Software detective

Python in security research

Przemek Samsel, 19.08.25

Whoami

- Przemek
- Tietoevry
- Network security

Agenda

- github.com/cheshie/code-analysis
- Security research
- Methodology
- Techniques
- Tools
- Case study

Security Research

What is it

- Understand digital threats & attacks
- Discover vulnerabilities
- Improve system defenses

Security Research

Why is it important

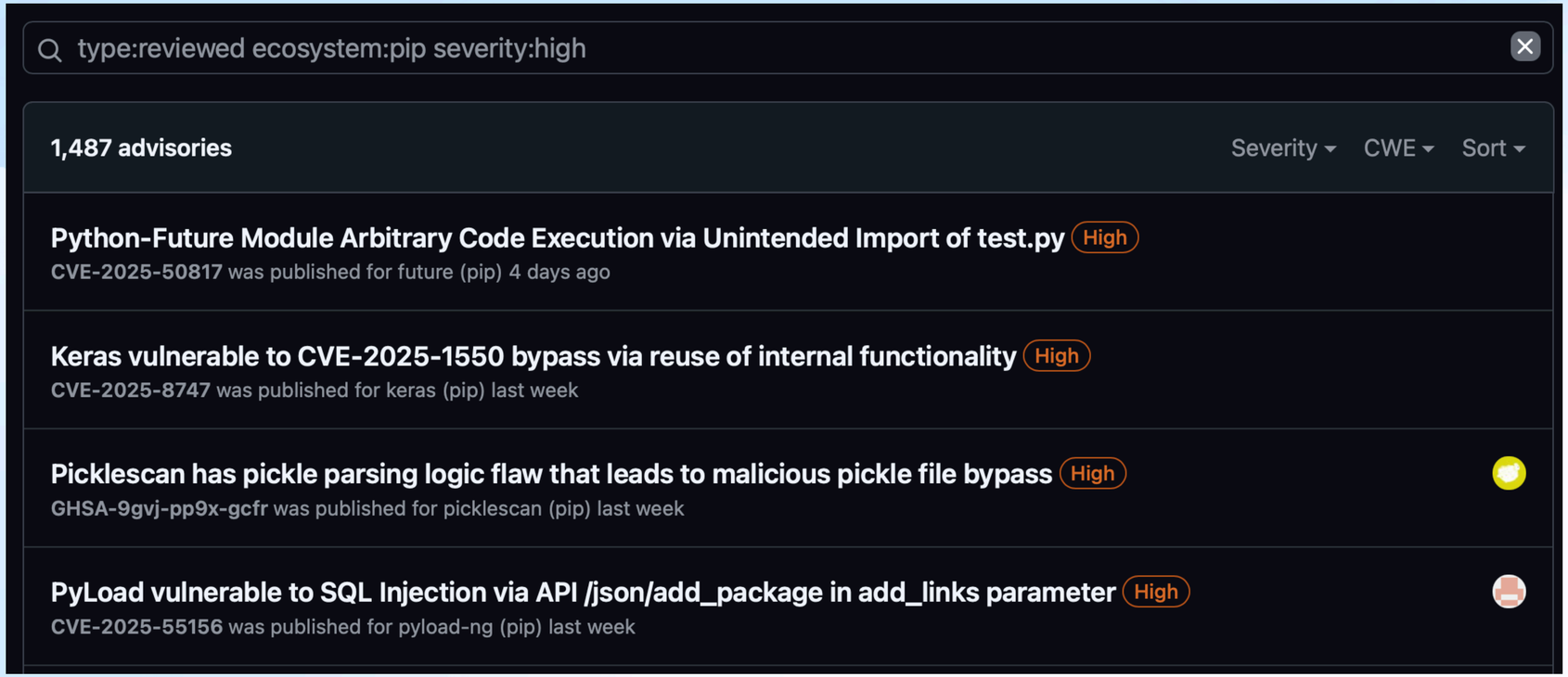
- CVE-2025-47273
- setuptools (pip) v78.1
- Impact: write to arbitrary files (with python permission)

```
def _download_url(self, url, tmpdir):
    # Determine download filename
    name, _fragment = egg_info_for_url(url)
    if name:
      while '..' in name:
        name = name.replace('..',
'.').replace('\\', '_')
    else:
    ...
       filename = os.path.join(tmpdir, name)
```

