L6
Application Programming

Thibault Sellam

Fall 2018

Topics

Interfacing with applications

- Database APIs (DBAPIS)
- Cursors

SQL != Programming Language

Not a general purpose programming language

- Tailored for data access/manipulation
- Easy to optimize and parallelize
- Can't perform "business logic"

Options

1. Extend SQL, make it Turing Complete
   goes from simple, easy to analyze to complex :(
2. Extend existing languages to understand SQL natively
3. Provide an API between programming languages and DBMSes

Many Database API options

Fully embed into language (embedded SQL)

Low-level library with core database calls (DBAPI)

Object-relational mapping (ORM)

- Ruby on rails, django, Hibernate, sqlalchemy, etc
  - define database-backed classes
  - magically maps between database rows & objects
  - magic is a double edged sword

Embedded SQL

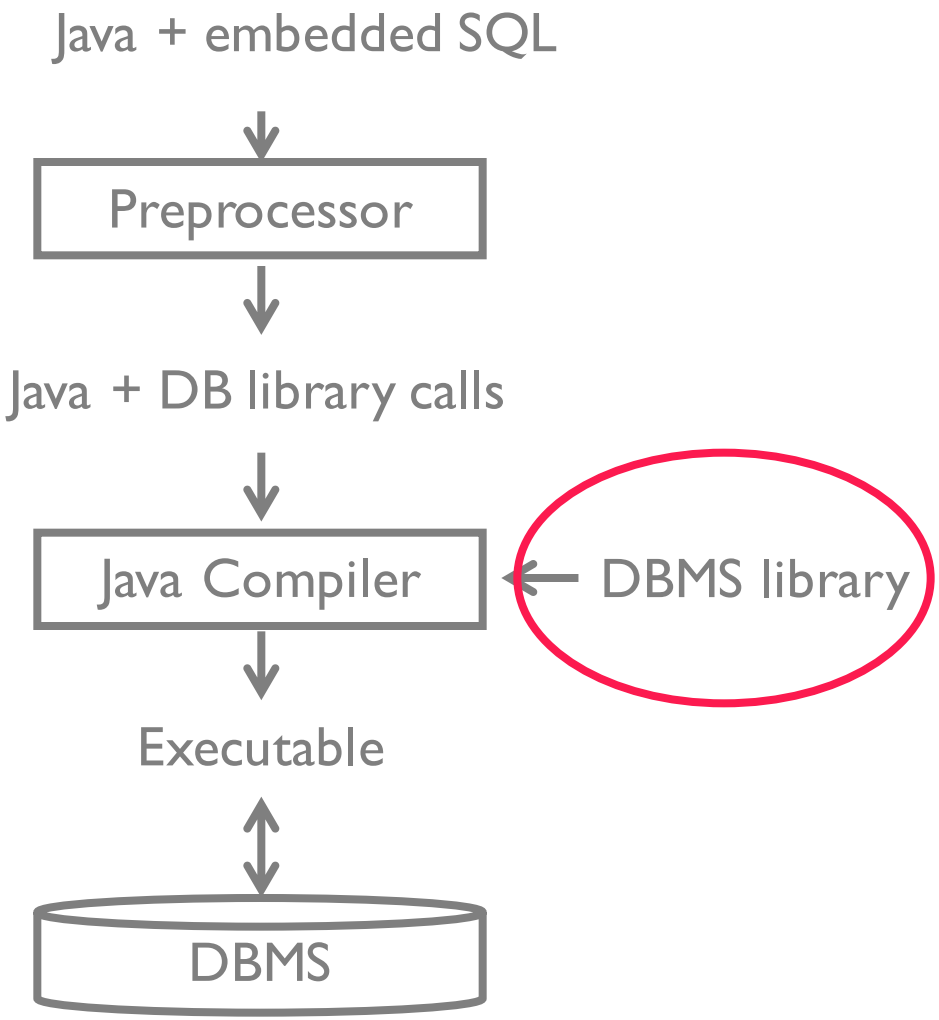
Extend host language (python) with SQL syntax

e.g., EXEC SQL *sql-query*

goes through a preprocessor

Compiled into program that interacts with DBMS directly

Embedded SQL




```
…
if (user == ‘admin’){
    EXEC SQL select * …
} else {
…
```

What does a library need to do?

