTransformOperationTypeGetTypeID(void) {  
    return wrap(  
        transform::OperationType::getTypeID()); }  
}
```

```
MlirType
```

```
mmlirTransformOperationTypeGet(MlirContext ctx,  
    MlirStringRef operationName) {  
    return wrap(transform::OperationType::get(  
        unwrap(ctx), unwrap(operationName))); }  
}
```

Creating Types (cont'd)

Declaration

```
MLIR_CAPI_EXPORTED MlirStringRef  
mlirTransformOperationTypeGetOperationName(  
    MlirType type);  
  
#ifdef __cplusplus  
}  
#endif
```

Creating Types (cont'd)

Declaration

```
MLIR_CAPI_EXPORTED MlirStringRef  
mlirTransformOperationTypeGetOperationName(  
    MlirType type);  
  
#ifdef __cplusplus  
}  
#endif
```

Definition

```
MlirStringRef  
mlirTransformOperationTypeGetOperationName(  
    MlirType type) {  
    return wrap(cast<transform::OperationType>(unwrap(type)).getOperationName());  
}
```

Creating Types (cont'd)

CMakeLists.txt

```
add_mlir_public_c_api_library(MLIRCAPITransformDialect
  Transform.cpp

  PARTIAL_SOURCES_INTENDED
  LINK_LIBS PUBLIC
  MLIRCAPIIR
  MLIRTransformDialect
)
```


Using Interfaces

Regular (instance) interfaces

Similar to operations/types:

- not materialized as a C struct
- is-a method can be replaced with TypeID

```
MLIR_CAPI_EXPORTED MlirTypeID
```

```
mmlirInferTypeOpInterfaceTypeID();
```

```
MLIR_CAPI_EXPORTED bool
```

```
mmlirOperationImplementsInterface(
```

```
    MlirOperation operation, MlirTypeID ifaceID);
```

```
MLIR_CAPI_EXPORTED int
```

```
mmlirSomeOpInterfaceDoSomething(MlirOperation)
```

Using Interfaces

Regular (instance) interfaces

Similar to operations/types:

- not materialized as a C struct
- is-a method can be replaced with TypeID

```
MLIR_CAPI_EXPORTED MlirTypeID
```

```
mLirInferTypeOpInterfaceTypeID();
```

```
MLIR_CAPI_EXPORTED bool
```

```
mLirOperationImplementsInterface(  
    MlirOperation operation, MlirTypeID ifaceID);
```

```
MLIR_CAPI_EXPORTED int
```

```
mLirSomeOpInterfaceDoSomething(MlirOperation)
```

Static interfaces

Uses MlirStringRef for operation name, MlirTypeID for attribute/type name.

```
MLIR_CAPI_EXPORTED bool
```

```
mLirOperationImplementsInterfaceStatic(  
    MlirStringRef operationName, MlirContext ctx,  
    MlirTypeID interfaceTypeID);
```

```
MLIR_CAPI_EXPORTED MlirLogicalResult
```

```
mLirInferTypeOpInterfaceInferReturnTypes(  
    MlirStringRef opName, ...);
```

Mutating IR from C

In case you want to run a compiler in something other than C++

Running a Pass Pipeline

```
#include "mlir-c/Pass.h"
```

```
void runPassPipeline(MlirContext context, MlirOperation module) {
```

Running a Pass Pipeline

```
#include "mlir-c/Pass.h"

void runPassPipeline(MlirContext context, MlirOperation module) {
    MlirPassManager pm = mlirPassManagerCreateOnOperation(
        context, mlirStringRefCreateFromCString("builtin.module"));
    MlirOpPassManager opm = mlirPassManagerGetAsOpPassManager(pm);
```

Running a Pass Pipeline

```
#include "mlir-c/Pass.h"

void runPassPipeline(MlirContext context, MlirOperation module) {
    MlirPassManager pm = mlirPassManagerCreateOnOperation(
        context, mlirStringRefCreateFromCString("builtin.module"));
    MlirOpPassManager opm = mlirPassManagerGetAsOpPassManager(pm);
    char *error = 0;
    MlirLogicalResult result = mlirParsePassPipeline(
        opm, mlirStringRefCreateFromCString("canonicalize,cse"), appendError,
        error);
}
```

Running a Pass Pipeline