Security Research

Why is it important

- https://github.com/advisories



Security Research

How to start

- **Build knowledge**

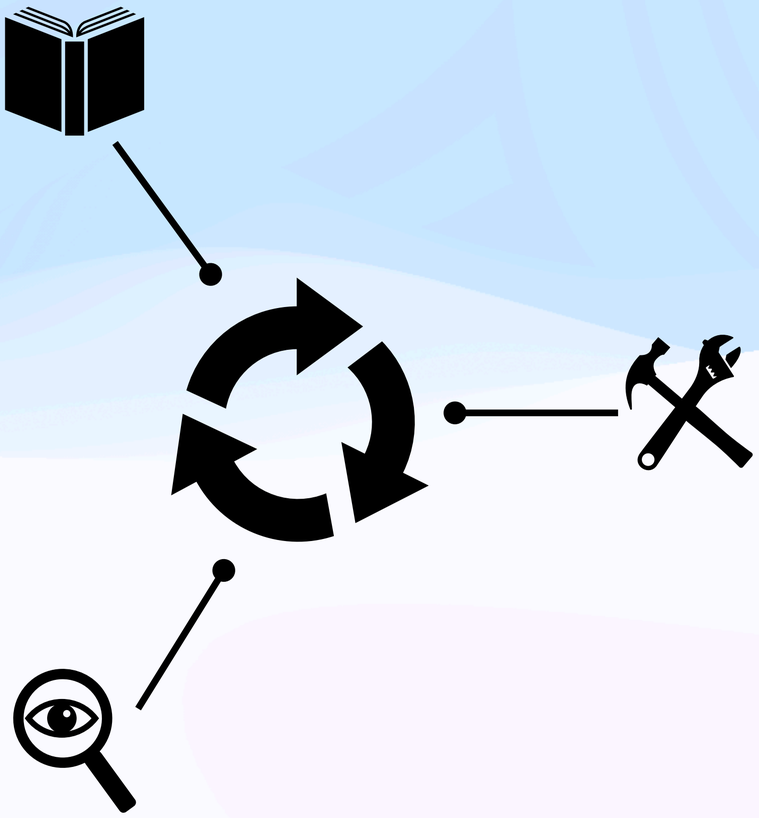
  Read published research, experiment

- **Learn codebase**

  Use software, understand code

- **Refine skills**

  Solve challenges, identify patterns



Methodology

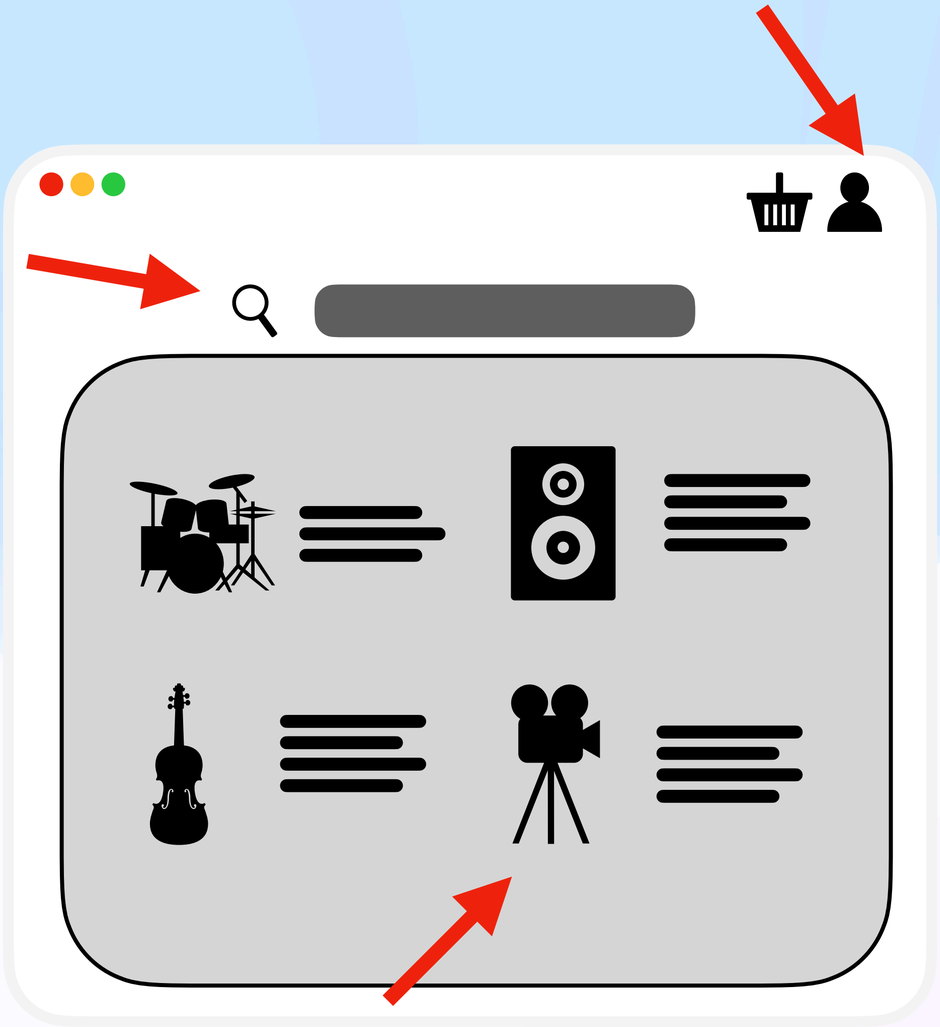
How to approach

- User interaction
- Threat model
- Attack scenarios

```
import ...

def list_products():
 ...

def add_to_basket():
 ...

def archive_product():
 ...
```

