PostgreSQL, Python, and Squid.

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Let's Talk Squid.

- What *is* a squid, anyway?
- For our purposes, a squid has three attributes:
  - length — in centimeters.
  - number of tentacles.
  - weight — in kilograms.

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And of course!

- We're using PostgreSQL.
- We're using Python.
- We're using psycopg2.

So, we do something like this.

```
class Squid(object):
    def __init__(self, length, tentacles, weight):
        self.length = length
        self.tentacles = tentacles
        self.weight = weight

    def __str__(self):
        return '(' + str(self.length) + ',' +
           str(self.tentacles) + ',' +
           str(self.weight) + ')'

s = Squid(length=12.5, tentacles=4, weight=5.7)
```

And we do something like this.

```
CREATE TABLE squid (
    squid_key           bigserial primary key,
    length              float,
    tentacles           integer,
    weight              float,
    CHECK (tentacles BETWEEN 3 AND 32)
);
```

And we write something like this.

```
cur.execute(“””
   INSERT INTO squid VALUES(%s, %s, %s)
“””, [s.length, s.tentacles, s.weight] )
cur.commit()
```

And something like this.

```
cur.execute(“””
    SELECT length, tentacles, weight FROM squid
       WHERE squid_key=%s
“””, [skey])

squid_row = cur.fetchone()

squid = Squid(length=squid_row[0],
   tentacles=squid_row[1],
   weight=squid_row[2])
```

And we're done.

- Well, that was a short presentation.
- But now, we want two different tables with Squid in them.
- That's OK, we just replicate the schema…

Like this...

```
CREATE TABLE atlantic_squid (
    squid_key           bigserial primary key,
    length              float,
    tentacles           integer,
    weight              float,
    CHECK (tentacles BETWEEN 3 AND 32)
);

CREATE TABLE pacific_squid
    (LIKE atlantic_squid INCLUDING ALL);
```

And then we write something like...

```
cur.execute(
   “INSERT INTO “ + ocean + “_squid VALUES(%s, %s, %s)”,
   [s.length, s.tentacles, s.weight] )
cur.commit()
```

And at this point, we think...

- Wait, PostgreSQL has types!
- Maybe we can use PostgreSQL's custom type facility.

But then you think...

- Oh, only big packages like PostGIS do stuff like that.
- We have to write C and PL/pgSQL and probably Scheme and Erlang for all we know.
- And how about operators? And indexing?
- Not for the likes of us Python people.

You would be wrong!

- It's easy to create custom types in PostgreSQL.
- You can use custom PostgreSQL types in your application without much nasty code.
- You can write functions in the PostgreSQL database in Python.

PostgreSQL Custom Types.

- PostgreSQL has an extensive type system.
- You can create your own types.
  - High-level aggregate types (structures of existing types).
  - Low-level C-language types.
    - Not today.

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Declaring an aggregate type.

- Any time you declare a table, you also get a type with the same name and same structure.
- You can also just create a type without creating a new table.

Like this!

```
CREATE TYPE squid AS (
    length      float,
    tentacles   integer,
    weight      float
);
```

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That's great, but...

- How do we get that custom type into and out of Python?
- psycopg2 has facilities for going both directions.
- Once set up, it Just Works.

Squids into the Database!

```
class Squid(object):

    #...

    def __conform__(self, protocol):
        if protocol is psycopg2.extensions.ISQLQuote:
            return self

    def getquoted(self):
        return "'" + str(self) + "'::squid"
```

ISQLQuote Protocol

- Implement __conform__ and getquoted.
- __conform__ returns the object that implements getquoted.
  - You can just return self.
- getquoted returns the object converted into "SQL quoted format."

What's "SQL Quoted Format"?

- Generally, it's just a string.
- Any internal quotes need to follow the SQL quoting conventions.
- Custom types are serialized into strings.
- Aggregate types are enclosed in parens, with fields separated by commas.

For squids, it's easy.

- We just use the string representation, since there are no fields that might contain quotes.
  - If there were, you could just call the appropriate getquoted method on them.
- We wrap the whole thing in SQL string quotes, and add a '::squid' cast to it.