```
#include "mlir-c/Pass.h"

void runPassPipeline(MlirContext context, MlirOperation module) {
    MlirPassManager pm = mlirPassManagerCreateOnOperation(
        context, mlirStringRefCreateFromCString("builtin.module"));
    MlirOpPassManager opm = mlirPassManagerGetAsOpPassManager(pm);
    char *error = 0;
    MlirLogicalResult result = mlirParsePassPipeline(
        opm, mlirStringRefCreateFromCString("canonicalize,cse"), appendError,
        error);
    if (mlirLogicalResultIsFailure(result))
        fprintf(stderr, "%s\n", error);

    ...
}
```

Running a Pass Pipeline

```
#include "mlir-c/Pass.h"
mlirRegisterTransformsCSE()
vmlirRegisterTransformsCanonicalizer()(t, MlirOperation module) {
  MlirPassManager pm = mlirPassManagerCreateOnOperation(
    mlirRegisterTransformsPasses())eFromCString("builtin.module"));
  MlirOpPassManager opm = mlirPassManagerGetAsOpPassManager(pm);
  char *error = 0;
  MlirLogicalResult result = mlirPa But, registration?!
    opm, mlirStringRefCreateFromCString("canonicalize,cse"), appendError,
    error);
  if (mlirLogicalResultIsFailure(result))
    fprintf(stderr, "%s\n", error);
  ...
}
```


Running a Pass Pipeline

```
#include "mlir-c/Pass.h"
```

```
void runPassPipeline(MlirContext context, MlirOperation module) {
```

```
    MlirPassManager pm = mlirPassManagerCreateOnOperation(  
        context, mlirStringRefCreateFromCString("builtin.module"));
```

```
    mlirPassManagerAddOwnedPass(pm, mlirCreateTransformsCanonicalizer());
```

```
    mlirPassManagerAddOwnedPass(pm, mlirCreateTransformsCSE());
```

← Where are these defined?

```
    MlirLogicalResult result = mlirPassManagerRunOnOp(pm, module);
```

```
    if (mlirLogicalResultIsFailure(result))
```

```
        // report pass error
```

```
    mlirPassManagerDestroy(pm);
```

```
}
```

Running a Pass Pipeline

```
set(LLVM_TARGET_DEFINITIONS Passes.td)
mlir_tablegen(Passes.h.inc -gen-pass-decls -name GPU)
mlir_tablegen(Passes.capi.h.inc -gen-pass-capi-header --prefix GPU)
mlir_tablegen(Passes.capi.cpp.inc -gen-pass-capi-impl --prefix GPU)
add_public_tablegen_target(MLIRGPUPassIncGen)
```

Creating an External Pass

```
struct MlirExternalPassCallbacks {  
    void (*construct)(void *userData); // Pass::Pass
```

Creating an External Pass

```
struct MlirExternalPassCallbacks {  
    void (*construct)(void *userData);           // Pass::Pass  
  
    void (*destruct)(void *userData);          // Pass::~~Pass  
};
```

Creating an External Pass

```
struct MlirExternalPassCallbacks {  
    void (*construct)(void *userData);           // Pass::Pass  
  
    void (*destruct)(void *userData);           // Pass::~~Pass  
  
    MlirLogicalResult (*initialize)(MlirContext ctx, void *userData); // Pass::initialize(MLIRContext *)  
};
```

Creating an External Pass

```
struct MlirExternalPassCallbacks {  
    void (*construct)(void *userData);           // Pass::Pass  
  
    void (*destruct)(void *userData);           // Pass::~~Pass  
  
    MlirLogicalResult (*initialize)(MlirContext ctx, void *userData); // Pass::initialize(MLIRContext *)  
  
    void *(*clone)(void *userData);             // Pass::clonePass()  
};
```

Creating an External Pass