Methodology

- **User interaction**
- Threat model
- Attack scenarios



Methodology

- User interaction
- **Threat model**
- Attack scenarios

Can I…

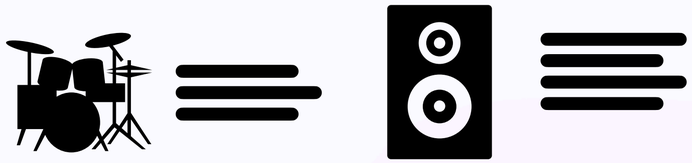
list hidden products?

list other information?

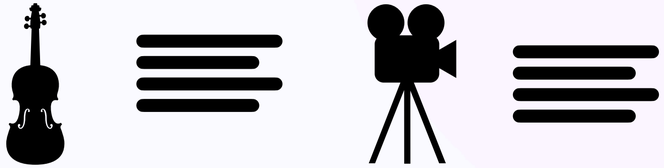
Change my data without password?

Access other users?

Modify products?



Change price?



Access basket of another user?

Methodology

- User interaction
- Threat model
- **Attack scenarios**

User account

Change email address ➡ Requires password?

Access user information ➡ Requires authorization?

Provide invalid login ➡ Descriptive error?

Search products

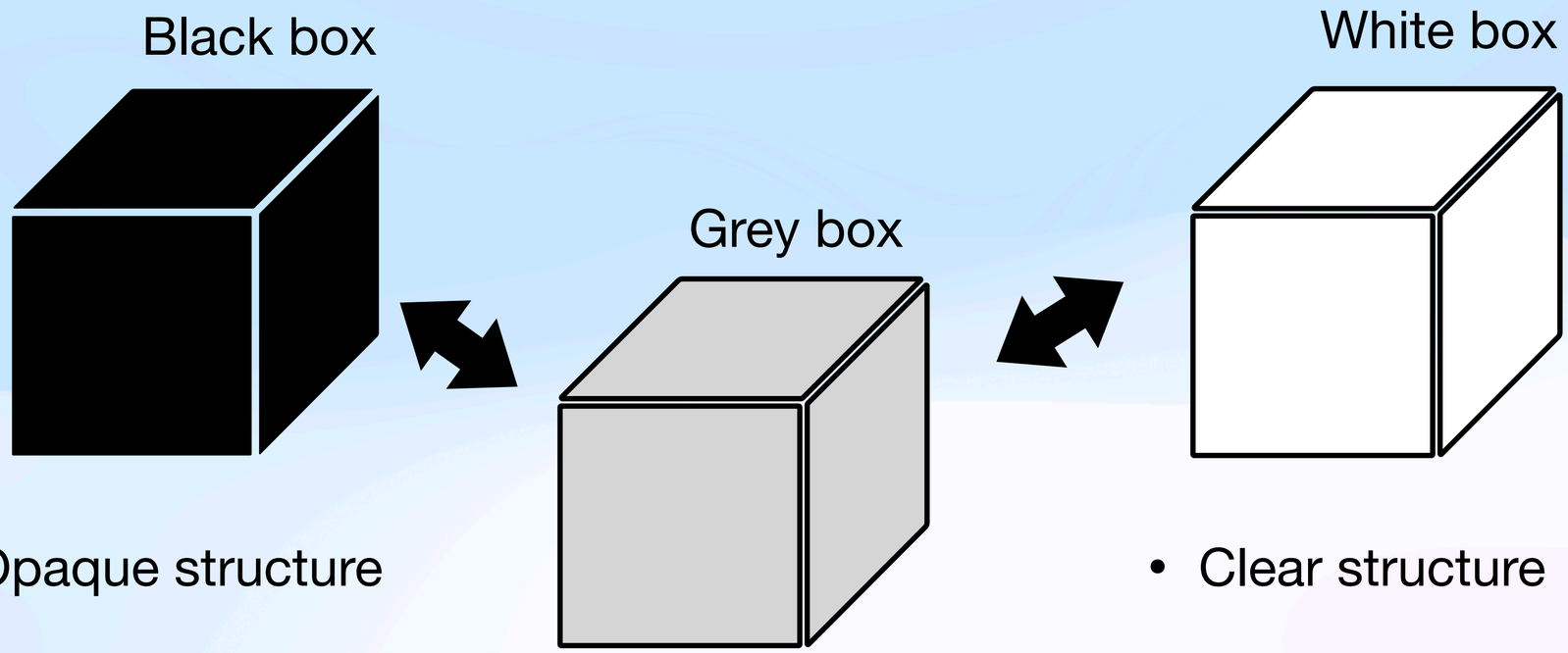
Use special characters ➡ Affects query results?