Other People's ~~Children~~ Classes

- What if we didn't write the class?
  - `psycopg2.extensions.register_adapter(class, adapter)`
- The adapter function takes the object, returns a object that implements getquoted.
- If the str() of the object is fine, you can use AsIs to just return that.

We can create a table like this...

```
CREATE TABLE squids (
    squid_key       bigserial primary key,
    a_squid         squid
);
```

... and insert into it like this!

```
s = Squid(length=12.5, tentacles=4, weight=5.7
cur.execute("INSERT INTO squids(a_squid) VALUES(%s)",
   [s,])
```

But how do we get the squids out?

- Need to write a cast function.
- Takes the string representation from the database, and returns the object.
- We then register that function with psycopg2.

Now you have two problems.

```
def cast_squid(value, cur):
    if value is None:
        return None

    match_object = re.match(r'\((?P<length>[0-9.]+),(?P<tentacles>[0-9]+),
(?P<weight>[0-9.]+)\)', value)
    if match_object is None:
        return None

    length = float(match_object.group('length'))
    tentacles = int(match_object.group('tentacles'))
    weight = float(match_object.group('weight'))

    return Squid(length=length, tentacles=tentacles, weight=weight)
```

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And then we register it.

```
SQUID = psycopg2.extensions.new_type((72007,),
   "squid", cast_squid)
psycopg2.extensions.register_type(SQUID)
```

Not so fast. 72007?

- That's the OID for the Squid type in *this particular* PostgreSQL database.
  - All database schema objects have an OID.
- It's different for every database that we create that type in.
- Changes if you restore the database from a pg_dump.

How do we get it?

```
cur.execute("SELECT NULL::Squid")
squid_oid = cur.description[0][1]
  # Can be executed once and cached.
```

And now SELECT works.

```
>>> cur.execute("SELECT a_squid FROM squids")
>>> s = cur.fetchone()[0]
>>> print s.__class__
<class '__main__.Squid'>
```

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OK, but...

- What happened to our CHECK constraint?
- We don't want mutant squids getting into our database.

- We could write a trigger…
  - … but we don't want to write PL/pgSQL.

We don't have to!

- PL/Python!
- We can write our triggers and other functions in Python.
- The functions run in the PostgreSQL backend just like any other server-side code.

Great! Sign me up!

- PL/Python isn't part of a database by default.
- `CREATE LANGUAGE plpythonu;`
- The "U" means Untrusted.
  - Can bypass PostgreSQL's access control system.
- Only superusers can create functions.

It didn't like that.

- If you are using a package, make sure you have installed the appropriate -contrib package.
- If you are building from source, make sure you build with the --with-python option.

Python 2? Python 3?

- PostgreSQL supports both.
- “plpython2u” “plpython3u”
- “plpythonu” gets you Python 2 right now, but might get you Python 3 in the future.
  - The far, far future.

Same syntax as any function.

```
CREATE OR REPLACE FUNCTION hello_world() RETURNS bool AS
$hello_world$

plpy.notice(“Hello, squids of the world!”)
return True
$hello_world$
  LANGUAGE plpythonu;
```

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And called the same.

```
squidy=# select hello_world();
NOTICE:  Hello, squids of the world!
CONTEXT:  PL/Python function "hello_world"
 hello_world
-------------
 t
(1 row)
```

Notes.

- Don't declare a function body; PL/Python wraps it for you.
- Can call any installed Python package, but:
- Cannot directly call any other stored procedure, in any language.
- Use the SPI for that.
- Module plpy contains that stuff.

One tentacle at a time, please.

- The PostgreSQL backend is single-threaded.
- Do not spawn threads within your PL/Python function.
- If you break it, you get to keep all the pieces.

So, let's create our trigger!

```
CREATE OR REPLACE FUNCTION squid_trigger() RETURNS trigger AS
$squid_trigger$

    from plpy import spiexceptions

    calamari = TD["new"]["a_squid"][1:-1].split(',')

    tentacles = int(calamari[1])

    if tentacles > 32 or tentacles < 3:
        raise spiexceptions.CheckViolation

    return "OK"
$squid_trigger$
    language plpythonu;
```

Calamari appetizer.

- In the TD structure, composite types are their string representation.
- In parameters to non-trigger stored procedures, they are passed (more logically) as hashes.