```
struct MlirExternalPassCallbacks {  
    void (*construct)(void *userData);           // Pass::Pass  
  
    void (*destruct)(void *userData);           // Pass::~~Pass  
  
    MlirLogicalResult (*initialize)(MlirContext ctx, void *userData); // Pass::initialize(MLIRContext *)  
  
    void *(*clone)(void *userData);             // Pass::clonePass()  
  
    void (*run)(MlirOperation op, MlirExternalPass pass, void *userData); // Pass::runOnOperation().  
};
```

Creating an External Pass

```
struct MlirExternalPassCallbacks {  
    void (*construct)(void *userData);           // Pass::Pass  
  
    void (*destruct)(void *userData);           // Pass::~~Pass  
  
    MlirLogicalResult (*initialize)(MlirContext ctx, void *userData); // Pass::initialize(MLIRContext *)  
  
    void *(*clone)(void *userData);             // Pass::clonePass()  
  
    void (*run)(MlirOperation op, MlirExternalPass pass, void *userData); // Pass::runOnOperation().  
};  
  
MLIR_CAPI_EXPORTED MlirPass mlirCreateExternalPass(MlirTypeID passID, MlirStringRef name,  
    MlirStringRef argument, MlirStringRef description, MlirStringRef opName, intptr_t nDependentDialects,  
    MlirDialectHandle *dependentDialects, MlirExternalPassCallbacks callbacks, void *userData);
```


Using MLIR from Python

Python is native to many ML frameworks

Python API Design

Support users who expect that an installed version of LLVM/MLIR will yield the ability to `import mlir` and use the API in a pure way out of the box.

Downstream integrations will likely want to include parts of the API in their private namespace or specially built libraries, probably mixing it with other python native bits.

- Build on C API
(avoid linking and exception problems)
- Use pybind11 to define API
(nanobind anyone?)
- Header-only C++ utilities are okay.
- Explicit registration.

Everything must be linked into one big library

MLIR registration mechanism is hard...

Typical symptoms: assertion about repeated registration, or
pass / operation not found despite being clearly loaded.

Traversing IR

Reminder: MLIR consists of:

- a top-level operation (module)
- with an attached list of regions
- that are linked lists of blocks
- that are linked lists of operations
 - with attached regions...

```
from mlir import ir
```

```
def traverse_ir(op: ir.Operation):
```

```
    for region in op.regions:
```

```
        for block in region.blocks:
```

```
            for nested in block.operations:
```

```
                print(nested.attributes["my_attr"])
```

iterables



dict-like



Structure and Packaging Conventions

Naming and Structure

- Drop the `mlir` prefix
(`Operation`, `Type`, `Context`)
- Use properties for simple, always-possible accessors and explicit methods otherwise
(`.context` vs `.get_asm()`)
- Use container-like objects compatible with Python protocols (`Iterable`, `Dict`).
- Objects nullable in C may be passed as `None`.

Structure and Packaging Conventions

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- Drop the `mlir` prefix
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(`.context` vs `.get_asm()`)
- Use container-like objects compatible with Python protocols (`Iterable`, `Dict`).
- Objects nullable in C may be passed as `None`.

Packaging

- Core IR components live in the `mlir.ir` package.
- Individual dialects live in subpackages of `mlir.dialects`, e.g., `mlir.dialects.linalg`.
- Dialect-specific passes, and generally other C++ libraries map to subpackages.

Simple Example

```
from mlir import ir
```

Simple Example

```
from mlir import ir
```

```
with ir.Context() as ctx:
```

```
// Context is a Python context manager
```


Simple Example

```
from mlir import ir

with ir.Context() as ctx:
    top_level = ir.Module.parse("...", context=ctx)

// Context is a Python context manager
// Parsing requires a context
```

Simple Example

```
from mlir import ir

with ir.Context() as ctx:
    top_level = ir.Module.parse("...", context=ctx)
    body = top_level.regions[0]
    body_block = body.blocks[0]

    // Context is a Python context manager
    // Parsing requires a context
    // Regions/blocks are directly indexable
    // but it is expensive as they are linked lists
```

Simple Example