Purchase products

Change price in basket ➡ Are changes reflected?

Methodology

Two perspectives



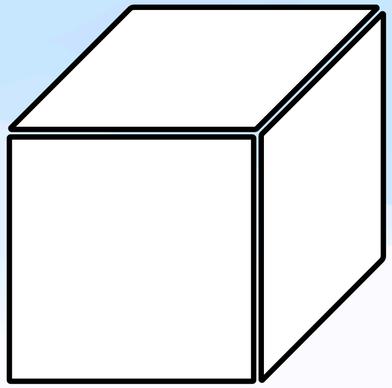
- Opaque structure
- Input/output
- Interaction

- Clear structure
- Deeper insight
- Functionality

Methodology

```
import ...

def list_products():
 ...

def add_to_basket():
 ...

def archive_product():
 ...
```

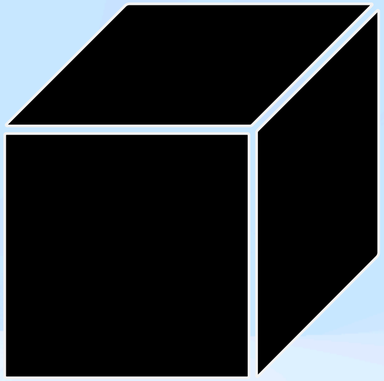
White box



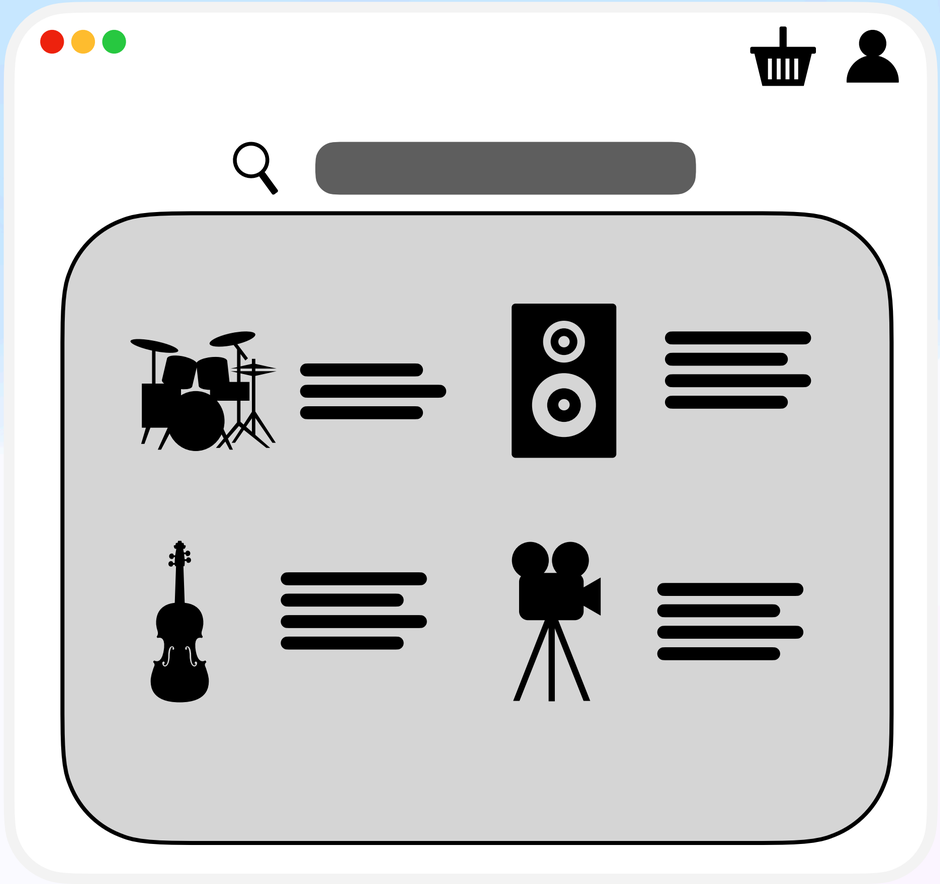
- Clear structure
- Deeper insight
- Functionality

