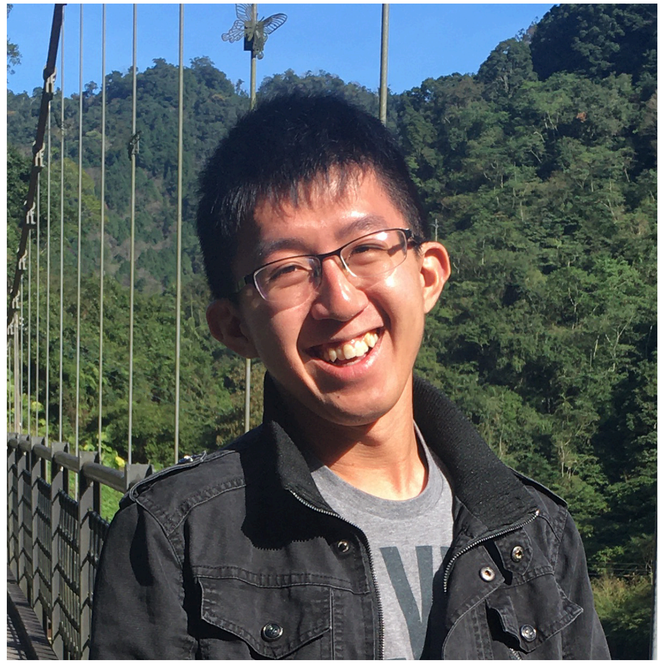
How to write a TableGen backend

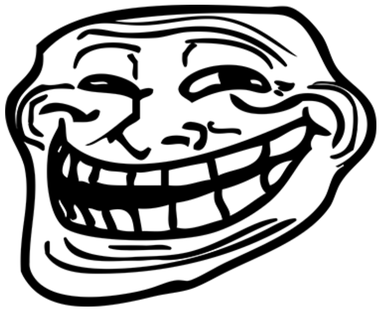
Min-Yih “Min” Hsu @ LLVM Dev Meeting 2021

$ whoami

“Min” Hsu

- Computer Science PhD Candidate in University of California, Irvine
- Code owner of M68k LLVM backend
- Author of book “*LLVM Techniques, Tips and Best Practices*” (2021)





TableGen Backend

TableGen in a nutshell

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- Now: Used in a wide variety of (completely) different areas inside LLVM.
  - Instruction scheduling info.
  - Declaring IR attributes.
  - LLVM `Option` subsystem (e.g. Clang's compiler flags).

```
class Stuff {


}
```

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Layout

```
class Stuff {

}
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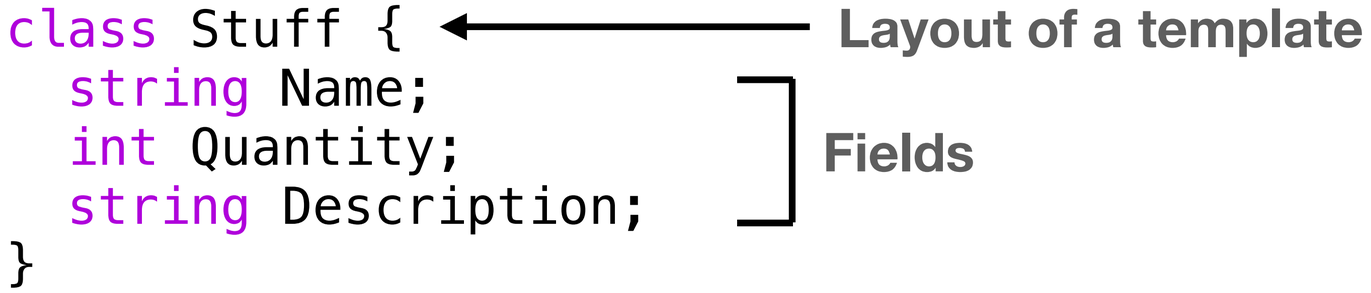
Layout of a template

```
class Stuff {
  string Name;
  int Quantity;
  string Description;
}
```

Layout of a template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Layout of a template
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def water_bottle : Stuff {



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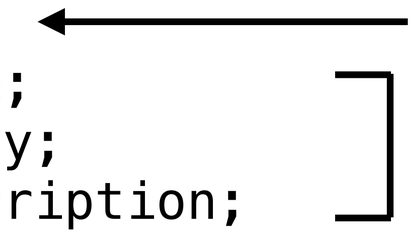

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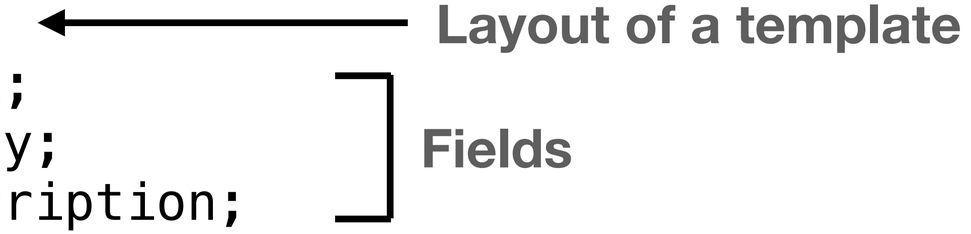

```
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  string Name;
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  string Description;
}

def water_bottle : Stuff {


}
```

Layout of a template

Fields

A *record* created with template `Stuff`

```
class Stuff {
  string Name;
  int Quantity;
  string Description;
}

def water_bottle : Stuff {
  let Name = "Water bottle";
  let Quantity = 1;
  let Description = "A stuff that helps you hydrate.";
}
```

Layout of a template

Fields

A *record* created with template `Stuff`

```
class Stuff {
  string Name;
  int Quantity;
  string Description;
}

def water_bottle : Stuff {
  let Name = "Water bottle";
  let Quantity = 1;
  let Description = "A stuff that helps you hydrate.";
}

def smart_phone : Stuff {
  let Name "Smart phone";
  let Quantity = 2;
  let Description = "A stuff that keeps you from hydrating.";
}
```

Layout of a template

Fields

A *record* created with template `Stuff`

Another record created with template `Stuff`

```
class Stuff <string name, int quantity, string description> {
  string Name = name;
  int Quantity = quantity;
  string Description = description;
}
```

```
class Stuff <string name, int quantity, string description> {
  string Name = name;
  int Quantity = quantity;
  string Description = description;
}

def water_bottle : Stuff<"Water bottle", 1,
                         "A stuff that helps you hydrate.">;

def smart_phone : Stuff<"Smart phone", 2,
                        "A stuff that prevents you from hydrating.">;
```

OOP v.s. TableGen

```
class Person {
    std::string Name;
    int Age;
    JobKind Job;
};
Person Me{"Min", 12, WEEBUS};
```

OOP v.s. TableGen

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class Person {
    std::string Name;
    int Age;
    JobKind Job;
};
Person Me{"Min", 12, WEEBUS};
```

✔ Encapsulating data

OOP v.s. TableGen

```
class Person {
    std::string Name;
    int Age;
    JobKind Job;
};
Person Me{"Min", 12, WEEBUS};

void foo(int N) {

  Me.Name = "Max";




}
```

✔ Encapsulating data

✘ Records are immutable

OOP v.s. TableGen

```
class Person {
    std::string Name;
    int Age;
    JobKind Job;
};
Person Me{"Min", 12, WEEBUS};

void foo(int N) {

  Me.Name = "Max";

  Person Rick{“Rick", N, SINGER};



}
```

- ✓ Encapsulating data
- ✗ Records are immutable
- ✗ Constant values in fields

OOP v.s. TableGen

```
class Person {
    std::string Name;
    int Age;
    JobKind Job;
};
Person Me{"Min", 12, WEEBUS};

void foo(int N) {

  Me.Name = "Max";

  Person Rick{“Rick", N, SINGER};

  for (i = 0; i < N; ++i)
    SomeList.emplace_back(Person{...});
}
```

- ✓ Encapsulating data
- ✗ Records are immutable
- ✗ Constant values in fields
- ✗ Constant numbers of records

Relational DB v.s. TableGen

Table “*Stuff*”

Name	Quantity	Description
Water Bottle	1	…
Smart Phone	2	…

Relational DB v.s. TableGen

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Relational DB v.s. TableGen

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Strong structure is *not* required