```
from mlir import ir

with ir.Context() as ctx:
    top_level = ir.Module.parse("...", context=ctx)
    body = top_level.regions[0]
    body_block = body.blocks[0]
    for op in body_block.operations:
        // Context is a Python context manager
        // Parsing requires a context
        // Regions/blocks are directly indexable
        // but it is expensive as they are linked lists
```

Simple Example

```
from mlir import ir

with ir.Context() as ctx:
    top_level = ir.Module.parse("...", context=ctx)
    body = top_level.regions[0]
    body_block = body.blocks[0]
    for op in body_block.operations:
        visibility = op.attributes["sym_visibility"]
        if visibility is None: continue

// Context is a Python context manager
// Parsing requires a context
// Regions/blocks are directly indexable
// but it is expensive as they are linked lists

// Attributes may be accessed by name
// None is used pervasively
```

Simple Example

```
from mlir import ir

with ir.Context() as ctx:
    top_level = ir.Module.parse("...", context=ctx)
    body = top_level.regions[0]
    body_block = body.blocks[0]
    for op in body_block.operations:
        visibility = op.attributes["sym_visibility"]
        if visibility is None: continue
        if (visibility.value == "public"):
            do_something(op)

// Context is a Python context manager
// Parsing requires a context
// Regions/blocks are directly indexable
// but it is expensive as they are linked lists

// Attributes may be accessed by name
// None is used pervasively
// Simple accessors are Python properties
```

Simple Example

Can be derived from surrounding context managers!



```
from mlir import ir

with ir.Context() as ctx:
    top_level = ir.Module.parse("...", context=ctx)
    body = top_level.regions[0]
    body_block = body.blocks[0]
    for op in body_block.operations:
        visibility = op.attributes["sym_visibility"]
        if visibility is None: continue
        if (visibility.value == "public"):
            do_something(op)
```

// Context is a Python context manager
// Parsing requires a context
// Regions/blocks are directly indexable
// *but it is expensive as they are linked lists*

// Attributes may be accessed by name
// **None** is used pervasively
// Simple accessors are Python properties

Creating IR from Python

The main use case

Ownership Model

Owned by Python caller:

- Context: `mlir.ir.Context`
- Module: `mlir.ir.Module`
- *Detached* operation, i.e. operation not nested in another operation, including modules:
`mlir.ir.Operation`

Kept alive:

- Immutable objects owned by context keep alive the context.
- Operations keep alive ancestors until a detached one or a module.

Warning: erasing an operation in C++ code is *invisible* to Python.

Trivial Example

```
from mlir import ir
```

```
with ir.Context(): # Context is a context manager
```

Trivial Example

```
from mlir import ir
```

```
with ir.Context():
```

```
    with ir.UnknownLoc():
```

```
        # Context is a context manager
```

```
            # Location is a context manager
```

Trivial Example

```
from mlir import ir
```

```
with ir.Context():
```

```
    with ir.UnknownLoc():
```

```
        module = ir.Module.create()
```

```
        with ir.InsertionPoint(module.regions[0].blocks[0]):
```

```
# Context is a context manager
```

```
    # Location is a context manager
```

```
# Context/location inferred from context
```

```
    # Insertion point is a context manager
```

Trivial Example

```
from mlir import ir
```

```
with ir.Context():  
    with ir.UnknownLoc():  
        module = ir.Module.create()  
        with ir.InsertionPoint(module.regions[0].blocks[0]):  
            ir.Operation.create("func.func",  
                                regions=1,  
                                attributes={"function_type":  
                                             ir.FunctionType.get([], []),  
                                             "sym_name": ir.StrAttr.get("f")})
```

```
# Context is a context manager  
    # Location is a context manager  
# Context/location inferred from context  
    # Insertion point is a context manager  
    # Created at the inferred insertion pt  
    # Operation state as kwargs  
    # NOTE: no verification  
  