Methodology

Black box



- Opaque structure
- Input/output
- Interaction



Techniques

What to use

DAST

Dynamic Application Security Testing

SAST

Static Application Security Testing

Techniques

DAST

Dynamic Application Security Testing

Activities

- Behavioral analysis
- Fuzzing
- Instrumentation

Tools

- BurpSuite
- Fuzzotron
- Frida

Techniques

Activities

- Code review
- Signature analysis
- Analyze Abstract Syntax Tree (AST)

Tools

- CodeQL
- Semgrep
- Bandit
- Nuclei

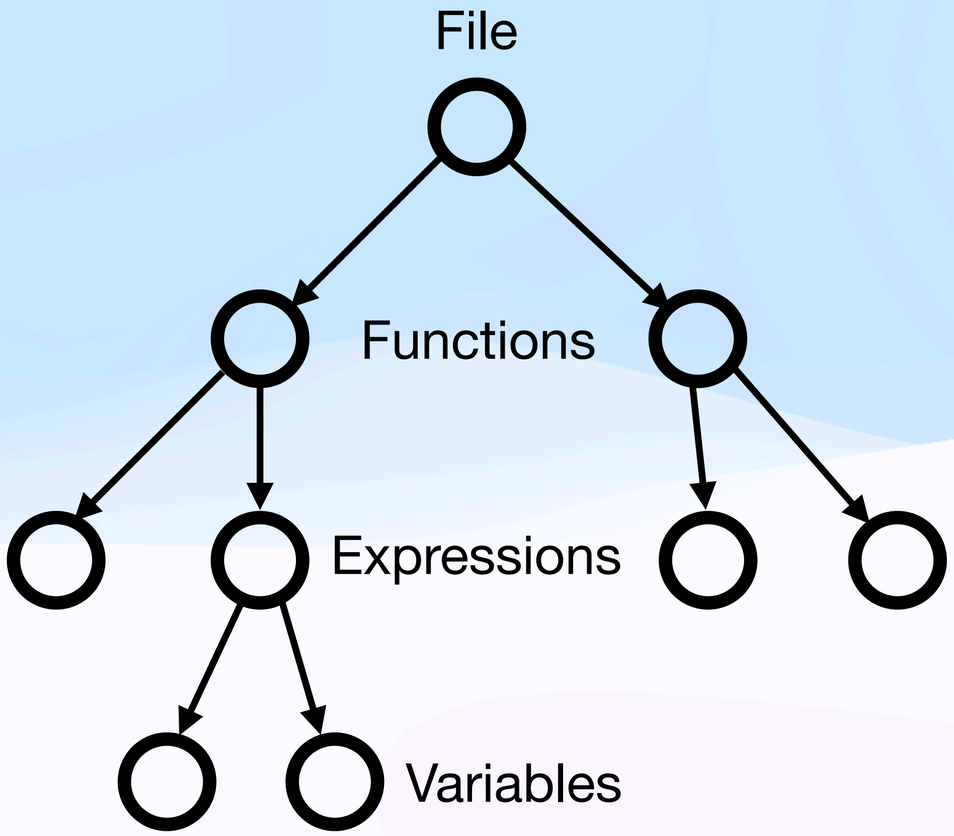
SAST

Static Application Security Testing

Abstract Syntax Trees

Basic information

- Data structure
- Graphical representation
- Abstract syntactic structure
- Used in compilers