Now, we attach the trigger!

```
CREATE CONSTRAINT TRIGGER squid_trigger
    AFTER INSERT OR UPDATE OF a_squid ON squids
    NOT DEFERRABLE
    FOR EACH ROW EXECUTE PROCEDURE squid_trigger();
```

Eldritch Monstrosities Avoided.

```
squidy=# INSERT INTO squids(a_squid)
VALUES( (100, 47, 4.5)::squid );
ERROR:  spiexceptions.CheckViolation:
CONTEXT:  Traceback (most recent call last):
  PL/Python function "squid_trigger", line
10, in <module>
    raise spiexceptions.CheckViolation
PL/Python function "squid_trigger"
```

The Null Squid Hypothesis.

- Row types have strange rules around NULL.
  - `(1.0, NULL, 1.0)::squid IS NULL;`
    - `True.`
  - `(1.0, NULL, 1.0)::squid IS NOT NULL;`
    - `Also true!`
- NULL is a never-ending source of delight.

The Elusive Squid.

```
 Seq Scan on squids  (cost=0.00..253093.09
rows=50000 width=53) (actual
time=6.917..2590.863 rows=1012 loops=1)
   Filter: (((a_squid).length >= 100::double
precision) AND ((a_squid).length <=
101::double precision))
   Rows Removed by Filter: 9998989
 Total runtime: 2591.113 ms
```

Squid total ordering.

- Squids are ordered by length, and nothing else.
  - That's just how squids roll.
- Can we speed up searching?
- Yes! We can create B-Tree indexes on custom types.

Defining ordering.

```
CREATE OR REPLACE FUNCTION squid_comp (left squid, right
squid)
   RETURNS int as
$squid_comp$
    if left["length"] < right["length"]:
        return -1
    elif left["length"] > right["length"]:
        return 1
    else:
        return 0

$squid_comp$
   LANGUAGE plpythonu
   IMMUTABLE STRICT;
```

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Defining Operators

```
CREATE OR REPLACE FUNCTION squid_eq (left squid, right squid)
  RETURNS bool AS
$squid_eq$

    return left["length"] == right["length"]

$squid_eq$
   LANGUAGE plpythonu
   IMMUTABLE STRICT;
```

Defining Operators

```
CREATE OPERATOR = (
    LEFTARG = squid,
    RIGHTARG = squid,
    PROCEDURE = squid_eq,
    COMMUTATOR = =,
    NEGATOR = <>,
    RESTRICT = eqsel,
    JOIN = eqjoinsel,
    HASHES, MERGES
);
```

Defining Operators

```
CREATE OPERATOR <= (
    LEFTARG = squid,
    RIGHTARG = squid,
    PROCEDURE = squid_le,
    COMMUTATOR = >=,
    NEGATOR = >,
    RESTRICT = scalarltsel,
    JOIN = scalarltjoinsel
);
```

Finally, an operator class...

```
CREATE OPERATOR CLASS squid_ops
    DEFAULT FOR TYPE squid USING btree AS
        OPERATOR        1       < ,
        OPERATOR        2       <= ,
        OPERATOR        3       = ,
        OPERATOR        4       >= ,
        OPERATOR        5       > ,
        FUNCTION        1       squid_comp(squid, squid);
```

And then, Squidex!

```
CREATE INDEX squidex ON squids(a_squid);
```

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Jet Propulsion!

```
Bitmap Heap Scan on squids  (cost=2176.56..113217.70
rows=50000 width=53) (actual time=10.991..12.367 rows=1012
loops=1)
   Recheck Cond: ((a_squid >= ROW(100::double precision, 4,
100::double precision)::squid) AND (a_squid <= ROW(101::double
precision, 4, 100::double precision)::squid))
   ->  Bitmap Index Scan on squidex  (cost=0.00..2164.06
rows=50000 width=0) (actual time=10.866..10.866 rows=1012
loops=1)
         Index Cond: ((a_squid >= ROW(100::double precision,
4, 100::double precision)::squid) AND (a_squid <=
ROW(101::double precision, 4, 100::double precision)::squid))
 Total runtime: 12.463 ms
```

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Thanks for all the seafood.

- We can implement a custom type in PostgreSQL that integrates nicely with a Python class.
- … without losing any database features.
- … and those types can even have custom operators and comparisons.
- … and their own indexes!