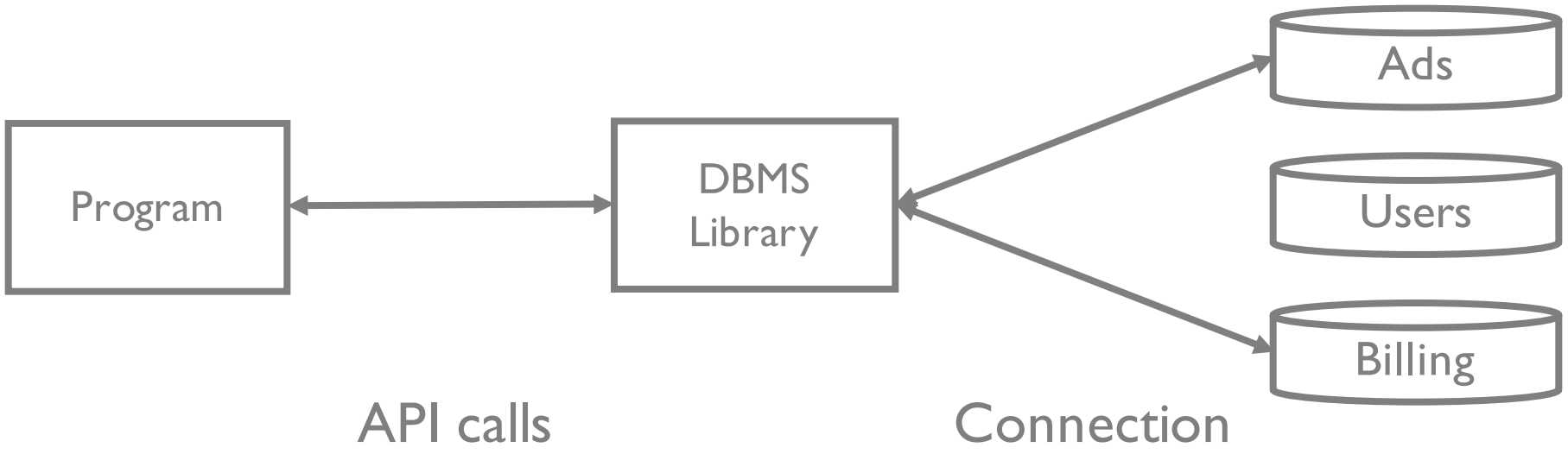
Single interface to possibly multiple DBMS engines

Connect to a database

Manage transactions (later)

Map objects between host language and DBMS

Manage query results



Overview

Library Components

Impedance Mismatches

1. Types
2. Classes/objects
3. Result sets
4. Functions
5. Constraints

Engines

Abstraction for a database engine

tries to hide DBMS language differences

driver://username:password@host:port/database

```
from sqlalchemy import create_engine
db1 = create_engine(
    “postgresql://localhost:5432/testdb”
)

db2 = create_engine(“sqlite:///testdb.db”)
//  note: sqllite has no host name (sqlite:///)
```

http://docs.sqlalchemy.org/en/rel_1_0/core/engines.html

Connections

Before running queries need to create a connection

- Tells DBMS to allocate resources for the connection
- Relatively expensive to set up, libraries often cache connections for future use
- Defines scope of a transaction (later)

```
conn1 = db1.connect()
conn2 = db2.connect()
```

Should close connections when done! Otherwise resource leak.

Query Execution

```
conn1.execute(“update table test set a = 1”)
conn1.execute(“update table test set s = ‘wu’”)
```

Query Execution

```
foo = conn1.execute("select * from big_table")
```

Challenges

- What is the return type of `execute()`?
- Type impedance
- How to pass data between DBMS and host language?
- Can we only pass data between DBMS and host language?

