Python Source Code Analysis

# Objective

Create a dataset for Python source code and fill it in with many projects. The code will be written by:

1. Novice programmers
2. Expert developers.

Once the database has been filled in, different data-mining algorithms could be executed. Examples are anomaly detection, frequency analysis, feature reduction and visualization, logistic regression, classification rules, clustering, and association rules.

Program insertion should be efficient, given the number of projects to be inserted. It must also be maintainable to allow its easy modification and extension.

# Python references

First, try to be fluent as a Python programmer. [This](https://docs.python.org/3/tutorial/index.html) is a standard tutorial.

https://docs.python.org/3/tutorial/index.html

Python provides AST creation and traversal. [Here](https://www.scaler.com/topics/python-ast/), you can find a brief explanation.

https://www.scaler.com/topics/python-ast/

The Python [ast module](https://docs.python.org/3/library/ast.html) is an important resource for checking the structure of Python ASTs.

https://docs.python.org/3/library/ast.html

# Database

The fields annotated with ψ should not be considered in the machine-learning or data-mining algorithms. The reason is that they correlate with problem complexity more than with programmer expertise.

What follows is an enumeration of the different tables to be defined.

**Projects**:

| **Name** | **Description** | **Domain** |
| --- | --- | --- |
| ProjectIDψ | Primary key of the project | Unique ID (Integer) |
| Nameψ | Project name | String |
| HasSubDirsWithCode | Within the root source code directories, there are subdirectories with Python code (.py files) \*but\* there is not an \_\_init\_\_.py file in it | Boolean |
| HasPackages | Within the root source code directories, there are subdirectories with Python code (.py files) and an \_\_init\_\_.py file in it | Boolean |
| NumberOfModulesψ | Number of .py files in the project | Integer |
| NumberOfSubDirsWithCodeψ | Number of subdirectories in the project with modules inside of them \*but\* without an \_\_init\_\_.py file | Integer |
| NumberOfPackagesψ | Number of subdirectories in the project with modules inside of them and an \_\_init\_\_.py file in it | Integer |
| ClassDefsPct | Proportion of definitions (functions, enums, or classes) that are classes | Real [0, 1] |
| FunctionDefsPct | Proportion of definitions (functions, enums or classes) that are functions | Real [0, 1] |
| EnumDefsPct | Proportion of classes derived from Enum | Real [0, 1] |
| HasCodeRootPackage | Whether the project has code in the root package | Boolean |
| AverageDefsPerModule | Average number of definitions (enum, class and function) per module | Real |
| IsExpert | Whether the programmer is expert or beginner | Boolean |

**Modules** (in Python, a module is a .py file):

| **Name** | **Description** | **Domain** |
| --- | --- | --- |
| ModuleIDψ | Primary key of the module | Unique ID (Integer) |
| Nameψ | Module name | String |
| Pathψ | Path to the .py file | String |
| NameConvention | Its naming convention | NamingConvention2 |
| HasDocString | Whether the module has a module comment. It is true when its first entry in body is a Constant with a string value | Boolean |
| GlobalStmtsPct | Proportion of statements written in the global scope (imports, class and function definitions are not considered) | Real [0, 1] |
| GlobalExpressions | Proportion of expressions in the global scope (most of them would be statements) | Real [0, 1] |
| NumberOfClassesψ | Number of classes defined in the module | Integer |
| NumberOfFunctionsψ | Number of functions defined in the module | Integer |
| ClassDefsPct | Proportion of definitions (functions, enums, or classes) that are classes | Real [0, 1] |
| FunctionDefsPct | Proportion of definitions (functions, enums or classes) that are functions | Real [0, 1] |
| EnumDefsPct | Proportion of classes derived from Enum | Real [0, 1] |
| AverageStmtsFunctionBody | Average number of statements in the function bodies | Real |
| AverageStmtsMethodBody | Average number of statements in the method bodies | Real |
| TypeAnnotationPct | Proportion of type annotations for the function and method parameters and return values | Real [0, 1] |
| HasEntryPoint | If the module has the Python idiom if \_\_name\_\_ == '\_\_main\_\_' | Boolean |
| ProjectIDψ | Primary key of the associated project | Unique ID (Integer) |
| ImportIDψ | Primary key where imports were written if any | Unique ID (Integer) |

**Imports** (one entry per module/file):

| **Name** | **Description** | **Domain** |
| --- | --- | --- |
| ImportIDψ | Primary key of the import | Unique ID (Integer) |
| NumberImportsψ | Number of imports in a module | Integer |
| ModuleImportsPct | Proportion of simple imports (Import nodes) | Real [0, 1] |
| AverageImportedModulesψ | Average of modules (alias) imported in the same import statement | Real |
| FromImportsPct | Proportion of “from” imports (ImportFrom nodes) | Real [0, 1] |
| AverageFromImportedModulesψ | Average of modules (alias) imported in the same from import statement | Real |
| AverageAsInImportedModules | Average of “as” aliases (asname) in the same from import statement, relative to the imported names (alias) | Real |
| LocalImportsPct | Proportion of imports (any type) not written at the beginning of the module | Real [0, 1] |
| ModuleIDψ | Primary key of the module where these imports were written | Unique ID (Integer) |