# Non-owned objects use implicit context
```

Trivial Example

```
from mlir import ir
```

```
with ir.Context():  
    with ir.UnknownLoc():  
        module = ir.Module.create()  
        with ir.InsertionPoint(module.regions[0].blocks[0]):  
            ir.Operation.create("func.func",  
                                regions=1,  
                                attributes={"function_type":  
                                             ir.FunctionType.get([], []),  
                                             "sym_name": ir.StrAttr.get("f")})  
# ...
```

```
# Context is a context manager  
    # Location is a context manager  
# Context/location inferred from context  
    # Insertion point is a context manager  
    # Created at the inferred insertion pt  
    # Operation state as kwargs  
    # NOTE: no verification  
  
# Non-owned objects use implicit context  
  
# Past this point, Python may  
# garbage-collect everything
```

Trivial Example

```
from mlir import ir
from mlir.dialects import func

with ir.Context():
    with ir.UnknownLoc():
        module = ir.Module.create()
        with ir.InsertionPoint(module.regions[0].blocks[0]):
            func.FuncOp("f", ([], []))
            # ...
```

Dialects may provide custom builders

Custom Builders

```
from mlir import ir
from mlir.dialects import func

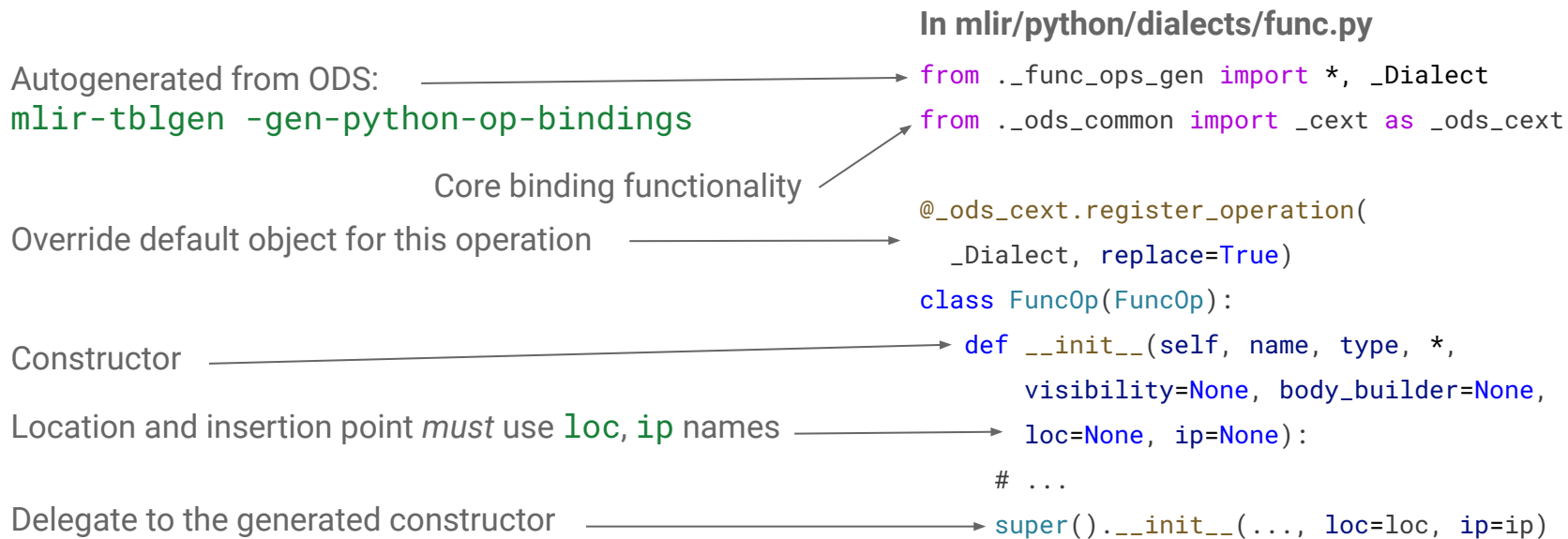
with ir.Context():
    with ir.UnknownLoc():
        module = ir.Module.create()
        with ir.InsertionPoint(module.regions[0].blocks[0]):
            func.FuncOp("f", ([], []))
        # ...
```

In mlir/python/dialects/func.py