(Type) Impedance Mismatch

SQL standard defines mappings between SQL and several languages

Most libraries can deal with common types

SQL types	C types	Python types
CHAR(20)	char[20]	str
INTEGER	int	int
SMALLINT	short	int
REAL	float	float

What about complex objects { x:'1', y:'hello' }

(Class) Impedance Mismatch

Programming languages usually have classes

Setting an attribute in User should save it

```
user.name = “Dr Seuss”
user.job = “writer”
```

```
class User { … }
class Employee extends User { … }
class Salaries {
    Employee worker;
    …
}
```

Object Relational Mappings designed to address this

Query Execution

How to pass values into a query?

```
Users(id int serial, name text)

name = “eugene”

conn1.execute(“““
   INSERT INTO users(name)
   VALUES(<what to put here??>)”””)
```

Query Execution

How to pass values into a query?

```
Users(id int serial, name text)
```

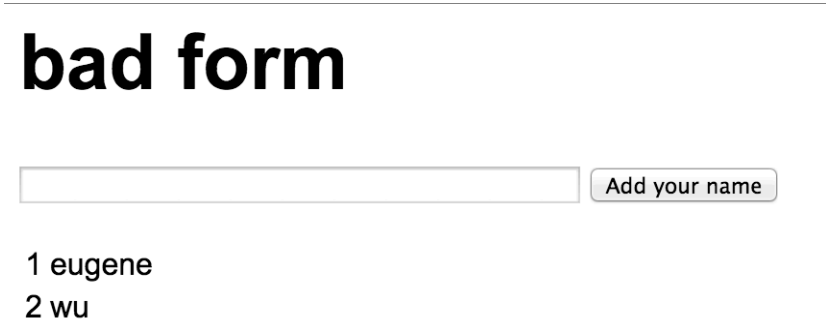
```
name = “eugene”

conn1.execute (“““
   INSERT INTO users(name)
   VALUES(‘{name}’)”””.format(name=name))
```

Why is this a *really* bad idea?

Detour: SQL Injections

http://w4111db1.cloudapp.net:8888

code on github:
syllabus/src/injection/




```
@app.route('/', methods=["POST", "GET"])
def index():
  if request.method == "POST":
    name = request.form['name']
    q = "INSERT INTO bad_table(name) VALUES('%s');" % name
    print q
    g.conn.execute(q)
```

Detour: SQL Injections

If we submit:

'); DELETE FROM bad_table; --

Query is

INSERT INTO bad_table(name) VALUES('');
DELETE FROM bad_table; -- ');

```
@app.route('/', methods=["POST", "GET"])
def index():
  if request.method == "POST":
    name = request.form['name']
    q = "INSERT INTO bad_table(name) VALUES('%s');" % name
    print q
    g.conn.execute(q)
```