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```
def foo {
  string A = “foo”;
  int B = 0;
}

def bar {
  int Z = 1;
}

def zoo;
```

TableGen data types

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- Primitive types (common): `int`, `string`, `bool`, `bit`

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- Bit vector: `bits<`*`N`*`>`
- List: `list<`*`T`*`>`
- Direct Acyclic Graph (DAG): `dag`
  - Represent DAG data *symbolically*
  - `dag foo = (`*`operator arg0, arg1, …`*`)`

How to use TableGen records?

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```
def water_bottle : Stuff<"Water bottle", 1,
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TableGen backends

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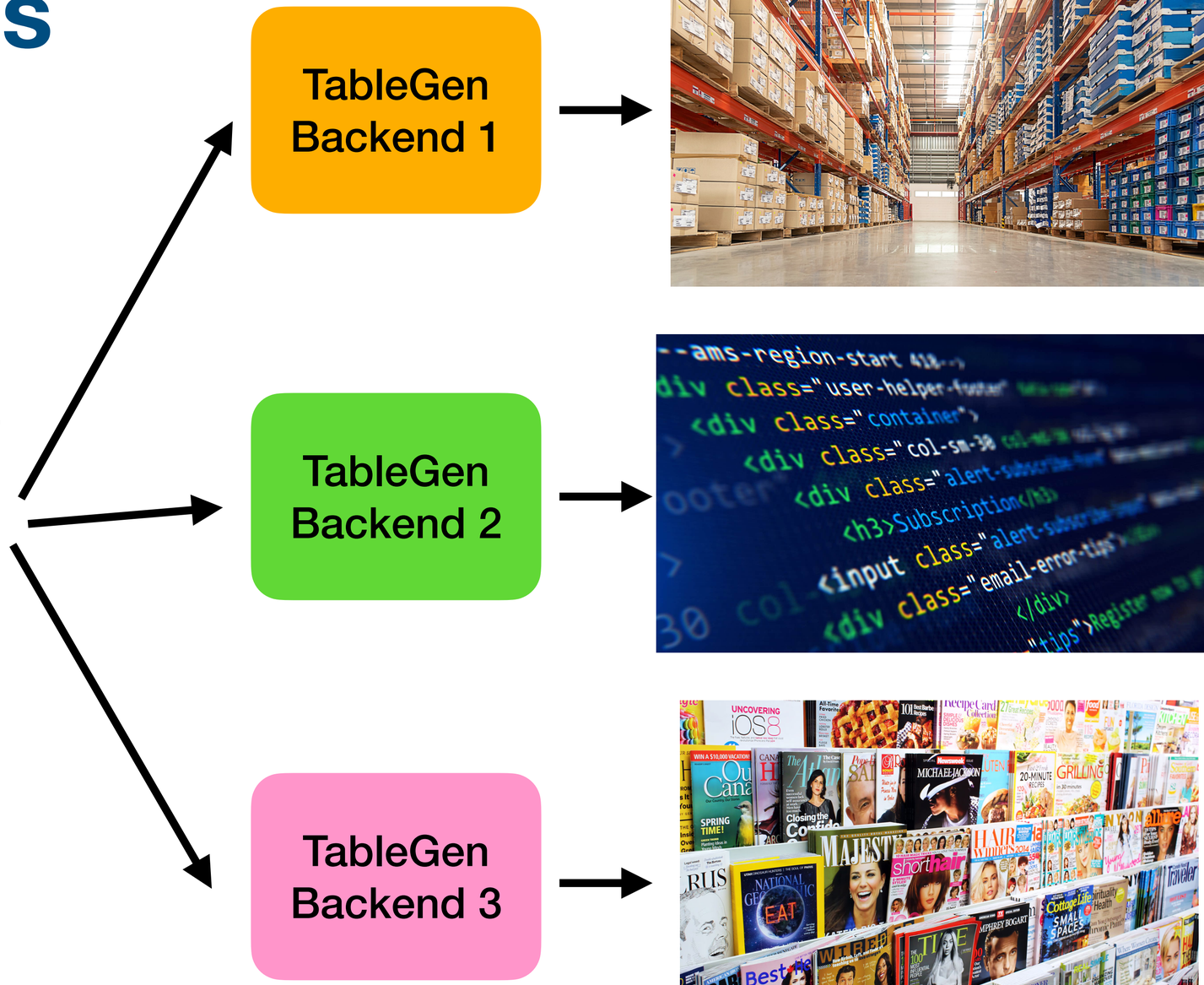
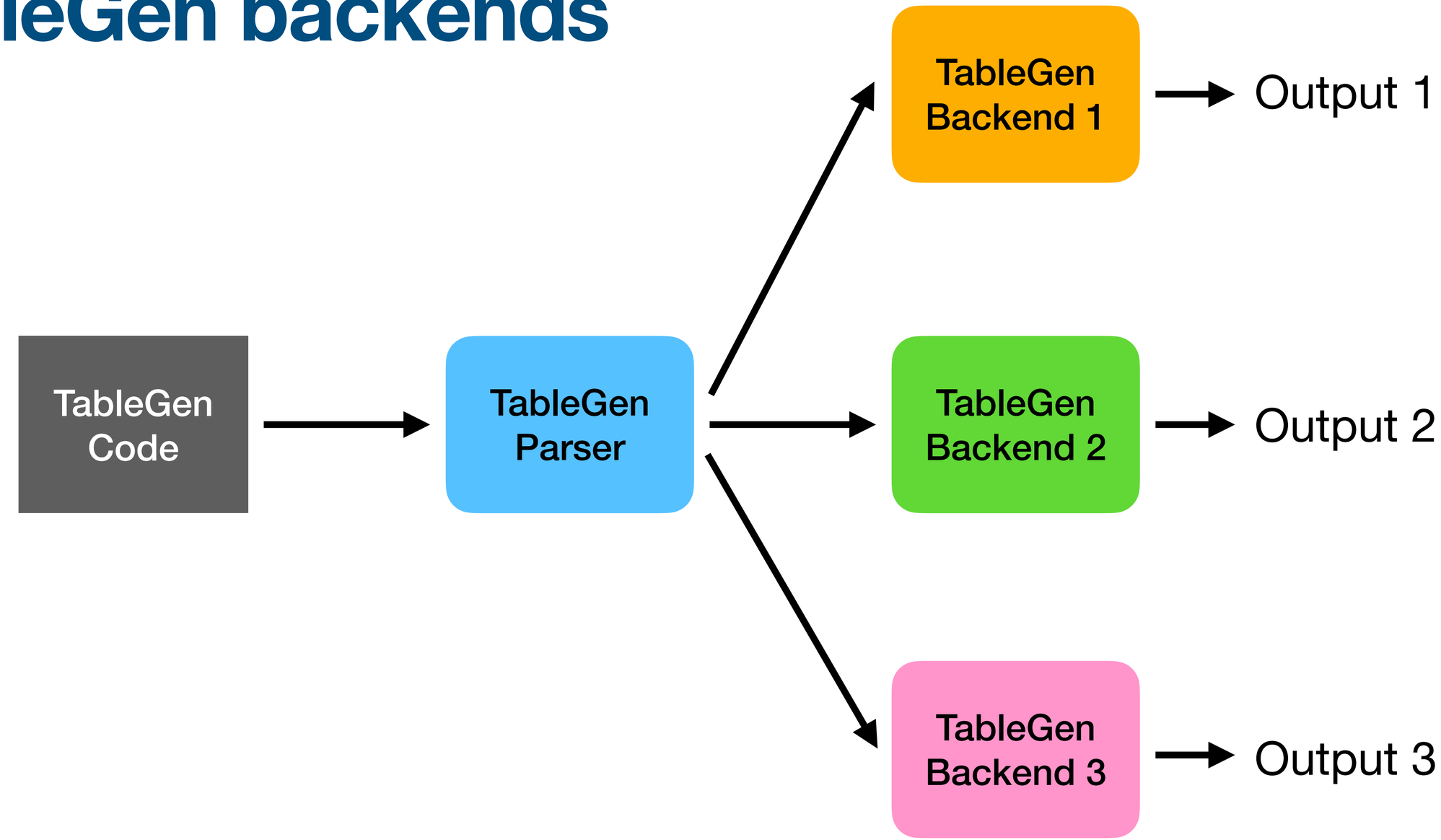


TableGen backends



TableGen usage in LLVM

An example in LLVM backend

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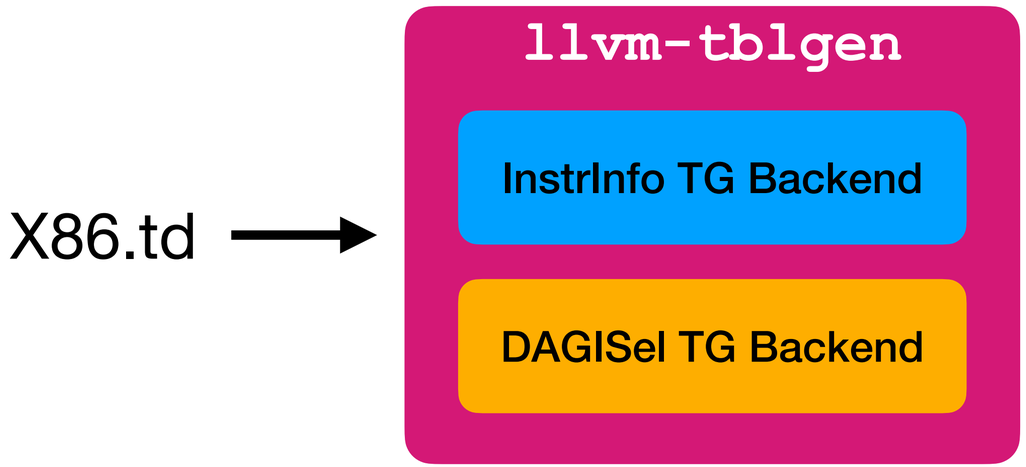

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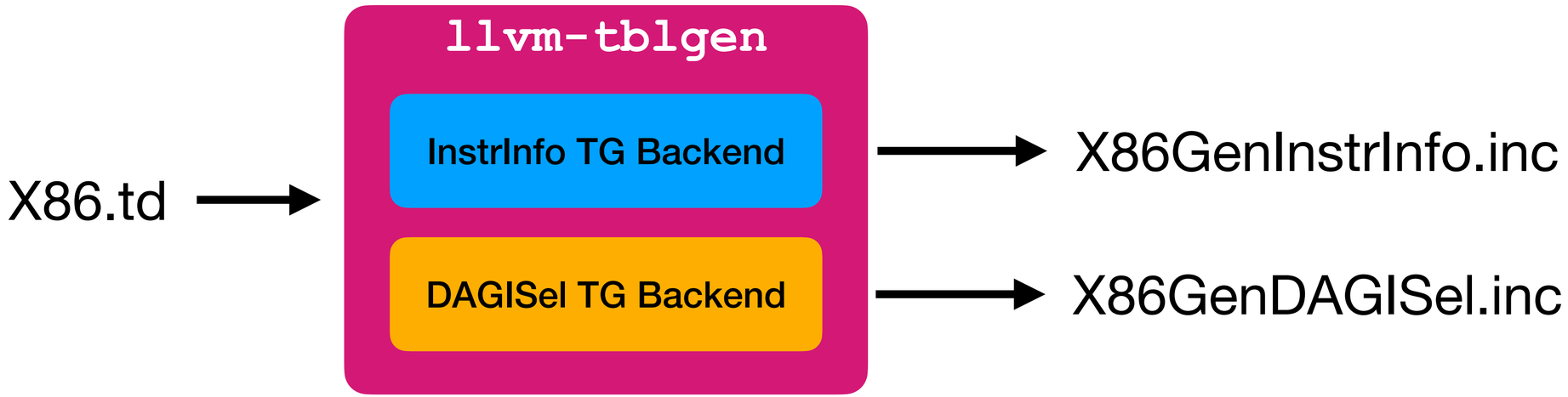

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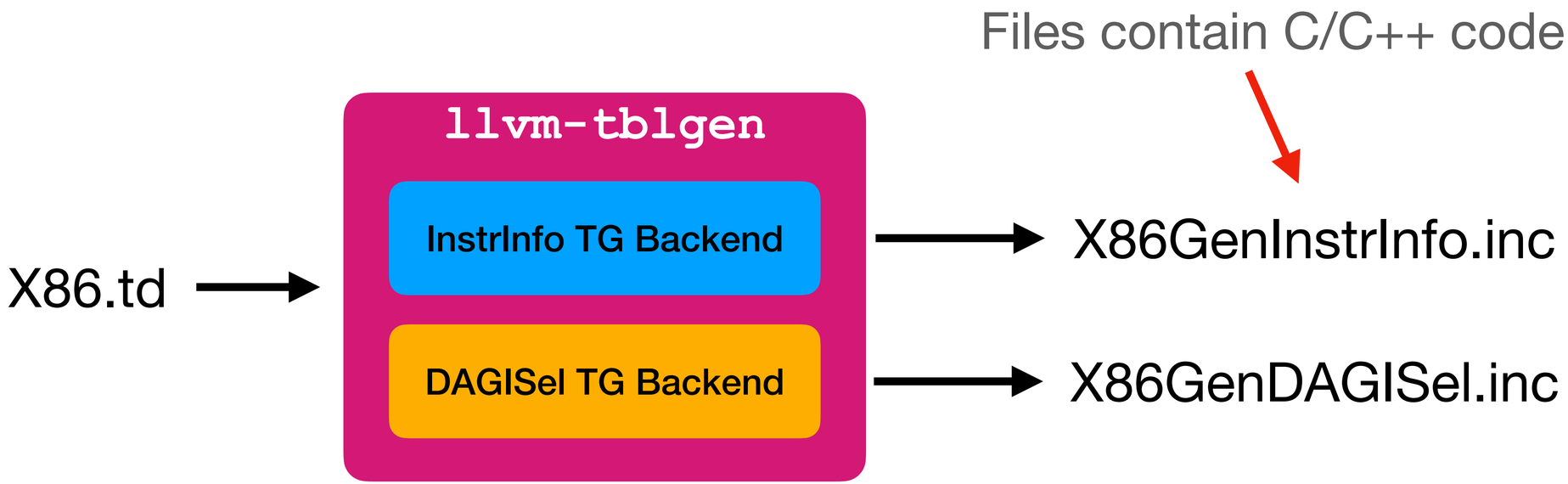

TableGen Backend Development