```
from ._func_ops_gen import *, _Dialect
from ._ods_common import _cext as _ods_cext

@_ods_cext.register_operation(
    _Dialect, replace=True)
class FuncOp(FuncOp):
    def __init__(self, name, type, *,
                 visibility=None, body_builder=None,
                 loc=None, ip=None):
        # ...
        super().__init__(..., loc=loc, ip=ip)
```

Custom Builders



Warning: inspect the generated constructor first

Additional Op Functionality

Autogenerated from ODS:

`mlir-tblgen -gen-python-op-bindings`

In `mlir/python/dialects/func.py`

```
from ._func_ops_gen import *, _Dialect
from ._ods_common import _cext as _ods_cext
```

```
@_ods_cext.register_operation(
    _Dialect, replace=True)
```

```
class FuncOp(FuncOp):
```

```
@property
```

```
def sym_name(self):
```

```
    return self.operation.attributes["sym_name"]
```

For example, convenience accessors
(many are autogenerated in the base class)

Custom Builders

Autogenerated from ODS:

```
mlir-tblgen -gen-python-op-bindings
```

```
@_ods_cext.register_operation(_Dialect)
class FuncOp(_ods_ir.OpView):
    def __init__(self, sym_name, function_type, *,
                 sym_visibility=None, arg_attrs=None,
                 res_attrs=None, loc=None, ip=None):
        ...
```

In mlir/include/mlir/Dialect/Func/IR/FuncOps.td

```
let arguments = (ins SymbolNameAttr:$sym_name,
                  TypeAttrOf<FunctionType>:$function_type,
                  OptionalAttr<StrAttr>:$sym_visibility,
                  OptionalAttr<DictArrayAttr>:$arg_attrs, ←
                  OptionalAttr<DictArrayAttr>:$res_attrs);
```

Same order as ODS arguments, types extracted from conversion rules

Automatic Conversion of Types

In mlir/include/mlir/Dialect/Func/IR/FuncOps.td

Autogenerated from ODS:

```
mlir-tblgen -gen-python-op-bindings
```

```
@_ods_cext.register_operation(_Dialect)
class FuncOp(_ods_ir.OpView):
    def __init__(self, sym_name, function_type, *,
                 sym_visibility=None, arg_attrs=None, ←
                 res_attrs=None, loc=None, ip=None):
        attributes["sym_name"] = (sym_name if (
            isinstance(sym_name, _ods_ir.Attribute) or
            not _ods_ir.AttrBuilder.contains('SymbolNameAttr')) else
            _ods_ir.AttrBuilder.get('SymbolNameAttr')(sym_name, context=_ods_context))
```

```
let arguments = (ins SymbolNameAttr:$sym_name,
                  TypeAttrOf<FunctionType>:$function_type,
                  OptionalAttr<StrAttr>:$sym_visibility,
                  OptionalAttr<DictArrayAttr>:$arg_attrs,
                  OptionalAttr<DictArrayAttr>:$res_attrs);
```

Automatic Conversion of Types

Autogenerated from ODS:

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mlir-tblgen -gen-python-op-bindings
```

```
@_ods_cext.register_operation(_Dialect)
class FuncOp(_ods_ir.OpView):
    def __init__(self, sym_name, function_type, *,
                 sym_visibility=None, arg_attrs=None,
                 res_attrs=None, loc=None, ip=None):
        attributes["sym_name"] = (sym_name if (
            isinstance(sym_name, _ods_ir.Attribute) or
            not _ods_ir.AttrBuilder.contains('SymbolNameAttr')) else
            _ods_ir.AttrBuilder.get('SymbolNameAttr')(sym_name, context=_ods_context))
```

In mlir/python/mlir/ir.py

```
def register_attribute_builder(kind):
    def decorator_builder(func):
        AttrBuilder.insert(kind, func)
        return func
    return decorator_builder

@register_attribute_builder("SymbolNameAttr")
def _symbolNameAttr(x, context):
    return StringAttr.get(x, context=context)
```

Automatic Conversion of Types

`Attr/TypeBuilder` is a map from ODS name to the function creating the corresponding object.

