Chasten Your Python Program: Configurable Program Analysis and Linting with XPath

Gregory M. Kapfhammer

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Access resources during the talk!

Scan the QR code to follow along

What is chasten? Why did we build it?

- Configurable **program analysis** and **linting** with XPath expressions
  - Avoid a unique performance anti-pattern?
  - Confirm the use of a new coding style?
  - Nervous about writing custom AST visitors?
  - Need configuration and data storage of results?

Chasten helps you automatically detect patterns in Python programs

Developers

- Project-specific checks
- Avoid code anti-patterns
- Facilitate code reviews

Students

- Explore different code style
- Avoid performance problems
- Confirm project criteria

Researchers

- Count code patterns
- Measure code quality
- Easily share results

Educators

- Give early feedback on code style
- Enforce assignment requirements
- Support use on laptops and in CI

Example: students and educators using `chasten` for a Python project

- Students may struggle to write **efficient** and **readable** Python code
- Manual review by instructors is **time-consuming** and **error-prone**
- Regex is **brittle** and AST-based tools are **hard to prototype**

Project Goal: `chasten` enables **scalable** and **structure-aware** feedback that effectively **supports** both **instructors** and **students**

Take a Step Back: Before diving into the implementation of `chasten`, it's worth surveying the landscape of **linting** and **checking**

Many Trade-Offs: Different tools with varying implementation, features, performance, and extensibility! Which one(s) to pick?

Building a source code analyzer! What are the options and trade-offs?

Regular Expressions

- Easy to write and try out
- Often brittle and confusing

Ruff

- Fast and easy to use
- No extension mechanism

Pylint and Flake8

- Extensible with plugins
- Must have AST knowledge

Treesitter and Ast-Grep

- Configurable with patterns
- Less support for tool building

Wow, `pyastgrep` offers a novel way query a program's AST! Is XPath sufficient? Can this tool support all envisioned use cases? How?

Wait, what is an abstract syntax tree?

Python Source Code

```python
def calculate_sum(x, y):
  """Add two numbers."""
  return x + y
```

Abstract Syntax Tree

```
Module(
  body=[
    FunctionDef(
      name='calculate_sum',
      args=...,
      body=[
        Return(
          value=BinOp(
            left=Name(id='x', ...),
            op=Add(),
            right=Name(id='y', ...)))],
      ...)],
  ...)
```

Understanding the AST

- Tree representation of code
- Nodes are syntax elements
- Great for program analysis
- Independent of code style

AST Analysis Challenges

- Complex structure for code
- Brittle regular expressions
- False positives and negatives
- Need easy way to query
- Avoid bespoke solutions
- Adopt XPath-like queries

Scanning code with `pyastgrep`

Define a Python file with functions

```python
def too_many_args(a, b, c, d, e, f):
def another_function(x, y):
def a_third_function(p, q, r, s, t, u, v):
```

Find functions with more than 5 arguments

```
pyastgrep '//FunctionDef[count(args/args) > 5]' example.py
```

Results from running the query with `pyastgrep`

```
example.py:1:1:def too_many_args(a, b, c, d, e, f):
example.py:7:1:def a_third_function(p, q, r, s, t, u, v):
```