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Despite being a DSL, TableGen is actually pretty **versatile**

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Always require a specific TableGen backend

Why should I learn to write a TG backend?

Despite being a DSL, TableGen is actually pretty **versatile**

Always require a specific TableGen backend

LLVM has provided nice infrastructures to work with TableGen code

Project overview

Project overview

Recap: Comparison with Relational DB

Relational DB

Table "*Stuff*"

Name	Quantity	Description
Water Bottle	1	…
Smart Phone	2	…

v.s.

TableGen

- ✓ Fields are similar to columns
- ✗ Records do not *belong* to any table
- ▲ Strong structure is *not* required

Project overview

Recap: Comparison with Relational DB

A more *flexible* way to represent **static** structural data

Relational DB **v.s.** **TableGen**

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SQLGen — Generate SQL from TableGen code

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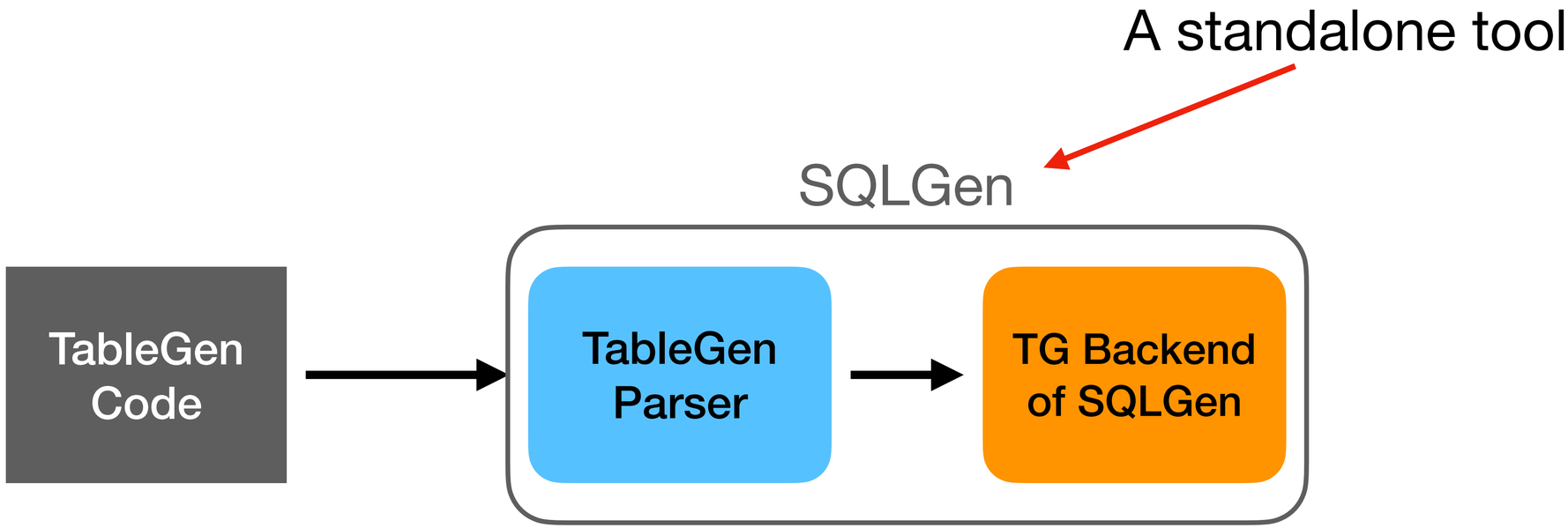
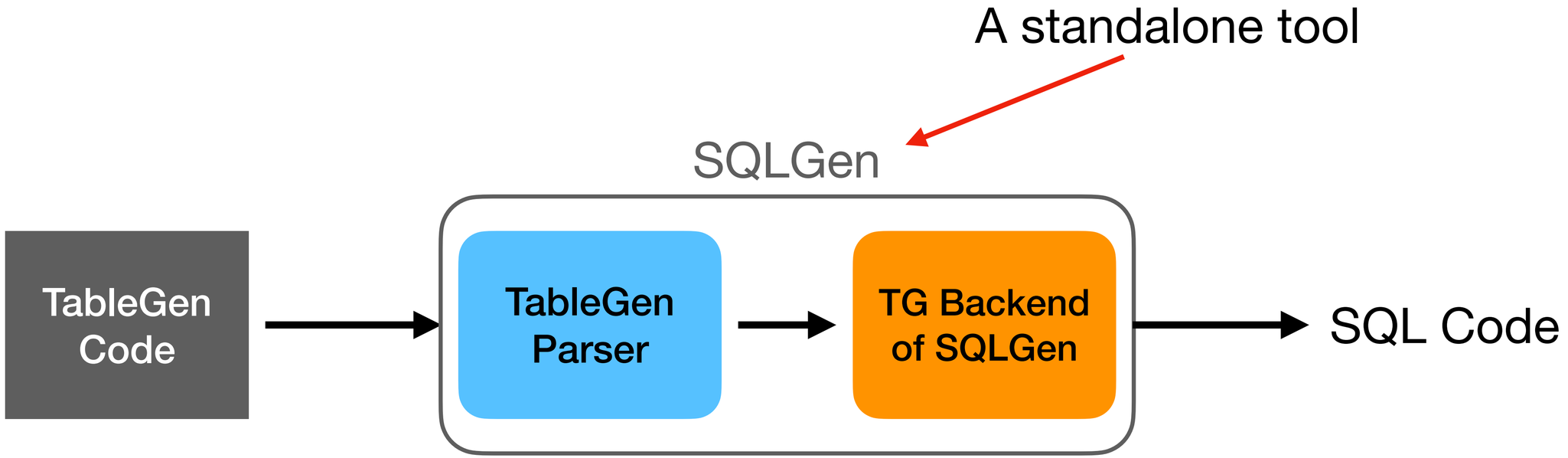


Project overview

SQLGen — Generate SQL from TableGen code



TableGen syntax in SQLGen

SQL table creation

Input TableGen Code

Generated SQL Code

TableGen syntax in SQLGen

SQL table creation