Already defined for (most) core types.

Can be easily added for user-defined attributes and types assuming they are available in Python.

In `mlir/python/mlir/ir.py`

```
def register_attribute_builder(kind):  
    def decorator_builder(func):  
        AttrBuilder.insert(kind, func)  
        return func  
    return decorator_builder
```

```
@register_attribute_builder("SymbolNameAttr")  
def _symbolNameAttr(x, context):  
    return StringAttr.get(x, context=context)
```

Bindings for Custom Attributes and Types

```
#include "mlir/Bindings/Python/PybindAdaptors.h"
```

```
auto operationType =  
    mlir_type_subclass(m, "OperationType", mlirTypeIsATransformOperationType,  
                      mlirTransformOperationTypeGetTypeID);  
operationType.def_classmethod("get",  
    [(py::object cls, const std::string &operationName, MlirContext ctx) {  
        return cls(mlirTransformOperationTypeGet(ctx, cOperationName));  
    }]);  
operationType.def_property_readonly(  
    "operation_name", [(MlirType type) {  
        MlirStringRef operationName = mlirTransformOperationTypeGetOperationName(type);  
        return py::str(operationName.data, operationName.length);  
    }]);
```

Requires is-a and TypeID

C types are supported by
pybind11 type casters

Don't forget other
conversions

Bindings for Custom Attributes and Types

```
#include "mlir/Bindings/Python/PybindAdaptors.h"

void populateSubmodule(const pybind11::module &m) {
    auto operationType =
        mlir_type_subclass(...);
    operationType.def_classmethod("get", ...);
    operationType.def_property_readonly(
        "operation_name", ...);
}

PYBIND11_MODULE(_mlirDialectsTransform, m) {
    m.doc() = "MLIR Transform dialect.";
    populateSubmodule(m);
}
```

In `mlir/python/mlir/dialects/transform/__init__.py`

```
from ..._mlir_libs._mlirDialectsTransform import *
```

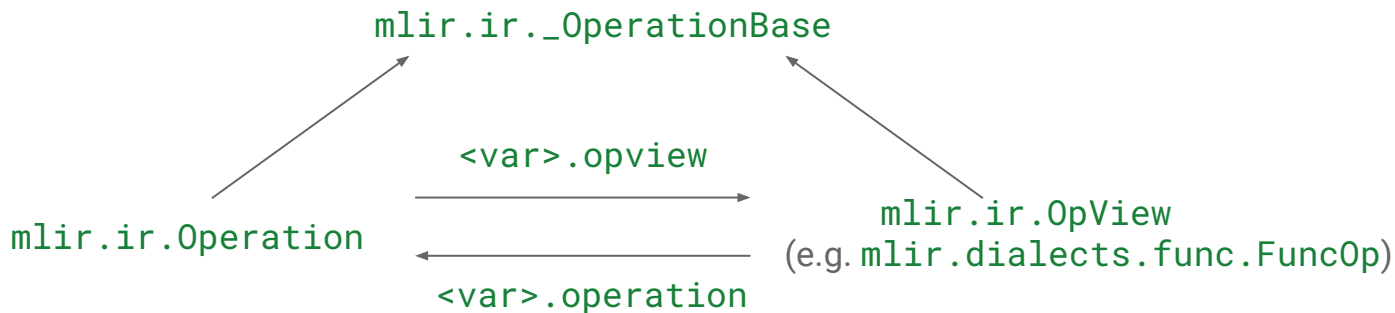


In `mlir/python/CMakeLists.txt`

```
declare_mlir_python_extension(
    MLIRPythonExtension.Dialects.Transform.Pybind
    MODULE_NAME _mlirDialectsTransform
    ADD_TO_PARENT MLIRPythonSources.Dialects.transform
    ROOT_DIR "${PYTHON_SOURCE_DIR}"
    SOURCES DialectTransform.cpp
    PRIVATE_LINK_LIBS LLVMSupport
    EMBED_CAPI_LINK_LIBS
        MLIRCAPIIR
        MLIRCAPITransform
)
```

Class Hierarchy

Types/Attributes (isinstance and
constructor+assert)



Warning: `isinstance(<var>, func.FuncOp) != isinstance(<var>.opview, func.FuncOp)`

Generic APIs work on `ir.Operation` not specific `OpView` instances

Class Hierarchy



Regular class hierarchy (`isinstance` works), including custom dialect attributes and types

Mutating IR from Python

Something the bindings were not really designed for, except maybe for running passes.