Detour: SQL Injections

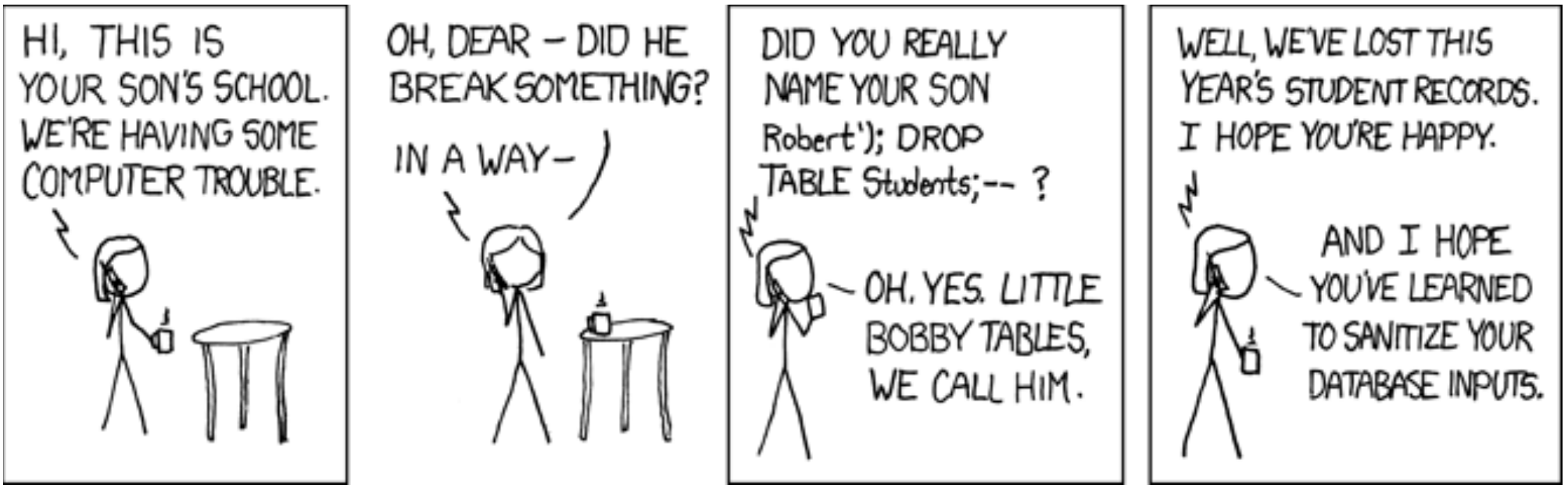
Safe implementation

Pass form values as arguments to the `execute()` function

Library sanitizes inputs automatically (and correctly!)

```
@app.route('/safe/', methods=["POST", "GET"])
def safe_index():
  if request.method == "POST":
    name = request.form['name']
    q = "INSERT INTO bad_table(name) VALUES(%s);"
    print q
    g.conn.execute(q, (name,))
```

Detour: SQL Injections



Project: You'll need to protect against simple SQL injections

More examples: https://corenumb.wordpress.com/2016/05/14/mr-robot-blind-sql-injection-vulnerability/

Query Execution

Pass *sanitized* values to the database

```
args = ('Dr Seuss', '40')
conn1.execute(
    "INSERT INTO users(name, age) VALUES(%s, %s)",
    args)
```

Pass in a tuple of query arguments

DBAPI library will *properly escape* input values

Most libraries support this

Never construct raw SQL strings

(results) Impedance Mismatch

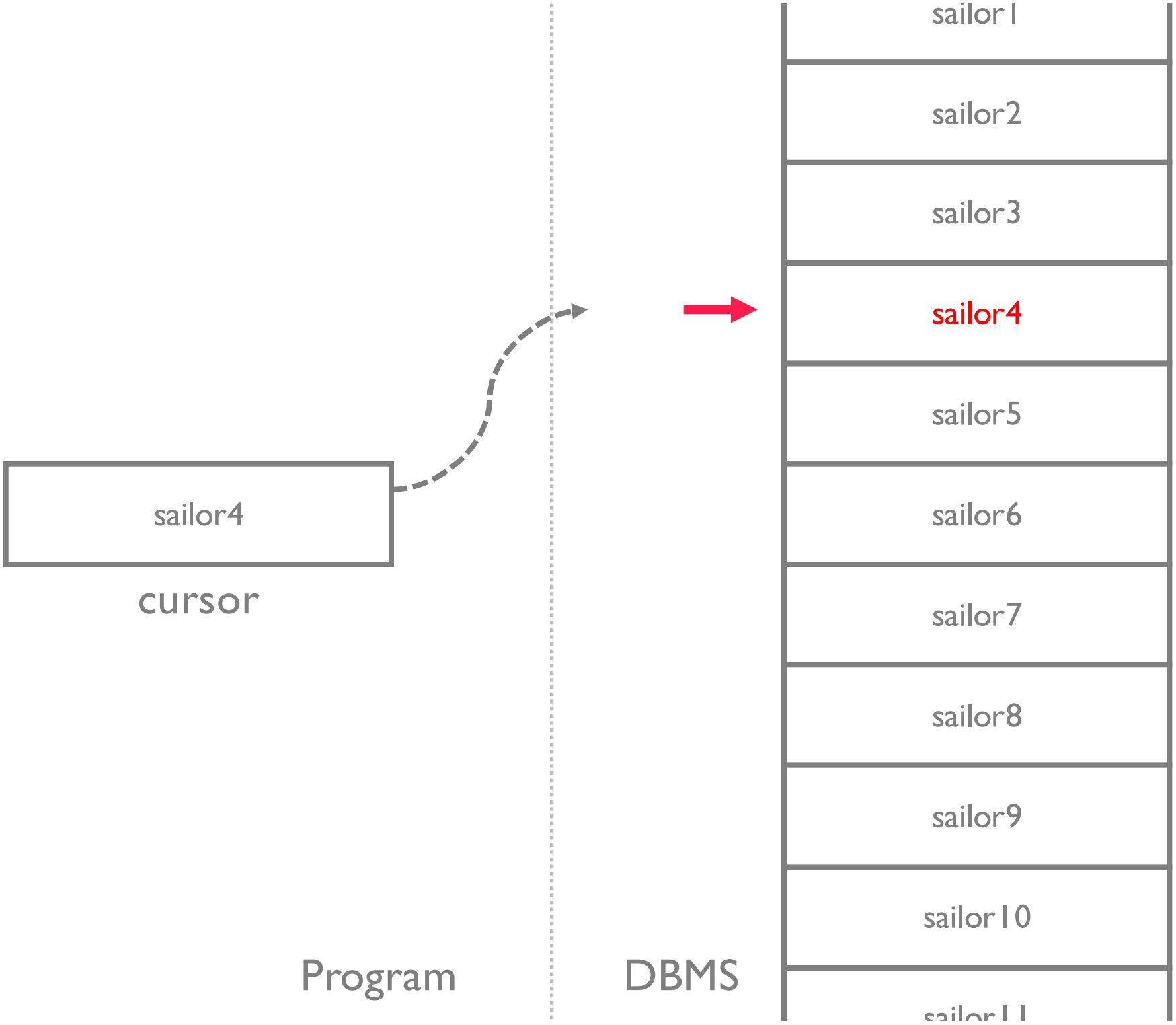
SQL relations and results are sets of records