```
CREATE TABLE Customer (
    ID          int,
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class Table {
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Inserting rows into a SQL table

Input TableGen Code

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TableGen syntax in SQLGen

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INSERT INTO Customer (
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TableGen syntax in SQLGen

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def john : Customer<"John Smith", "UC Irvine">;
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Generated SQL Code

SQLGen entry point

```
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bool CallbackFunc(raw_ostream &OS, RecordKeeper &Records)
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- **OS**: Stream to the output file (i.e. Output stream to print the SQL code)
- **Records**: In-memory representation of the *parsed* TableGen code

Creating SQL Tables

TableGen syntax in SQLGen

Recap: SQL table creation

```
class Table {
  int PrimaryKey = 0;
}

class Customer <string name,
                string affiliation> : Table {
  int ID = PrimaryKey;
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```

Input TableGen Code

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CREATE TABLE Customer (
    ID          int,
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Generated SQL Code

Enumerating TableGen class-es

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Enumerating TableGen class-es

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```

```
std::map<std::string,                                    >
```

Enumerating TableGen class-es

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bool CallbackFunc(raw_ostream &OS, RecordKeeper &Records) {
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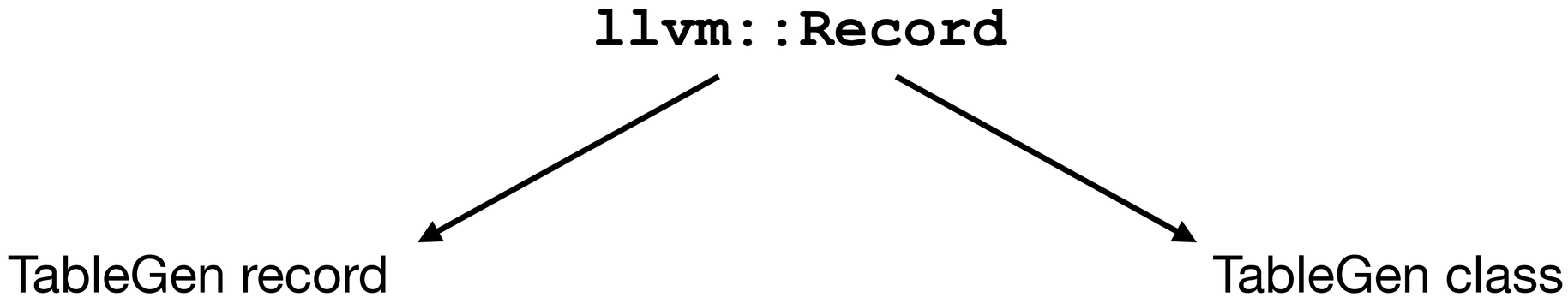
}
```

```
std::map<std::string, std::unique_ptr<llvm::Record>>
```

`llvm::Record`


llvm::Record
TableGen record
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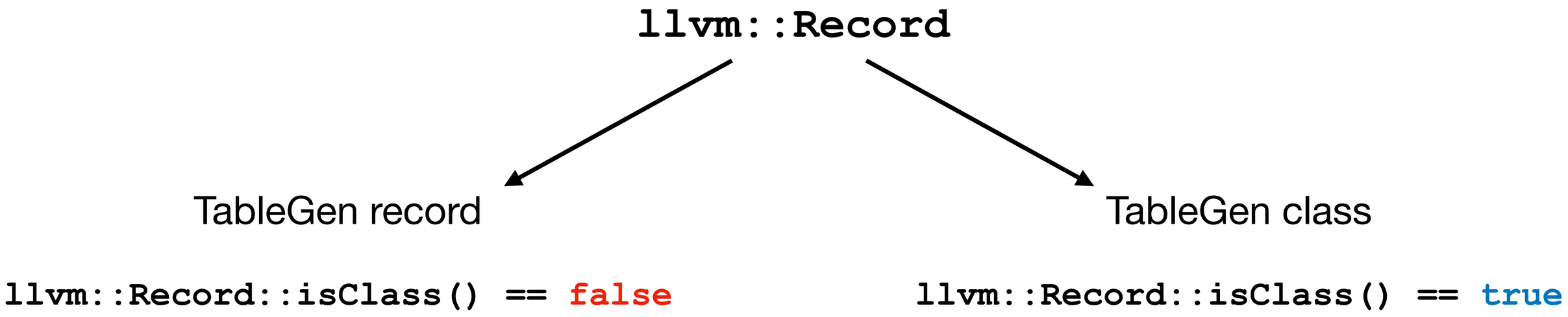
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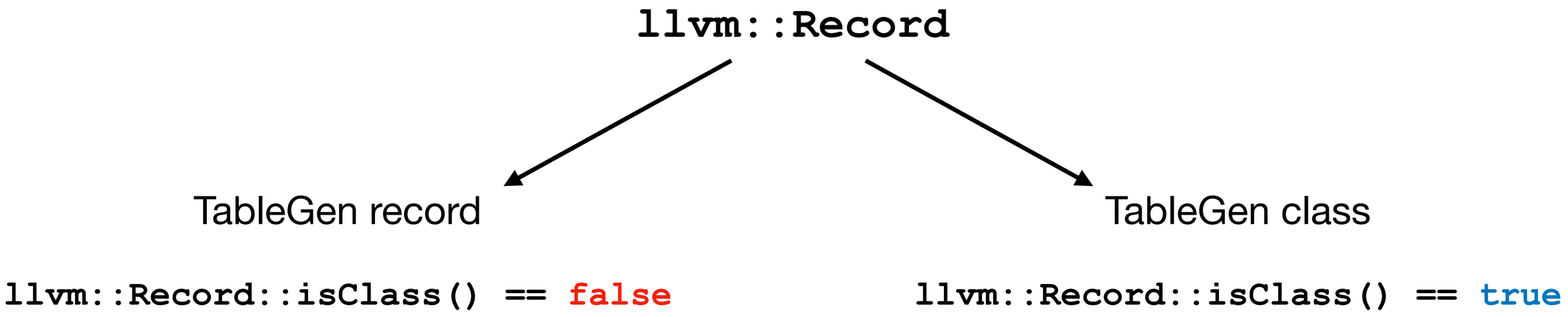
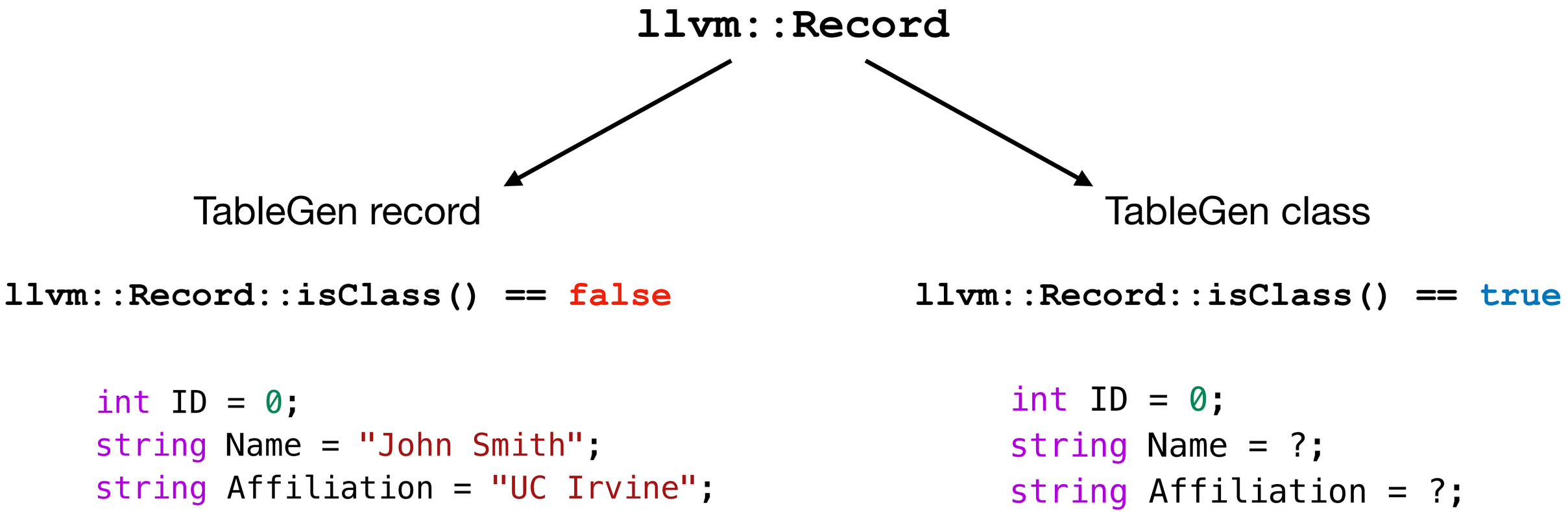