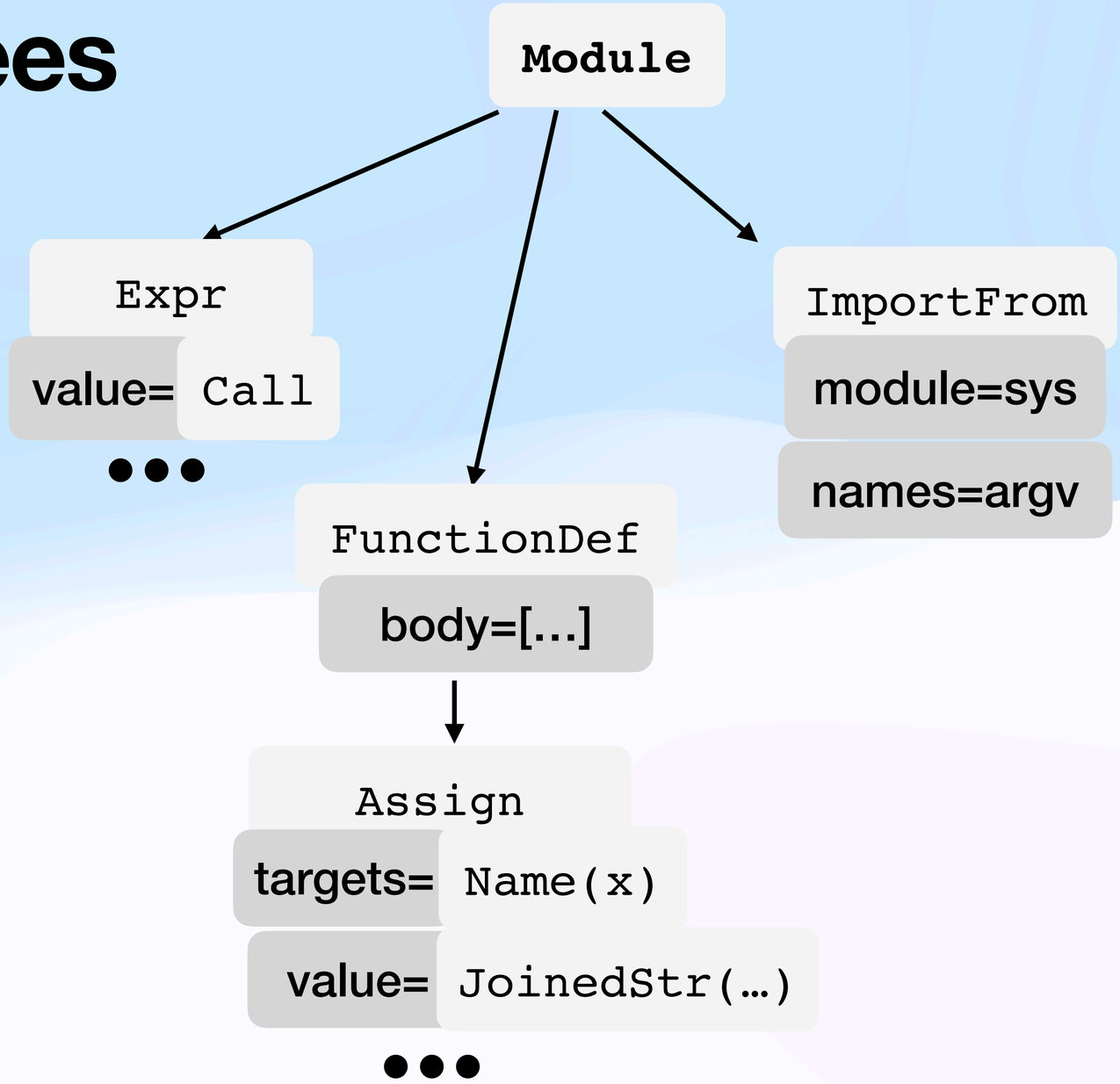
Abstract Syntax Trees

- Data structure
- Graphical representation
- Abstract syntactic structure
- Used in compilers

```
from ast import parse, dump
from sys import argv


file = open(argv[1])
tree = parse(file.read())
print(dump(tree, indent=2))
```

Abstract Syntax Trees

```
1 from sys import argv
2
3 def hello(name):
4     x = f"hello {name}!"
5     return x
6
7 print(hello(argv[1]))
```



Abstract Syntax Trees

Exercise

Exercises/ex1.py

```
1 from this import s
2
3 words = [x for x in s.split()]
4 print(len(words))
```

```
$ get_ast.py Exercises/ex1.py
```

Bandit

Overview

- Open-source security linter for Python
- Builds AST -> checks against set of defined plugins
- Active, occasionally updated, several open issues
- http://bandit.readthedocs.io/

Install

```
$ python -m venv bvenv
$ source bvenv/bin/activate
(bvenv)$ pip install bandit
```

Bandit

Basic use

- List default plugins
- Run plugins for specific issue type
- Run specific plugin

```
$ bandit -r file.py
```

```
$ bandit -r file.py -s MEDIUM
```

```
$ bandit -r file.py -t B703
```

Bandit

Implementation

- Process target file -> build AST -> run set of plugins against nodes
- Uses a variant of the NodeVisitor (bandit/core/node_visitor.py) paradigm
- Reporting vulnerabilities, categorizing their impact and filtering (bandit/core/issue.py)

Bandit

Plugins

- Rules are written with Python using the Bandit API
- Default - reports severity levels of medium and higher
- Use `# nosec` on line above specific issue to ignore it

```
Test results:
Issue: [<ID>] Use of weak MD5 for hashing.
    Severity: Low
    Confidence: High
   Location: example.py:5
   More Info: https://bandit.readthedocs.io/plugins/...
   MD5 is a known broken hash algorithm. Avoid using it.
```

Bandit

Plugins

Bandit informs user about vulnerabilities as follows

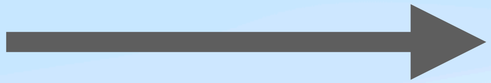
- **File path** - Python file where the issue was detected
- **Line number** - where the issue is located
- **Test ID** - plugin unique identifier related to vulnerability type
- **Severity** - severity level of the issue (low, medium, high)
- **Confidence** - if issue is actually a security problem (low, medium, high)
- **Message** - brief description of the security issue