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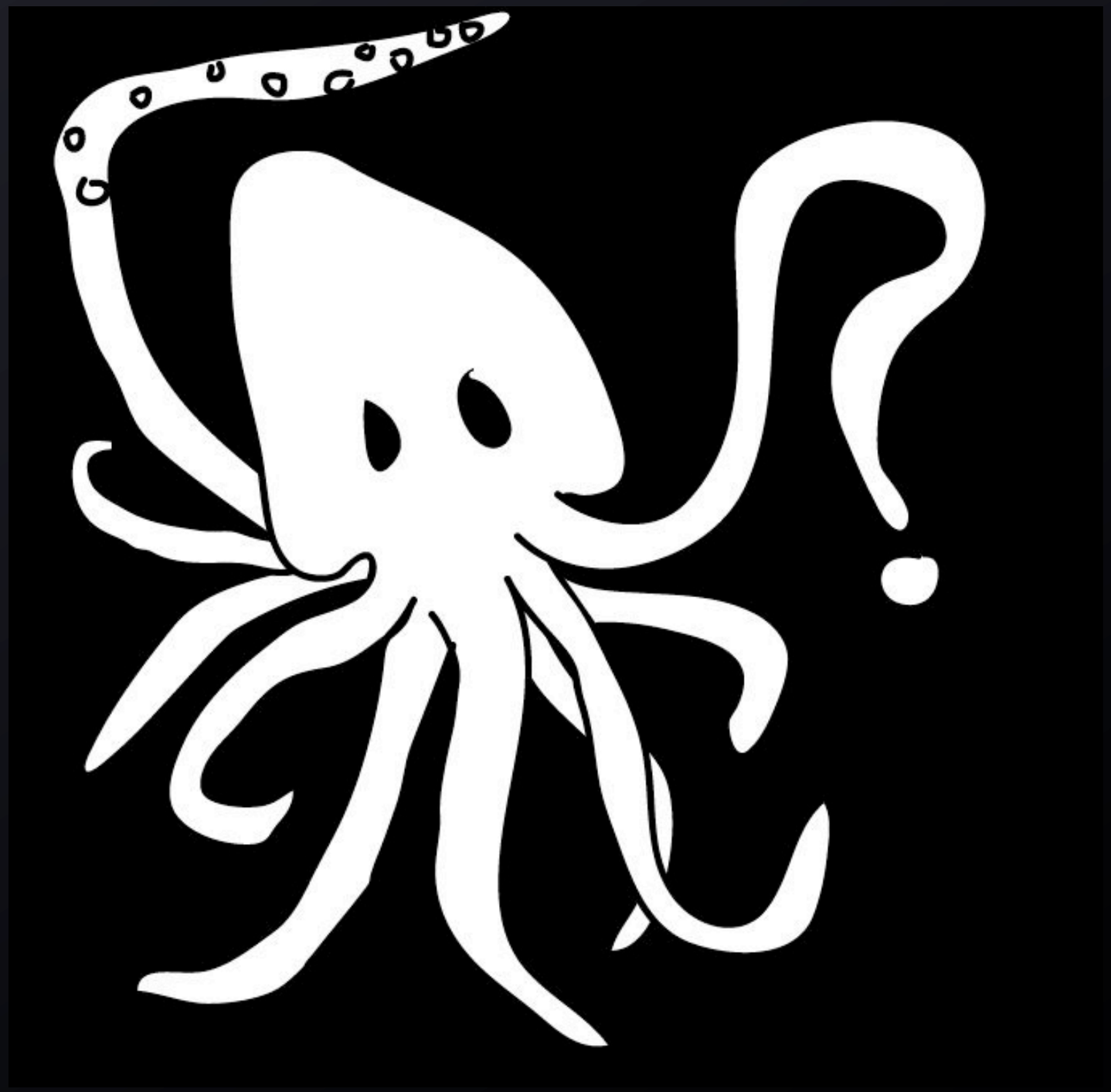
I'm allergic to shellfish.

- This works with lots of stuff.
  - Range types, citext…
- Any time you have an advanced attribute type that you want to adapt to Python.
  - Whether or not you defined the type.
- Not just for squid anymore!

Questions?



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Thank you!

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