```
int ID = 0;
string Name = "John Smith";
string Affiliation = "UC Irvine";
```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int ID = 0;
string Name = ?;
string Affiliation = ?;

```
class Customer <string name, string affiliation> : Table {
  int ID = PrimaryKey;
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}


def john : Customer<"John Smith", "UC Irvine">;
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```

[redacted] llvm::Record

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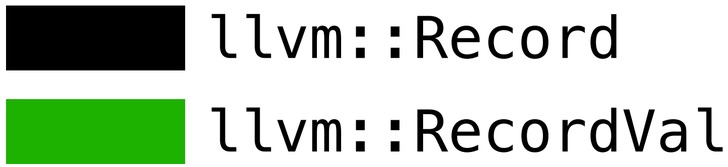

```
const auto &Classes = Records.getClasses();
for (const auto &P : Classes) {
  auto ClassName = P.first;
  Record &ClassRecord = *P.second;









}
```

```
const auto &Classes = Records.getClasses();
for (const auto &P : Classes) {
  auto ClassName = P.first;
  Record &ClassRecord = *P.second;
  OS << "CREATE TABLE " << ClassName << " (";




  OS << ");\n";
}
```

```
CREATE TABLE Customer (


);
```

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const auto &Classes = Records.getClasses();
for (const auto &P : Classes) {
  auto ClassName = P.first;
  Record &ClassRecord = *P.second;
  OS << "CREATE TABLE " << ClassName << " (";
  for (const RecordVal &RV : ClassRecord.getValues()) {




  }
  OS << ");\n";
}
```

```
CREATE TABLE Customer (


);
```

```
const auto &Classes = Records.getClasses();
for (const auto &P : Classes) {
  auto ClassName = P.first;
  Record &ClassRecord = *P.second;
  OS << "CREATE TABLE " << ClassName << " (";
  for (const RecordVal &RV : ClassRecord.getValues()) {
    OS << "\t" << RV.getName() << " ";




  }
  OS << ");\n";
}
```

```
CREATE TABLE Customer (
    ID
    Name
    Affiliation

);
```

```
const auto &Classes = Records.getClasses();
for (const auto &P : Classes) {
  auto ClassName = P.first;
  Record &ClassRecord = *P.second;
  OS << "CREATE TABLE " << ClassName << " (";
  for (const RecordVal &RV : ClassRecord.getValues()) {
    OS << "\t" << RV.getName() << " ";
    if (isa<IntRecTy>(RV.getType()))
      OS << "int,";


  }
  OS << ");\n";
}
```

```
CREATE TABLE Customer (
    ID          int,
    Name
    Affiliation

);
```

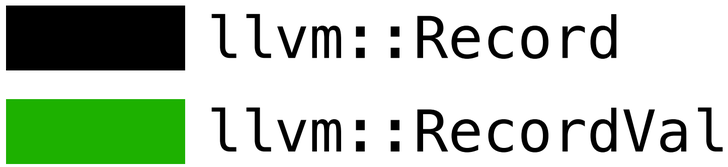
```
const auto &Classes = Records.getClasses();
for (const auto &P : Classes) {
  auto ClassName = P.first;
  Record &ClassRecord = *P.second;
  OS << "CREATE TABLE " << ClassName << " (";
  for (const RecordVal &RV : ClassRecord.getValues()) {
    OS << "\t" << RV.getName() << " ";
    if (isa<IntRecTy>(RV.getType()))
      OS << "int,";
    if (isa<StringRecTy>(RV.getType()))
      OS << "varchar(255),";
  }
  OS << ");\n";
}
```

```
CREATE TABLE Customer (
    ID          int,
    Name        varchar(255),
    Affiliation varchar(255),

);
```

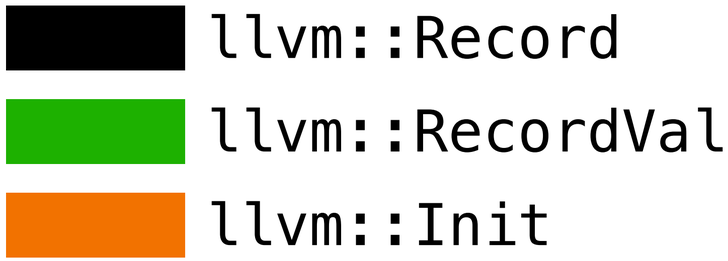
```
class Customer <string name, string affiliation> : Table {
  int ID = PrimaryKey;
  string Name = name;
  string Affiliation = affiliation;
}
```

```
def john {
  int PrimaryKey = 0;
  int ID = 0;
  string Name = "John Smith";
  string Affiliation = "UC Irvine";
}
```

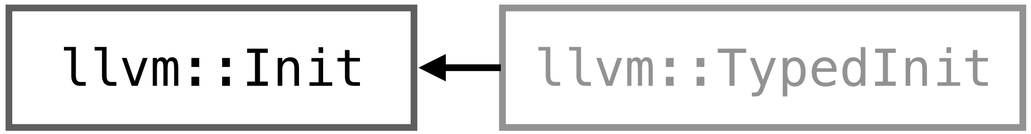