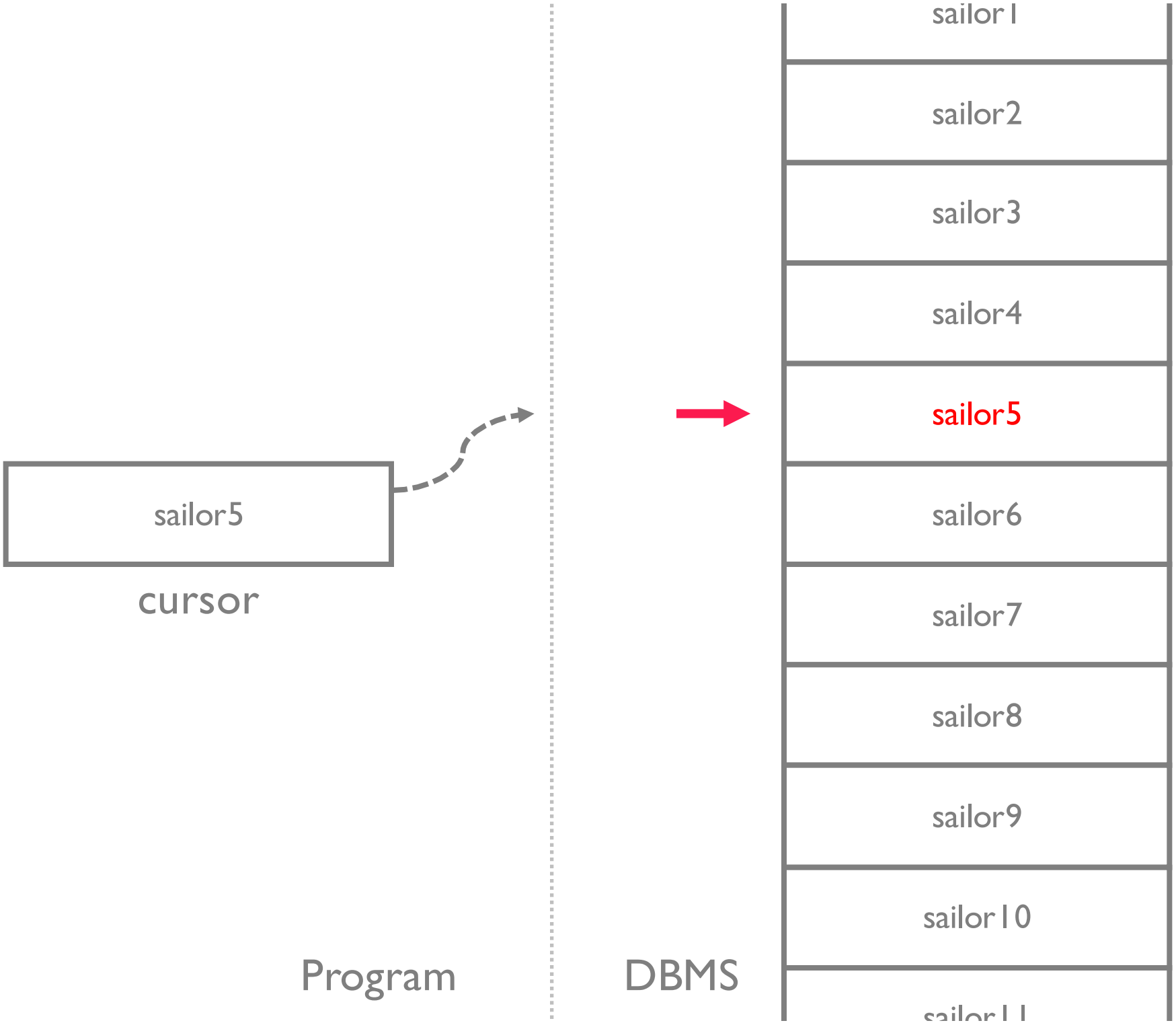
What is the type of `table`?

```
table = execute("SELECT * FROM big_table")
```