SQL Injection

SQL Injection

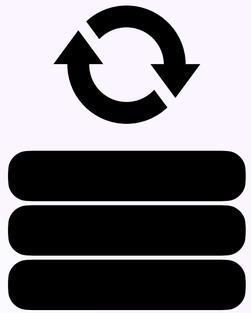
Database query

SELECT * **FROM** Products **WHERE** name = "**Guitar**"



1	Guitar	Music	200

ID	Name	Category	Price
1	Guitar	Music	200
2	Bow	Sport	500
3	Desk	Furniture	800
…	…	…	…



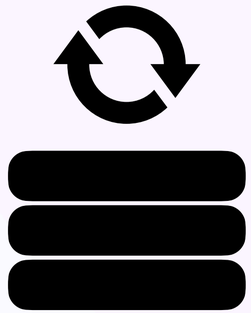
SQL Injection

Attack idea

SELECT * **FROM** Products **WHERE** name = "**" OR 1=1;-- "**

List of all products…

ID	Name	Category	Price
1	Guitar	Music	200
2	Bow	Sport	500
3	Desk	Furniture	800
...	…	…	…

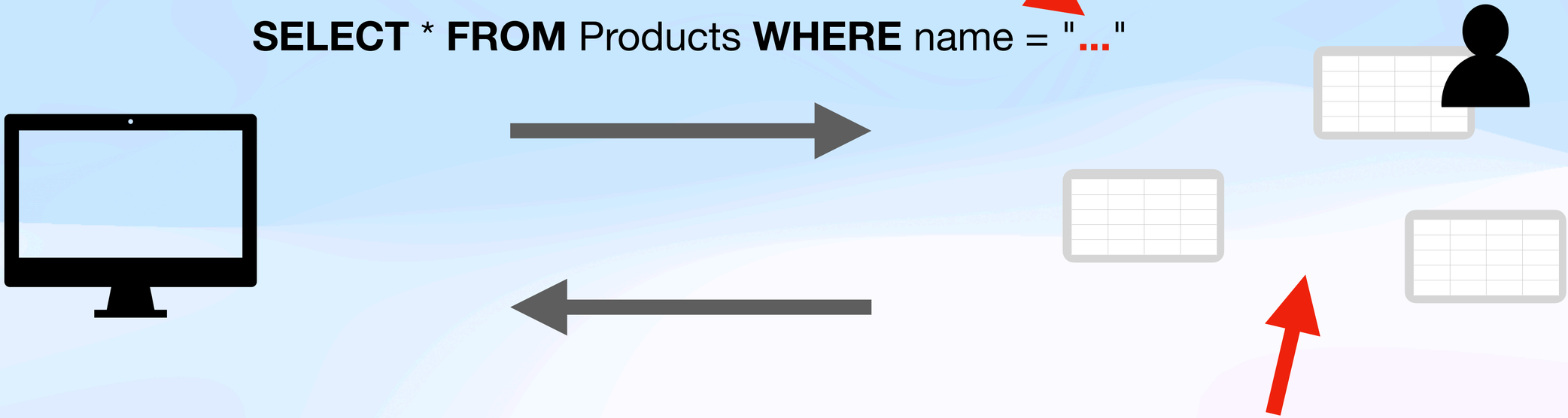


SQL Injection

Effects

Complex queries

SELECT * **FROM** Products **WHERE** name = "**...**"



Access other tables

SQL Injection

Vulnerable implementation

```
@app.route('/product', methods=['GET'])
def products():
    name = request.form['name']
    conn = get_db_connection()
    products = conn.execute(
     "SELECT * FROM products WHERE product_name = '"+name+"'"
    ).fetchall()
    conn.close()
    ...
```

Bandit

Detection

1. Evaluate AST - find instances of string concatenation
2. Extract string statement, compare to regular expression
3. Check methods that use specific statement

Bandit

1. Evaluate AST - find instances of string concatenation

```
def _evaluate_ast(node):
    if isinstance(node._bandit_parent, ast.BinOp):
        ...
    elif isinstance(
        node._bandit_parent, ast.Attribute
    ) and node._bandit_parent.attr in ("format", "replace"):
        ...
    elif hasattr(ast, "JoinedStr") and isinstance(
        node._bandit_parent, ast.JoinedStr
    ):
       ...
```

Bandit

```
conn.execute("SELECT * FROM products WHERE product_name = '"+name+"'")
```

```
if isinstance(node._bandit_parent, ast.BinOp):
    out = utils.concat_string(node, node._bandit_parent)
    wrapper = out[0]._bandit_parent
    statement = out[1]
```

node → SELECT * FROM products WHERE product_name = '

node->parent → ast.BinOp (ast.Add)

wrapper → ast.Call (execute)

statement → "SELECT * FROM products WHERE product_name = ' '"