Make the connection by comparing the `pyastgrep` and `chasten` tools

`pyastgrep`

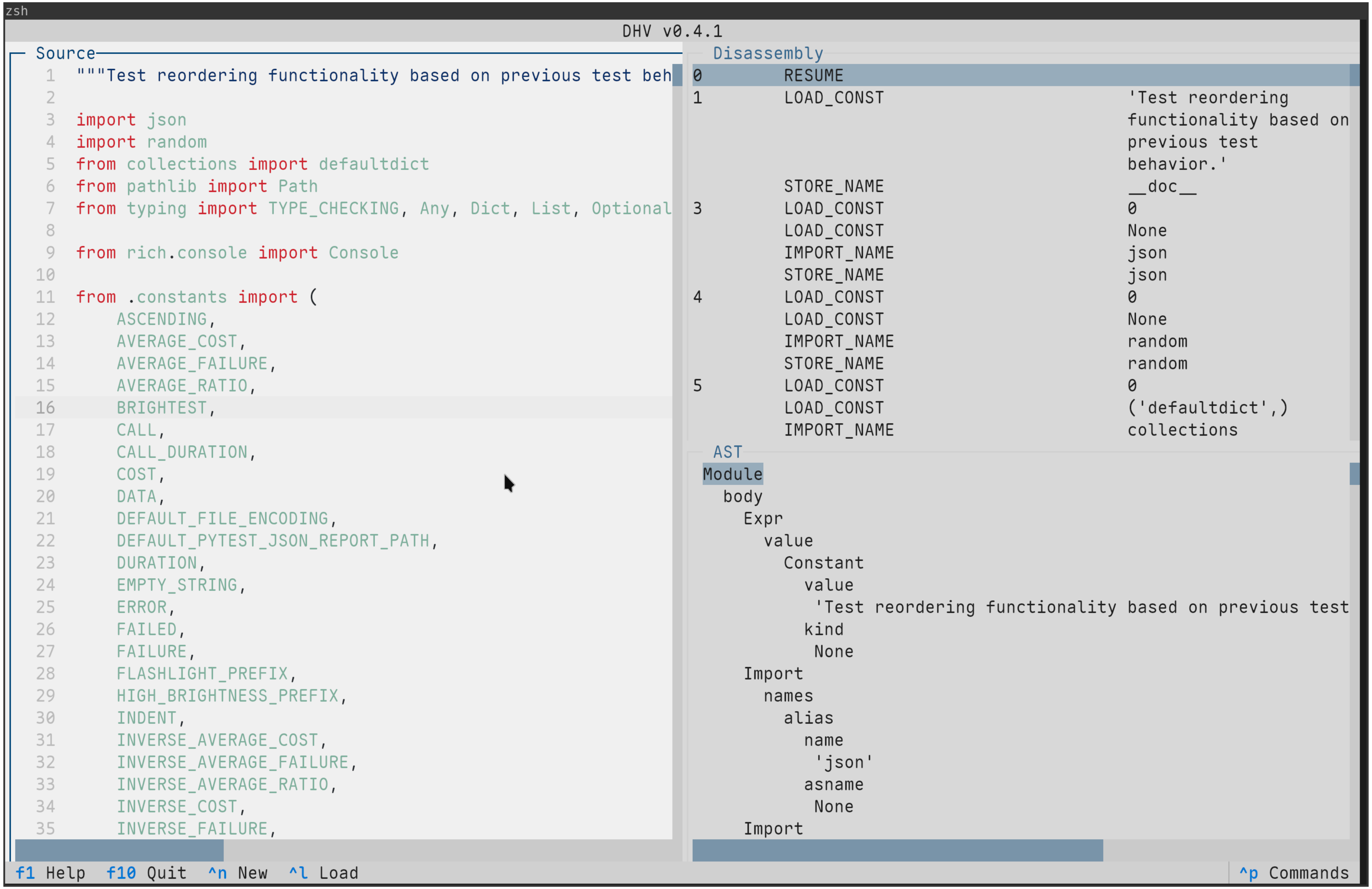
- Interactive AST search tool
- Ad-hoc queries from the CLI
- Uses raw XPath expressions
- `grep`-like console output

`chasten`

- Built using `pyastgrep`'s API
- Runs checks from a YAML file
- Saves results in JSON, CSV, DB
- View results with `datasette`

Key Idea: `chasten` uses `pyastgrep`'s powerful search to build a configurable, project-oriented linter. Developers, researchers, students, and instructors can "`chasten`" Python projects and save the results!

Use dhv to explore a Python AST!



Quick recap of referenced projects

Click these links to preview documentation for referenced tools!