Cursor over the Result Set

- similar to an iterator interface
- Note: relations are unordered!
  - Cursors have no ordering guarantees
  - Use ORDER BY to ensure an ordering


sailor1
sailor2
sailor3
sailor4
sailor5
sailor6
sailor7
sailor8
sailor9
sailor10
sailor4
cursor
Program
DBMS


sailor1
sailor2
sailor3
sailor4
sailor5
sailor6
sailor7
sailor8
sailor9
sailor10
sailor11
sailor5
cursor
Program
DBMS

(results) Impedance Mismatch

Cursor similar to an iterator (next() calls)

```
cursor = execute("SELECT * FROM bigtable")
```

Cursor attributes/methods (logical)

```
rowcount
keys()
previous()
next()
get(idx)
```

(results) Impedance Mismatch

Cursor similar to an iterator (next() calls)

```
cursor = execute(“SELECT * FROM bigtable”)
cursor.rowcount()  # 1000000
cursor.fetchone()  # (0, ‘foo’, …)
for row in cursor: # iterate over the rest
   print row
```

Actual Cursor methods vary depending on implementation

(functions) Impedance Mismatch

What about functions?

```
def add_one(val):
   return val + 1

conn1.execute(“SELECT add_one(1)”)
```

Would need to embed a language runtime into DBMS

- Many DBMSes support runtimes e.g., python
- Can register User Defined Functions (UDFs)

(constraints) Impedance Mismatch

DB-style constraints often as conditionals or exceptions

Constraints often duplicated throughout program

JS

```
age = get_age_input();
if (age > 100 or age < 18)
    show_error("age should be 18 – 100");
```

DBMS

```
CREATE TABLE Users (
    …
    age int CHECK(age >= 18 and age <= 100)
    …
)
```

(constraints) Impedance Mismatch

Some ORMs try to have one place to define constraints

```
class Person(models.Model):
    first_name = models.CharField(max_length=30)
    last_name  = models.CharField(max_length=30, null=True)
```

```
CREATE TABLE myapp_person (
    "id" serial NOT NULL PRIMARY KEY,
    "first_name" varchar(30) NOT NULL,
    "last_name" varchar(30)
);
```

Some Useful Names

DBMS vendors provide libraries for most libraries

Two heavyweights in enterprise world

ODBC Open DataBase Connectivity

Microsoft defined for Windows libraries

JDBC Java DataBase Connectivity

Sun developed as set of Java interfaces

java.sql.*

javax.sql.* (recommended)

Modern Database APIs

DryadLinq, SparkSQL

DBMS executor in same language (dotNET, Spark) as app code

- what happens to language impedance?
- what happens to exception handling?
- what happens to host language functions?

```
val lines = spark.textFile(“logfile.log”)
val errors = lines.filter(_ startswith “Error”)
val msgs = errors.map(_.split(“\t”)(2))

msgs.filter(_ contains “foo”).count()
```

Summary

DBAPIs

- Impedance mismatch
- Cursors
- SQL injection

Some hard queries

- More in the HW

Windows are optional material

SQL Injection: only what's in slides

What to Understand

Impedance mismatch

    examples, and possible solutions

SQL injection and how to protect

The different uses of a DBAPI

Why Embedded SQL is no good

What good are cursors?