**ClassDefs**:

| **Name** | **Description** | **Domain** |
| --- | --- | --- |
| ClassDefIDψ | Primary key of the class definition | Unique ID (Integer) |
| NameConvention | Its naming convention | NamingConvention2 |
| IsEnumClass | Whether the class inherits from Enum | Boolean |
| NumberOfCharacters | The number of characters of the function ID | Integer |
| NumberOfDecorators | Number of decorators | Integer |
| NumberOfMethods | Number of methods | Integer |
| NumberOfBaseClasses | Number of base classes | Integer |
| HasGenericTypeAnnotations | In Python 3.12, classes can have generic type annotations (e.g., class list[T]: pass). These type annotations can be obtained in the type\_params field of the ClassDef ast node. | Boolean |
| HasDocString | Whether the class has a class comment. It is true when its first entry in body is a Constant with a string value | Boolean |
| BodyCount | Number of statements in the class body (not inside of the methods) | Integer |
| AssignmentsPct | Proportion of assignments in the class body (not inside of the methods); this kind of assignment is an alternative way to define fields | Real [0, 1] |
| ExpressionsPct | Proportion of expressions in its body (most of them would be statements) | Real [0, 1] |
| UsesMetaclass | Whether the class uses a metaclass (defines “meta=” in the inheritance clause) | Boolean |
| NumberOfKeyWords | Number other keywords, different to metaclass | Integer |
| Height | Distance (number of edges) from the current node to the root node in the enclosing module (not program) | Integer |
| AverageStmtsMethodBody | Average number of statements in the method bodies | Real |
| TypeAnnotationsPct | Proportion of type annotations for the method parameters and return values | Real [0, 1] |
| PrivateMethodsPct | Proportion of private methods (starting with “\_”) in the class | Real [0, 1] |
| MagicMethodsPct | Proportion of magic methods in the class | Real [0, 1] |
| AsyncMethodsPct | Proportion of async methods in the class | Real [0, 1] |
| ClassMethodsPct | Proportion of class methods in the class | Real [0, 1] |
| StaticMethodsPct | Proportion of static methods in the class | Real [0, 1] |
| AbstractMethodsPct | Proportion of abstract methods in the class | Real [0, 1] |
| PropertyMethodsPct | Proportion of property methods in the class | Real [0, 1] |
| SourceCodeψ | Python code of the expression (use ast.unparse()) | String |
| ModuleIDψ | Primary key of the module where this class was defined | Unique ID (Integer) |

**FunctionDefs**:

| **Name** | **Description** | **Domain** |
| --- | --- | --- |
| FunctionDefIDψ | Primary key of the function definition | Unique ID (Integer) |
| NameConvention | Its naming convention | NamingConvention2 |
| NumberOfCharacters | The number of characters of the function ID | Integer |
| IsPrivate | Whether the variable name starts with the “\_” character | Boolean |
| IsMagic | Whether the variable name starts and ends with two “\_” characters. In that case, IsPrivate must be false. | Boolean |
| BodyCount | Number of statements in the function body | Integer |
| ExpressionsPct | Proportion of expressions in its body (most of them would be statements) | Real [0, 1] |
| IsAsync | Whether the method is asynchronous | Boolean |
| NumberOfDecorators | Number of decorators | Integer |
| HasReturnTypeAnnotation | Whether the function has a return type annotation | Boolean |
| HasDocString | Whether the function has a function comment. It is true when its first entry in body is a Constant with a string value | Boolean |
| Height | Distance (number of edges) from the current node to the root node in the enclosing module (not program) | Integer |
| TypeAnnotationsPct | Proportion of type annotations for the function parameters and return values | Real [0, 1] |
| SourceCodeψ | Python code of the expression (use ast.unparse()) | String |
| ModuleIDψ | Primary key of the module where these function was written | Unique ID (Integer) |
| ParametersIDψ | Primary key of a Parameters entry where its parameters are defined | Unique ID (Integer) |