Direct Mutation

```
operation.attributes["attr_name"] = ir.IntegerAttr.get(...) ← Attributes are assignable
```

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`operation.attributes["attr_name"] = ir.IntegerAttr.get(...)` ← Attributes are assignable

`operation.operands[0] = some_value` ← Operand list items are assignable

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`operation.operands[1].set_type(ir.SomeType.get(...))` ← Types can be updated

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`operation.regions.append(...)`
`operation.regions[0].blocks.append(...)` ← Linked lists can be appended to

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`operation.erase()` ← Operations can be erased

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`operation.operands[1].set_type(ir.SomeType.get(...))` ← Types can be updated

`operation.regions.append(...)`
`operation.regions[0].blocks.append(...)` ← Linked lists can be appended to

`operation.erase()` ← Operations can be erased

That's all, folks!

Running Passes

```
from mlir import ir
from mlir.passmanager import PassManager
```

```
with ir.Context():
    pm = PassManager.parse("builtin.module(canonicalize,cse)")
    try:
        pm.run(operation)
    except MLIRError as e:
        # Do something...
        raise
```

Textual pass pipeline syntax 🧑

A failing pass will raise an exception

Running Passes

```
from mlir import ir
from mlir.passmanager import PassManager
```

```
handle = operation.regions[0].blocks[0].operations[0]
with ir.Context():
    pm = PassManager.parse("builtin.module(canonicalize, cse)")
    try:
        pm.run(operation)
    except MLIRError as e:
        # Do something...
        raise
print(handle) ## Will assert
```

Textual pass pipeline syntax 🧑

A failing pass will raise an exception

Warning: running a pass manager invalidates Python handles to operations nested under the root operation.

Registration

Not recommended: include all upstream passes.

- CMake dependency on `MLIRPythonExtension.RegisterEverything`
- Automatically registers when loading any package.

Recommended:

Create a new pybind11 package and register on initialization.

```
PYBIND11_MODULE(_mlirGPUPasses, m) {  
    m.doc() = "MLIR GPU Dialect Passes";  
  
    // Register all GPU passes on load.  
    mlirRegisterGPUPasses();  
}
```



```
import mlir.dialects.gpu.passes
```

Registration

Alternative

Create a new pybind11 package and register in a function.

```
PYBIND11_MODULE(_mlirGPUPasses, m) {  
    m.doc() = "MLIR GPU Dialect Passes";  
  
    m.def("register", [] {  
        mlirRegisterGPUPasses();  
    });  
}
```




```
import mlir.dialects.gpu.passes  
passes.register()
```

Recommended:

Create a new pybind11 package and register on initialization.

```
PYBIND11_MODULE(_mlirGPUPasses, m) {  
    m.doc() = "MLIR GPU Dialect Passes";  
  
    // Register all GPU passes on load.  
    mlirRegisterGPUPasses();  
}
```



```
import mlir.dialects.gpu.passes
```

Error Handling

```
def handler(diag: ir.Diagnostic):  
    if diag.severity == ir.DiagnosticSeverity.ERROR:  
        assert False, diag.message  
    pass
```

```
context.attach_diagnostic_handler(handler)
```

Diagnostic handlers can be provided in Python

Where to find more information?

<https://mlir.llvm.org/docs/CAPI/>

<https://mlir.llvm.org/docs/Bindings/Python/>

Inside `mlir/lib/Bindings/Python/IRCore.cpp`

Inside `mlir/include/mlir-c/...h`