```
class Customer <string name, string affiliation> : Table {
  int ID = PrimaryKey;
  string Name = name;
  string Affiliation = affiliation;
}
```

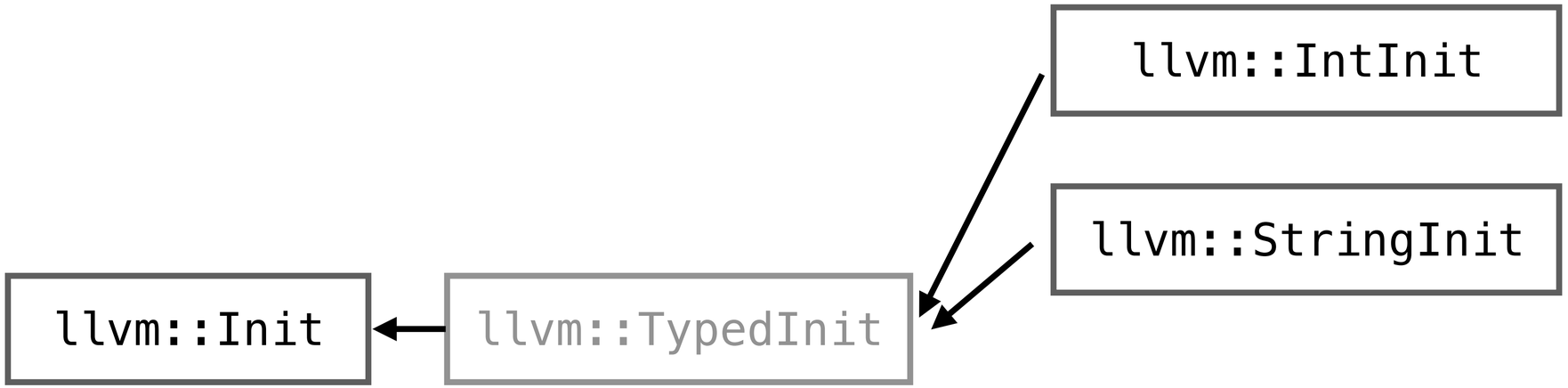
```
def john {
  int PrimaryKey = 0;
  int ID = 0;
  string Name = "John Smith";
  string Affiliation = "UC Irvine";
}
```



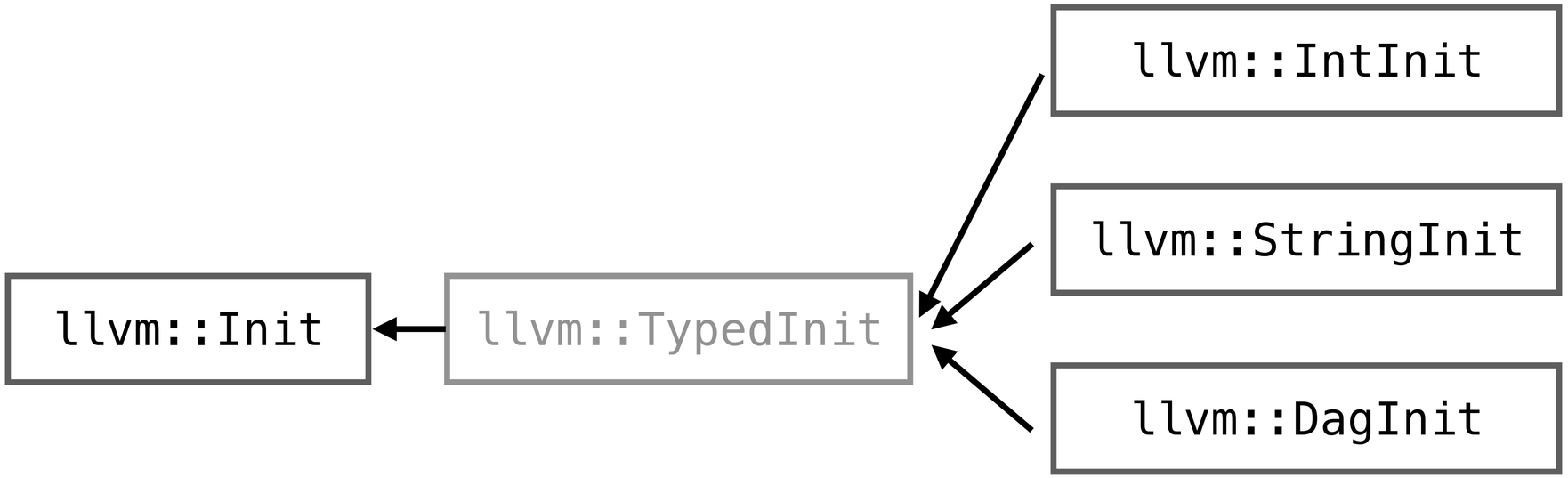
Common derived classes of llvm::Init



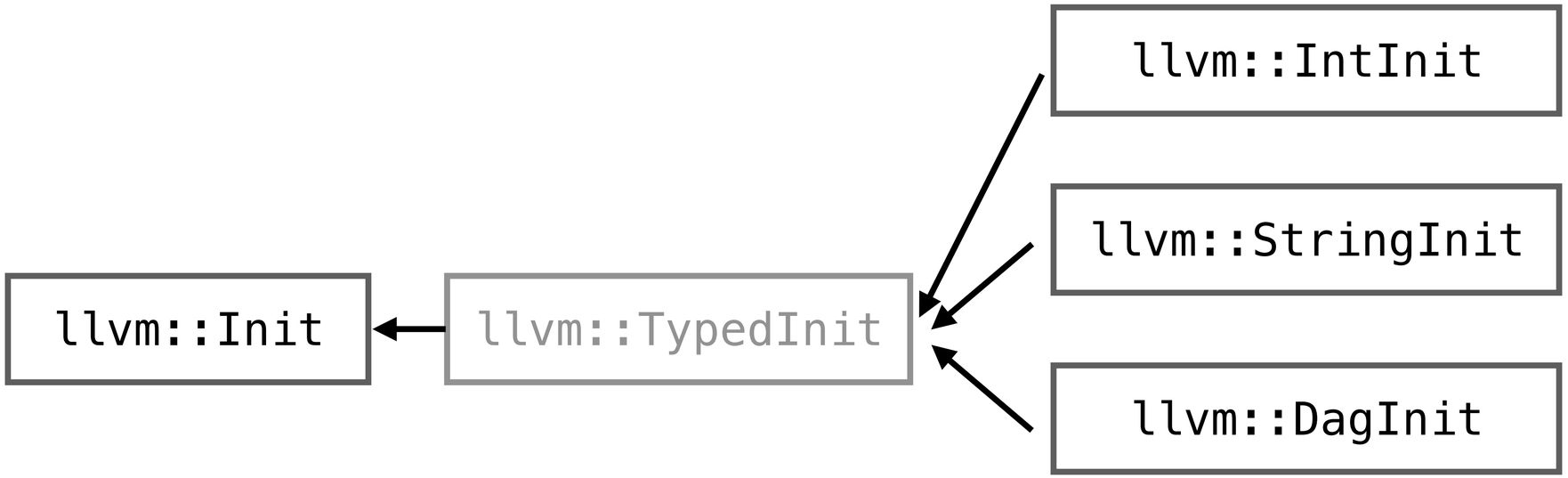
Common derived classes of llvm::Init



Common derived classes of llvm::Init

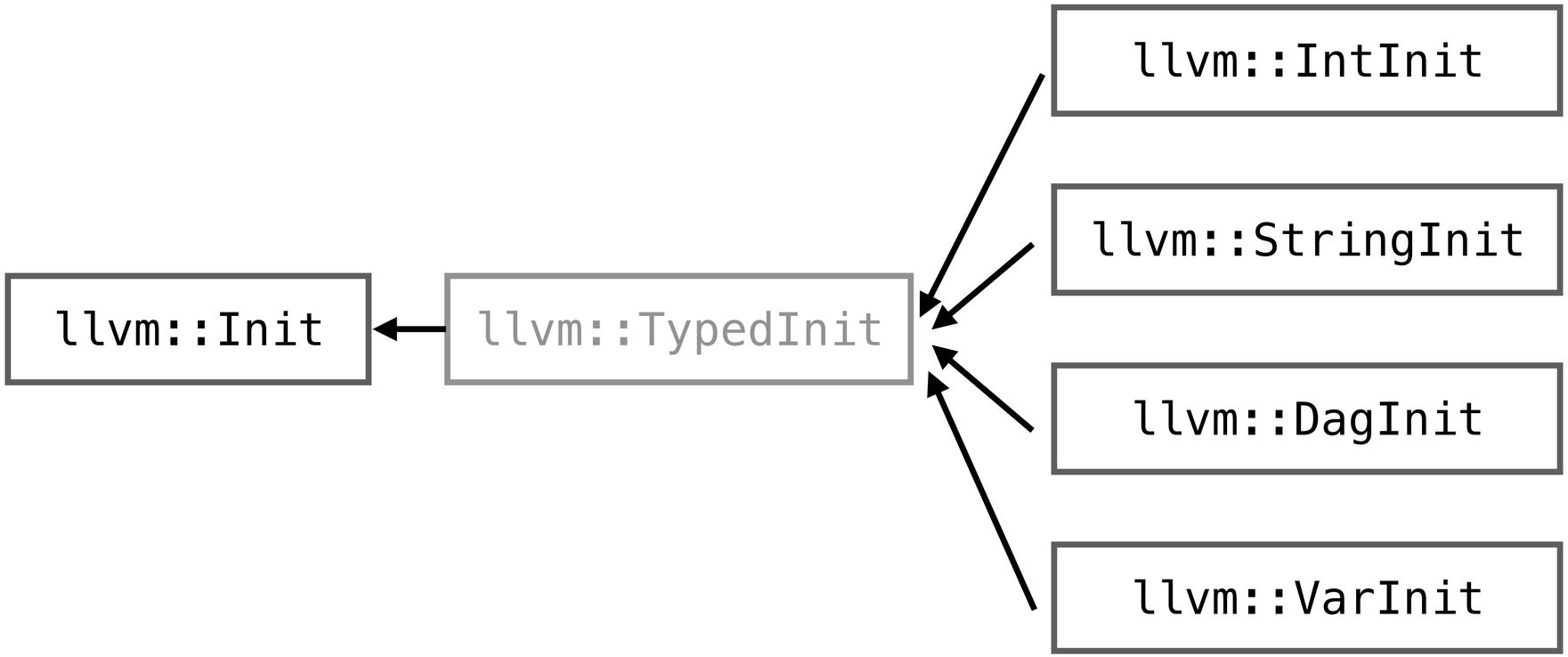


Common derived classes of llvm::Init




```
int PrimaryKey = 0;
int ID = PrimaryKey;
```

Common derived classes of llvm::Init




```
int PrimaryKey = 0;
int ID = PrimaryKey;
```

```
for (const auto &P : Classes) {
  ...
  OS << "CREATE TABLE " << ClassName << " (";
  for (const RecordVal &RV : ClassRecord.getValues()) {
    OS << "\t" << RV.getName() << " ";
    ...

  }
  OS << ");\n";
}
```

```
CREATE TABLE Customer (
    ID          int,
    Name        varchar(255),
    Affiliation varchar(255),

);
```

```
for (const auto &P : Classes) {
  ...
  OS << "CREATE TABLE " << ClassName << " (";
  for (const RecordVal &RV : ClassRecord.getValues()) {
    OS << "\t" << RV.getName() << " ";
    ...
    Init *Val = RV.getValue();




  }
  OS << ");\n";
}
```

```
CREATE TABLE Customer (
    ID          int,
    Name        varchar(255),
    Affiliation varchar(255),

);
```

```
for (const auto &P : Classes) {
  ...
  OS << "CREATE TABLE " << ClassName << " (";
  for (const RecordVal &RV : ClassRecord.getValues()) {
    OS << "\t" << RV.getName() << " ";
    ...
    Init *Val = RV.getValue();
    if (auto *VI = dyn_cast<VarInit>(Val)) {
      if (VI->getName() == "PrimaryKey")
        OS << "PRIMARY KEY (" << RV.getName() << ")";
    }
  }
  OS << ");\n";
}
```

```
CREATE TABLE Customer (
    ID          int,
    Name        varchar(255),
    Affiliation varchar(255),
    PRIMARY KEY (ID)
);
```

SQL Row Insertion

TableGen syntax in SQLGen

Recap: Inserting rows into a SQL table

```
class Customer <string name,
                string affiliation> : Table {
  int ID = PrimaryKey;
  string Name = name;
  string Affiliation = affiliation;
}

def john : Customer<"John Smith", "UC Irvine">;
```

Input TableGen Code

```
INSERT INTO Customer (
    ID,
    Name,
    Affiliation
)
VALUES (0, "John Smith", "UC Irvine");
```

Generated SQL Code

Enumerating TableGen Records