**MethodDefs** (inherits all the columns from FunctionDefs; only the new columns are specified):

| **Name** | **Description** | **Domain** |
| --- | --- | --- |
| MethodDefIDψ | Primary key of the method definition | Unique ID (Integer) |
| IsClassMethod | Whether the method has a @classmethod decorator | Boolean |
| IsStaticMethod | Whether the method has a @staticmethod decorator | Boolean |
| IsConstructorMethod | Whether the method is a constructor (\_\_init\_\_) | Boolean |
| IsAbstractMethod | Whether the method has an @abstract decorator | Boolean |
| IsProperty | Whether the method has a @property decorator | Boolean |
| IsWrapper | Whether the method has a @wraps decorator | Boolean |
| IsCached | Whether the method has a @cache decorator | Boolean |
| ClassDefIDψ | Primary key of its Class Definition | Unique ID (Integer) |

**Statements** (if an expression is created as a statement, it is will not be included in this table but in Expressions):

| **Name** | **Description** | **Domain** |
| --- | --- | --- |
| StatementIDψ | Primary key of the statement | Unique ID (Integer) |
| Category | Syntactic category of the current node | StatementCategory4 |
| Parent | Syntactic category of the parent node | Module | ClassDef | FunctionDef | MethodDef | StatementCategory4 |
| StatementRole | Role played by the current node in the structure of its parent node | StatementRole5 |
| Height | Distance (number of edges) from the current node to the root node in the enclosing module (not program) | Integer |
| Depth | Maximum distance (number of edges) of the longest path from the current node to a leaf node. | Integer |
| SourceCodeψ | Python code of the expression (use ast.unparse()) | String |
| HasOrElse | Whether the statement has else body or not. True or false for Try, TryStar, If, For, AsyncFor and While (N/A otherwise) | N/A, True, False |
| BodySize | The number of statements in the body. Only valid for While, If (no else), While, For, AsyncFor, Try, TryStar, With, AsyncWith (N/A otherwise). | N/A, Integer |
| First, second and third child’s IDs (expressions) | Foreign keys of Expressions | Unique ID (integer) |
| ParentIDψ | Primary key of the parent | Unique ID (Integer) |

4StatementCategory (the AST node of the Python ast module is stated between parenthesis):

* Return (one expression child, at most).
* Delete (one expression child).
* AssignmentStmt (still binary for multiple assignments because operands are modelled as tuples)
* TypeAlias (two children: first, its name; second the first type parameter (type\_params), if any; third, the value).
* AugmentedAssignment (the operator is not stored)
* AnnotatedAssignment (first child is the variable name (target), second one the type annotation (annotation), third one the assigned value, if any).
* For (first child is the for element (target), second one the enumerable (iter); no third child (bodies are not included)).
* If (first child is the condition (test); no more children).
* While (first child is the condition (test); no more children).
* With (first child is the first element (withitem plus context\_expr), second one the first “as” (withitem plus optional\_vars), third one the second with element, if any).
* AsyncWith (first child is the first element (withitem plus context\_expr), second one the first “as” (withitem plus optional\_vars), third one the second with element, if any).
* Match (its only child is the condition expression (subject)).
* Raise (first child is the expression risen (exc); second one the “from” (cause)).
* Try (includes TryStar; no children).
* Assert (first child is test; second is msg, if any).
* Global (no children).
* NonLocal (no children).
* Pass (no children).
* Break (no children).
* Continue (no children).

StatementRole5: Module (global statement), FunctionDef, AsyncFunctionDef, MethodDef, AsyncMethodDef, ClassDef (inside the class, not inside a method), For, ForElse, AsyncFor, AsyncForElse, With, AsyncWith, Try (includes TryStar), TryElse (includes TryStar), TryFinally (includes TryStar), TryHandler (does not include TryStar), TryHandlerStar (handler for TryStar), Case

**Cases** (one entry per Match statement):

| **Name** | **Description** | **Domain** |
| --- | --- | --- |
| NumberOfCases | Number of cases in a match statement | Integer |
| Guards | Number of guards / number of cases (in a match statement) | Real [0, 1] |
| AverageBodyCount | Average number of statements in the cases’ bodies | Real |
| AverageMatchValue | Average number of MatchValue patterns in the cases of the match statement | Real [0 ,1] |
| AverageMatchSingleton | Average number of MatchSingleton patterns in the cases of the match statement | Real [0 ,1] |
| AverageMatchSequence | Average number of MatchSequence patterns in the cases of the match statement | Real [0 ,1] |
| AverageMatchMapping | Average number of MatchMapping patterns in the cases of the match statement | Real [0 ,1] |
| AverageMatchClass | Average number of MatchClass patterns in the cases of the match statement | Real [0 ,1] |
| AverageMatchStar | Average number of MatchStar patterns in the cases of the match statement | Real [0 ,1] |
| AverageMatchAs | Average number of MatchAs patterns in the cases of the match statement | Real [0 ,1] |
| AverageMatchOr | Average number of MatchOr patterns in the cases of the match statement | Real [0 ,1] |
| StatementIDψ | Primary key of the match statement | Unique ID (Integer) |