Bandit

2. Extract string statement, compare to regular expression

```
SIMPLE_SQL_RE = re.compile(
    r"(select\s.*from\s|"
    r"delete\s+from\s|"
    r"insert\s+into\s.*values\s|"
    r"update\s.*set\s)",
    re.IGNORECASE | re.DOTALL,
)


def _check_string(data):
    return SIMPLE_SQL_RE.search(data) is not None
```

Bandit

3. Check methods that use specific statement

```
if isinstance(wrapper, Call):
    names = ["execute", "executemany"]
    name = utils.get_called_name(wrapper)
    return (name in names, statement, str_replace)
else:
    return (False, statement, str_replace)
```

Bandit

```
@test.checks("Str")
@test.test_id("B667")
def hardcoded_sql_expressions(context):
  execute_call, statement, str_replace = _evaluate_ast(context.node)
  if _check_string(statement):
        return bandit.Issue(
            severity=bandit.MEDIUM,
            confidence=(
                bandit.MEDIUM
                if execute_call and not str_replace
                else bandit.LOW
            ),
            cwe=Cwe.SQL_INJECTION,
            text="Possible SQL injection ...")
```

Add own plugins

Bandit

Plugin structure

- **context** (bandit/core/context.py) - object of analysis
- **helper tools** (bandit/core/utils.py) - make evaluation of AST nodes
- @checks (bandit/core/test_properties.py) - determine type of AST node

```
import …

@test.checks("<AST TYPE>")
@test.test_id("B###")
def main_check(context):
  if ...:
    return Issue(
                    severity=bandit.LOW,
                    confidence=bandit.HIGH,
                    cwe=Cwe.###,
                    text=f"Vulnerable ...")
```

Bandit

Context

Main object of analysis

- Function properties *(name, arguments, keywords, named argument)*
- Import properties *(is it imported name? is it aliased?)*
- AST node
- Bytes representation
- File-related properties

Bandit

Python package

```
bandit_plugin
├── bandit_plugin
│   ├── init.py
│   └── myplugin.py
└── setup.py
```

```
from setuptools import setup

setup(
    name='bandit_plugin_test',
    version='0.0.1',
    description='...',
    packages=['bandit_plugin'],
    author='',
    install_requires=['bandit'],
    entry_points={
        'bandit.plugins': [
            'os_getcwd =
bandit_plugin.myplugin:function',
        ],
 })
```

Bandit

Adding plugin

- Create plugin module
- Add test ID -> @test_properties.test_id
- Install local package
- Provide plugin ID to use it
- Modify installed package

```
$ python -m pip install ./bandit_plugin
```

```
$ bandit -t B### -f custom <file.py>
```

```
bvenv/lib/python3.13/site-packages/bandit/plugins/
```

Exercises

Bandit

Future plans

- Extend plugin coverage
- Introduce taint tracking
- Implement VS Code plugin

Bandit

Plugins

ID	Description	Count	Examples	CWE
B1xx	misc tests	13	hardcoded credentials, unsafe functions	CWE-703, CWE-78, CWE-732
B2xx	misconfiguration	2	configuration, archive extraction	CWE-94, CWE-22
B3xx/B4xx	blacklists (calls/ imports)	1	Insecure cryptography	CWE-327
B5xx	cryptography	9	Insecure configuration, missing validations	CWE-295, CWE-327, CWE-326
B6xx	injection	15	code injection	CWE-78, CWE-89, CWE-94
B7xx	XSS	4	Cross-Site Scripting	CWE-94

Static analysis tools

Comparison

Bandit	Semgrep	CodeQL
Open source	Open source	Closed source
Python API	YAML	Free for research
<50 plugins	~350 rules	~50 queries

GitHub - Python CodeQL queries

Semgrep - Python security rules

Bandit - security plugins

Summary

- Security research aims to discover software vulnerabilities
- Whitebox - focus on code structure
- AST - code structure visualisation
- Static analysis provides helps to analyze relationships between code entities

References

Security research

- https://portswigger.net/research/top-10-web-hacking-techniques-of-2024
- https://www.offsec.com/blog/
- https://blog.trailofbits.com/
- https://pagedout.institute/

Security tutorials

- https://tryhackme.com/careers/quiz/
- https://portswigger.net/web-security
- https://www.hackthebox.com/

Security research

- https://github.blog/security/vulnerability-research/codeql-zero-to-hero-part-4-gradio-framework-case-study/
- https://github.blog/security/vulnerability-research/cybersecurity-researchers-digital-detectives-in-a-connected-world/

Thank you