```
bool CallbackFunc(raw_ostream &OS, RecordKeeper &Records) {



}
```

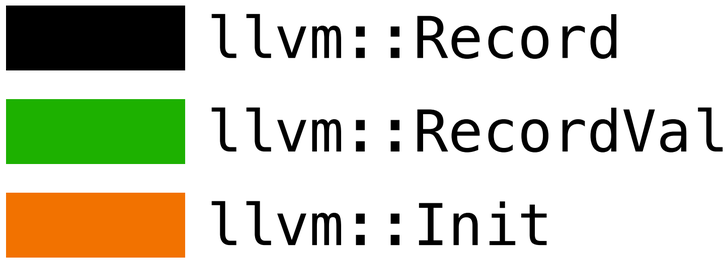
Enumerating TableGen Records

```
bool CallbackFunc(raw_ostream &OS, RecordKeeper &Records) {
  auto SQLRows = Records.getAllDerivedDefinitions("Table");
  for (const Record *RowRecord : SQLRows) {
    ...
  }
}
```

Recap: In-memory representations for TableGen records / classes

```
class Customer <string name, string affiliation> : Table {
  int ID = PrimaryKey;
  string Name = name;
  string Affiliation = affiliation;
}
```

```
def john {
  int PrimaryKey = 0;
  int ID = 0;
  string Name = "John Smith";
  string Affiliation = "UC Irvine";
}
```



```
for (const Record *RowRecord : SQLRows) {
  for (const RecordVal &RV : RowRecord->getValues()) {

  }




}
```

```
                                                    INSERT INTO Customer (

for (const Record *RowRecord : SQLRows) {                        )
  OS << "INSERT INTO " << ClassName << " (\n";
  for (const RecordVal &RV : RowRecord->getValues()) {


  }
  OS << ")\n";




}
```

```
INSERT INTO Customer (
    ID,
    Name,
    Affiliation
)
```

```
for (const Record *RowRecord : SQLRows) {
  OS << "INSERT INTO " << ClassName << " (\n";
  for (const RecordVal &RV : RowRecord->getValues()) {
    auto Name = RV.getName();
    OS << "\t" << Name << ",\n";
  }
  OS << ")\n";









}
```

```
for (const Record *RowRecord : SQLRows) {
  OS << "INSERT INTO " << ClassName << " (\n";
  for (const RecordVal &RV : RowRecord->getValues()) {
    auto Name = RV.getName();
    OS << "\t" << Name << ",\n";
  }
  OS << ")\n";
  OS << "VALUES (";
  for (const RecordVal &RV : RowRecord->getValues()) {



  }
  OS << ");\n";
}
```

```
INSERT INTO Customer (
    ID,
    Name,
    Affiliation
)
VALUES (                                    );
```

```
for (const Record *RowRecord : SQLRows) {
  OS << "INSERT INTO " << ClassName << " (\n";
  for (const RecordVal &RV : RowRecord->getValues()) {
    auto Name = RV.getName();
    OS << "\t" << Name << ",\n";
  }
  OS << ")\n";
  OS << "VALUES (";
  for (const RecordVal &RV : RowRecord->getValues()) {
    const Init *Val = RV.getValue();
    OS << Val->getAsString() << ", ";
  }
  OS << ");\n";
}
```

```
INSERT INTO Customer (
    ID,
    Name,
    Affiliation
)
VALUES (0, "John Smith", "UC Irvine");
```

Making SQL Queries

TableGen syntax in SQLGen

Making queries

```
class Query <string table,
             dag query_fields, dag condition> {



}
```

Input TableGen Code

```
SELECT                  FROM
```

Generated SQL Code

TableGen syntax in SQLGen

Making queries

```
class Query <string table,
             dag query_fields, dag condition> {

  dag Fields = query_fields;

}
```

Input TableGen Code

```
SELECT Affiliation FROM
```

Generated SQL Code

TableGen syntax in SQLGen

Making queries

```
class Query <string table,
             dag query_fields, dag condition> {
  string TableName = table;
  dag Fields = query_fields;

}
```

Input TableGen Code

```
SELECT Affiliation FROM Customer
```

Generated SQL Code

TableGen syntax in SQLGen

Making queries

```
class Query <string table,
             dag query_fields, dag condition> {
  string TableName = table;
  dag Fields = query_fields;
  dag WhereClause = condition;
}
```

Input TableGen Code

```
SELECT Affiliation FROM Customer
WHERE Name = "John Smith";
```

Generated SQL Code

TableGen syntax in SQLGen

Making queries

```
class Query <string table,
             dag query_fields, dag condition> {
  string TableName = table;
  dag Fields = query_fields;
  dag WhereClause = condition;
}

def : Query<"Customer", (fields "Affiliation"),
            (eq "Name", "John Smith"     )>;
```

Input TableGen Code

```
SELECT Affiliation FROM Customer
WHERE Name = "John Smith";
```

Generated SQL Code

TableGen syntax in SQLGen

Making queries

```
class Query <string table,
             dag query_fields, dag condition> {
  string TableName = table;
  dag Fields = query_fields;
  dag WhereClause = condition;
}

def : Query<"Customer", (fields "Affiliation"),
            (eq "Name", "John Smith"     )>;
```

Anonymous record

Input TableGen Code

```
SELECT Affiliation FROM Customer
WHERE Name = "John Smith";
```

Generated SQL Code

TableGen syntax in SQLGen

Making queries

```
class Query <string table,
             dag query_fields, dag condition> {
  string TableName = table;
  dag Fields = query_fields;
  dag WhereClause = condition;
}

def : Query<"Customer", (fields "Affiliation"),
            (eq "Name", "John Smith"     )>;
```

Anonymous record

Input TableGen Code

```
SELECT Affiliation FROM Customer
WHERE Name = "John Smith";
```

Generated SQL Code

Example of the dag type

An expression tree

Modeling expression: *9 + 4 * (x - 3)*

```
def plus;
def minus;



dag expr = (                                        );
```

Example of the dag type

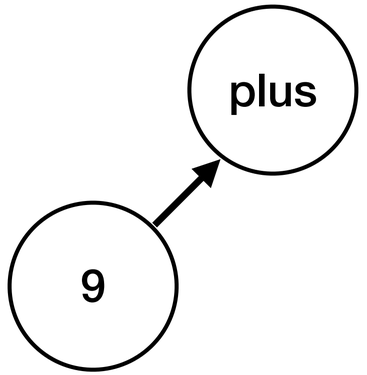
An expression tree

Modeling expression: *9 + 4 * (x - 3)*

```
def plus;
def minus;



dag expr = (plus 9,                                    );
```



Example of the dag type

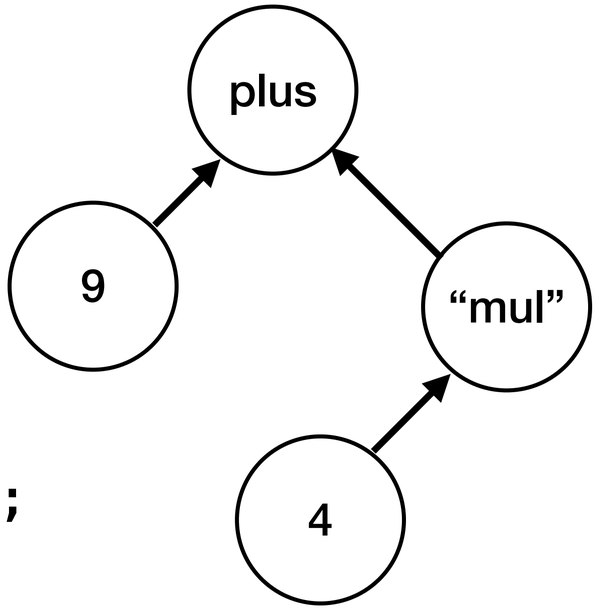
An expression tree

Modeling expression: *9 + 4 * (x - 3)*

```
def plus;
def minus;



dag expr = (plus 9, ("mul" 4,                    ));
```



Example of the dag type

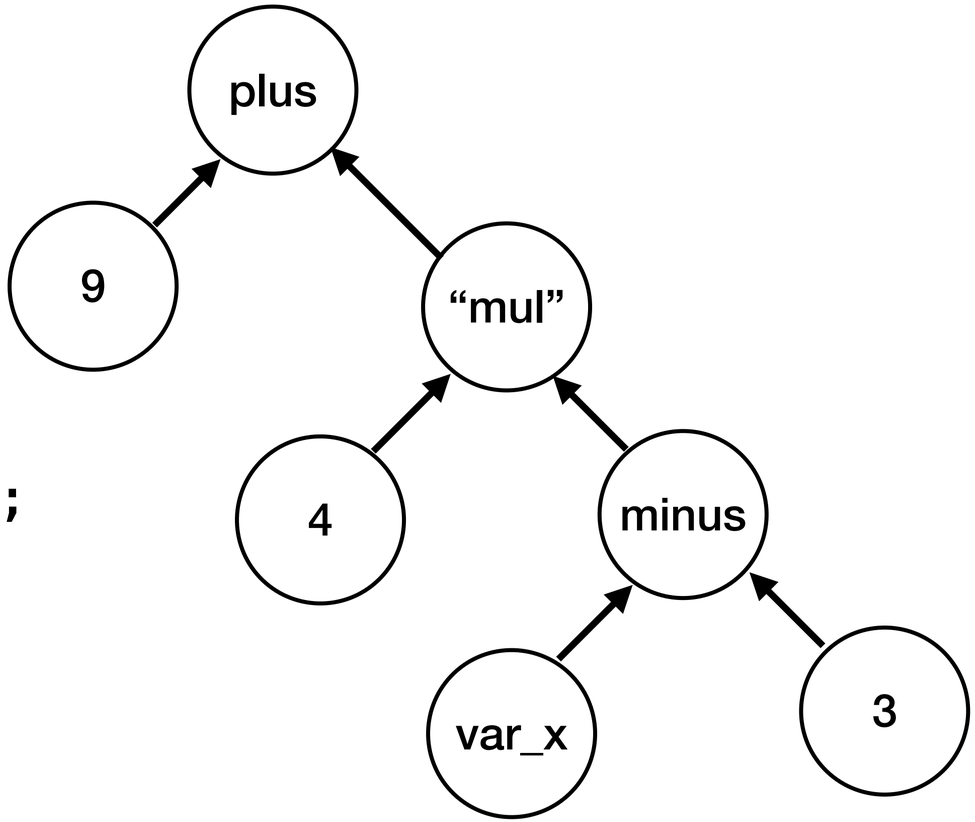
An expression tree

Modeling expression: *9 + 4 * (x - 3)*