- Python `ast` module: Python's abstract syntax tree module
- Pylint: A popular static code analyzer for Python
- Flake8: An extensible wrapper around PyFlakes, pycodestyle, and McCabe
- Ruff: An extremely fast Python linter and code formatter, written in Rust
- Tree-sitter: A parser generator tool and incremental parsing library
- Ast-grep: A CLI tool for searching and rewriting code with ASTs
- Pyastgrep: A tool for searching Python code with XPath expressions
- Dhv: A comprehensive TUI for Python code exploration built with Textual
- Datasette: A SQL-based tool for exploring and publishing data to the web

Next Steps: Use case for Python project analysis with `chasten`

Avoid time complexity of $O(n^2)$

```python
# O(n) is acceptable
seen = set()
for item in items:
    if item in seen:
        return True
    seen.add(item)
```

```python
# O(n²) is not okay
for i in range(len(items)):
    for j in range(len(items)):
        if i != j
         and items[i] == items[j]:
            return True
```

- **Goal**: Automatically scan the source code that students submit to confirm that there are no inefficient looping constructs
- **Challenge**: Linters like Ruff and Pylint don’t have rules to detect nested control structures that either are or are not acceptable
- **Build**: An extensible tool allowing instructors to scan for arbitrary code patterns without detailed AST knowledge

Chasten to the rescue!

- Uses XPath to search Python’s AST
- Rules written in simple YAML
- Structure-first, not just style
- Outputs to JSON, CSV, or SQLite

Result: Instructors define checks once and use Chasten to easily apply them at scale across all student submissions

```yaml
- name: "nested-loops"
  code: "PERF001"
  pattern: "//For[descendant::For]"
  description: "Detects doubly nested for-loops that are often O(n²)"
```

Let's run chasten!

Install the Tool

```
pipx install chasten  # Install Chasten in venv
pipx list             # Confirm installation
chasten --help        # View available commands
```

Run Chasten

```
chasten analyze time-complexity-lab \
        --config chasten-configuration \
        --search-path time-complexity-lab \
        --save-directory time-complexity-results \
        --save
```

- Save results to a **JSON file** and produce **console output**
- Configure the **return code** for different **detection goals**

Results from running `chasten`

Nested loop analysis

Check ID	Check Name	File	Matches
PERF001	nested-loops	analyze.py	1
PERF001	nested-loops	display.py	7
PERF001	nested-loops	main.py	0

Check ID → A unique short rule code (e.g., `PERF001`)

Check Name → The rule name that matched (e.g., `nested-loops`)

File → The Python file that the tool scanned (e.g., `analyze.py`)

Matches → Number of times the pattern was detected in that file (e.g., `1` match)

Exploring a bespoke AST visitor

```python
import ast
import json
import os
import sys

class ForVisitor(ast.NodeVisitor):
    """
    An AST visitor that detects doubly-nested for loops.
    """
    def __init__(self, filepath):
        self.filepath = filepath
        self.nested_for_loops = []
        self._for_depth = 0

    def visit_For(self, node):
        """
        Visit a for-loop node in the AST.
        """
        self._for_depth += 1
        if self._for_depth > 1:
```

What role should generative AI play in program analysis and `chasten`?

- The prior program was automatically generated by Gemini 2.5 Pro with `gemini-cli`. And, it works! Impressive!
- Similar programs can also be generated by GPT4.1 or Claude Sonnet 4 with `open-code`. Again, really nice!
    - `npx https://github.com/google-gemini/gemini-cli`
    - `npx opencode-ai@latest`
- Or, use these tools to generate `chasten` configurations!

Limitations and future directions

- **Limitations of the current version of `chasten`**
  - Doesn’t handle style, formatting, or type inference
  - Not optimized for fast use in continuous integration
  - Pattern matches through XPath on Python’s AST
- **Empirical study of `chasten`’s effectiveness and influence**
  - Frequency of false positives or false negatives?
  - How do students respond to the tool’s feedback?
  - Differences in scores with varied feedback types?

Chasten your Python program!

- Help developers, researchers, students, and educators
- Write declarative rules for AST-based code checks
- Focus on bespoke code structure patterns in Python
- Automated grading aligned with learning outcomes
- Generate data-rich insights into your code patterns

- **Try out Chasten and contribute to its development!**
  - GitHub: https://github.com/AstuteSource/chasten
  - PyPI: https://pypi.org/project/chasten/