```
def plus;
def minus;

def var_x : Var {...}

dag expr = (plus 9, ("mul" 4, (minus var_x, 3)));
```



Making SQL queries

More examples

TableGen

```
def : Query<"Orders", (fields "Person", "Amount"),
            (gt "Amount", 8)>
```

SQL

```
SELECT Person, Amount FROM Orders
WHERE Amount > 8;
```

Making SQL queries

More examples

TableGen

```
def : Query<"Orders", (fields "Person", "Amount"),
            (gt "Amount", 8)>
```

SQL

```
SELECT Person, Amount FROM Orders
WHERE Amount > 8;
```

TableGen

```
def : Query<"Orders", (fields "ProductName", "Person"),
            (and (gt "Amount", 8), (ne "Person", 1))>;
```

SQL

```
SELECT ProductName, Person FROM Orders
WHERE Amount > 8 AND Person <> 1;
```

TableGen syntax in SQLGen

Making queries

```
class Query <string table,
             dag query_fields, dag condition> {
  string TableName = table;
  dag Fields = query_fields;
  dag WhereClause = condition;
}

def : Query<"Customer", (fields "Affiliation"),
            (eq "Name", "John Smith"     )>;
```

Input TableGen Code

```
SELECT Affiliation FROM Customer
WHERE Name = "John Smith";
```

Generated SQL Code

TableGen syntax in SQLGen

Making queries

```
class Query <string table,
             dag query_fields, dag condition> {
  string TableName = table;
  dag Fields = query_fields;
  dag WhereClause = condition;
}

def : Query<"Customer", (fields "Affiliation"),
            (eq "Name", "John Smith":$str)>;
```

Input TableGen Code

```
SELECT Affiliation FROM Customer
WHERE Name = "John Smith";
```

Generated SQL Code

TableGen syntax in SQLGen

Making queries

```
class Query <string table,
             dag query_fields, dag condition> {
  string TableName = table;
  dag Fields = query_fields;
  dag WhereClause = condition;
}

def : Query<"Customer", (fields "Affiliation"),
            (eq "Name", "John Smith":$str)>;
```

An argument with *tag*

Input TableGen Code

```
SELECT Affiliation FROM Customer
WHERE Name = "John Smith";
```

Generated SQL Code

```
auto SQLQueries = Records.getAllDerivedDefinitions("Query");
for (const Record *Query : SQLQueries) {









}
```

```
auto SQLQueries = Records.getAllDerivedDefinitions("Query");
for (const Record *Query : SQLQueries) {
  auto TableName = Query->getValueAsString("TableName");
  const DagInit *Fields = Query->getValueAsDag("Fields");




}
```

SELECT

```
auto SQLQueries = Records.getAllDerivedDefinitions("Query");
for (const Record *Query : SQLQueries) {
  auto TableName = Query->getValueAsString("TableName");
  const DagInit *Fields = Query->getValueAsDag("Fields");
  OS << "SELECT ";



}
```

```
                                                    SELECT Affiliation
```

```
auto SQLQueries = Records.getAllDerivedDefinitions("Query");
for (const Record *Query : SQLQueries) {
  auto TableName = Query->getValueAsString("TableName");
  const DagInit *Fields = Query->getValueAsDag("Fields");
  OS << "SELECT ";
  for (const Init *Arg : Fields->getArgs())
    OS << Arg->getAsUnquotedString() << ",";

}
```

```
SELECT Affiliation FROM Customer
```

```
auto SQLQueries = Records.getAllDerivedDefinitions("Query");
for (const Record *Query : SQLQueries) {
  auto TableName = Query->getValueAsString("TableName");
  const DagInit *Fields = Query->getValueAsDag("Fields");
  OS << "SELECT ";
  for (const Init *Arg : Fields->getArgs())
    OS << Arg->getAsUnquotedString() << ",";
  OS << " FROM " << TableName << "\n";
}
```

```
void visitWhereClause(const DagInit *Term, raw_ostream &OS) {
  const Init *Operator = Term->getOperator();

}
```

TableGen

```
(                                    )
```

SQL

```
SELECT Affiliation FROM Customer
WHERE
```

```
void visitWhereClause(const DagInit *Term, raw_ostream &OS) {
  const Init *Operator = Term->getOperator();
```

TableGen

```
(eq                                    )
```

SQL

```
SELECT Affiliation FROM Customer
WHERE
```

```
}
```

```
void visitWhereClause(const DagInit *Term, raw_ostream &OS) {
  const Init *Operator = Term->getOperator();
  for (int i = 0; i < Term->arg_size(); ++i) {
    const Init *Arg = Term->getArg(i);









  }
}
```

TableGen

```
(eq                                    )
```

SQL

```
SELECT Affiliation FROM Customer
WHERE
```

```
void visitWhereClause(const DagInit *Term, raw_ostream &OS) {
  const Init *Operator = Term->getOperator();
  for (int i = 0; i < Term->arg_size(); ++i) {
    const Init *Arg = Term->getArg(i);
    if (const auto *ArgDag = dyn_cast<DagInit>(Arg))
      visitWhereClause(ArgDag, OS);
```

TableGen

```
(eq                                    )
```

SQL

```
SELECT Affiliation FROM Customer
WHERE
```

```
  }
}
```

```
void visitWhereClause(const DagInit *Term, raw_ostream &OS) {
  const Init *Operator = Term->getOperator();
  for (int i = 0; i < Term->arg_size(); ++i) {
    const Init *Arg = Term->getArg(i);
    if (const auto *ArgDag = dyn_cast<DagInit>(Arg))
      visitWhereClause(ArgDag, OS);
    else {



    }


  }
}
```

TableGen

```
(eq                                    )
```

SQL

```
SELECT Affiliation FROM Customer
WHERE
```

```
void visitWhereClause(const DagInit *Term, raw_ostream &OS) {
  const Init *Operator = Term->getOperator();
  for (int i = 0; i < Term->arg_size(); ++i) {
    const Init *Arg = Term->getArg(i);
    if (const auto *ArgDag = dyn_cast<DagInit>(Arg))
      visitWhereClause(ArgDag, OS);
    else {
      if (Term->getArgName(i) == "str")
        OS << Arg->getAsString();



    }



  }
}
```

TableGen

```
(eq          "John Smith":$str)
```

SQL

```
SELECT Affiliation FROM Customer
WHERE         “John Smith";
```

```
void visitWhereClause(const DagInit *Term, raw_ostream &OS) {
  const Init *Operator = Term->getOperator();
  for (int i = 0; i < Term->arg_size(); ++i) {
    const Init *Arg = Term->getArg(i);
    if (const auto *ArgDag = dyn_cast<DagInit>(Arg))
      visitWhereClause(ArgDag, OS);
    else {
      if (Term->getArgName(i) == "str")
        OS << Arg->getAsString();
      else
        OS << Arg->getAsUnquotedString();
    }


  }
}
```

TableGen

```
(eq "Name", "John Smith":$str)
```

SQL

```
SELECT Affiliation FROM Customer
WHERE Name   “John Smith";
```

```
void visitWhereClause(const DagInit *Term, raw_ostream &OS) {
  const Init *Operator = Term->getOperator();
  for (int i = 0; i < Term->arg_size(); ++i) {
    const Init *Arg = Term->getArg(i);
    if (const auto *ArgDag = dyn_cast<DagInit>(Arg))
      visitWhereClause(ArgDag, OS);
    else {
      if (Term->getArgName(i) == "str")
        OS << Arg->getAsString();
      else
        OS << Arg->getAsUnquotedString();
    }
    if (i < Term->arg_size() - 1)
      printOperator(Operator);
  }
}
```

TableGen

```
(eq "Name", "John Smith":$str)
```

SQL

```
SELECT Affiliation FROM Customer
WHERE Name = "John Smith";
```

Epilogue

Other useful TableGen syntax

The `multiclass` - creating multiple records at once

TableGen operators (a.k.a *bang* operators) - e.g. `!add`, `!mul`, `!or`

Bits slice

String concatenation via ‘#’

Casting from string to a record

Sample code

https://github.com/mshockwave/SQLGen

Some additional features / highlights…

- Hierarchical records via `FOREIGN KEY`
- Ordering fields via `ORDER BY`
- Using LLVM LIT for testing

Q&A

GitHub: mshockwave

Email: minyihh@uci.edu

Book URL: https://tinyurl.com/3xnc5r3t