**Handlers** (one entry per Try or TryStar statement):

| **Name** | **Description** | **Domain** |
| --- | --- | --- |
| NumberOfHandlers | Number of handlers in a try statement | Integer |
| HasFinally | Whether the handlers include a finally body | Boolean |
| HasCatchAll | Whether the handlers include a catch-all (type==None) handler | Boolean |
| AverageBodyCount | Average number of statements in the bodies of the handlers | Real |
| HasStar | Whether it includes a handler with star (TryStar) | Boolean |
| StatementIDψ | Primary key of the Try or TryStar statement | Unique ID (Integer) |

**Expressions**:

| **Name** | **Description** | **Domain** |
| --- | --- | --- |
| ExpressionIDψ | Primary key of the expression | Unique ID (Integer) |
| Category | Syntactic category of the current node | ExpressionCategory1 |
| First, second, third and fourth child | Syntactic category of the i-th child (one column per child, four max) | Parameter | ExpressionCategory1 |
| Parent | Syntactic category of the parent node | Module | ClassDef | FunctionDef | MethodDef | StatementCategory4| ExpressionCategory1 |
| ExpressionRole | Role played by the current node in the structure of its parent node | ExpressionRole3 |
| Height | Distance (number of edges) from the current node to the root node in the enclosing module (not program) | Integer |
| Depth | Maximum distance (number of edges) of the longest path from the current node to a leaf node. | Integer |
| SourceCodeψ | Python code of the expression (use ast.unparse()) | String |
| ParentIDψ | Primary key of the parent | Unique ID (Integer) |

1ExpressionCategory (the AST node of the Python ast module is stated between parenthesis):

* Logical (BoolOp)
* AssignmentExp (NamedExpr)
* Arithmetic (BinOp with Add, Sub, Mult, Div, FloorDiv and Mod operators)
* Pow (BinOp with Pow operator)
* Shift (BinOp with LShift and RShift operators)
* BW[[1]](#footnote-1)Logical (BinOp with BitOr, BitXor and BitAnd operators)
* MatMult (BinOp with MatMult operator)
* UnaryAritmetic (BinOp with UAdd y USub operators)
* UnaryNot (BinOp with Not operator)
* UnaryBWNot (BinOp with Invert operator)
* Lambda (Lambda). A lambda expression is a unary expression, where its only child is the body field from the ast. However, it must also contain a link to the Parameters table.
* Ternary (IfElse)
* SetLiteral (Set). This node has as many children as elements, but it also has a link to the Vectors table.
* ListLiteral (List) This node has as many children as elements, but it also has a link to the Vectors table.
* TupleLiteral (Tuple) This node has as many children as elements, but it also has a link to the Vectors table.
* DictionaryLiteral (Dict). This node has as many children as elements, but it also has a link to the Vectors table. Different from the Python ast representation, we consider each child as a 2-typle collecting (key, value).
* ListComprehension (ListComp). This node has as many children as elements, but it also has a link to the Comprehensions table. The first child represents the ExpressionCategory1 of the element (elt). The second, the ExpressionCategory1 of the target. Third, the ExpressionCategory1 of the iteration (it). Fourth, the ExpressionCategory1 of the first if (ifs).
* SetComprehension (SetComp). The same as ListComprehension.
* DictComprehension (DictComp) . The same as ListComprehension.
* GeneratorComprehension (GeneratorExp) . The same as ListComprehension.
* Await (Await)
* Yield (Yield)
* YieldFrom (YieldFrom)
* Relational (Compare with Eq, NotEq, Lt, LtE, Gt and GtE operators)
* Is (Compare with Is and IsNot operators)
* In (Compare with In and NotIn operators)
* Call (Call). This node has as many children as arguments, but it also has a link to the CallArgs table.
* FString (JoinedStr). This node has a link to the Fstrings table.
* IntLiteral (Constant with int value)
* FloatLiteral (Constant with float value)
* ComplexLiteral (Constant with complex value)
* NoneLiteral (Constant with None value)
* BoolLiteral (Constant with True or False value)
* StringLiteral (Constant with str value)
* EllipsisLiteral (Constant with Ellipsis value)
* Dot (Attribute)
* Variable (Name). This node has a link to the Variables table.
* Slice (Slice)
* Indexing (Subscript). Notice that, by using tuples and slices, this expression is always binary: l[1:2,3] has a tuple as the second parameter, where the first child is a Slice and the second one a IntLiteral.
* Star (Starred)

2 ExpressionRole: Module, FuncDecorator, FuncBody, ReturnType (returns), ClassBase, ClassDecorator, MethodBody, ClassBody (expressions inside a class definition, not inside methods), Return, Delete, AssignLHS, AssignRHS, TypeAliasLHS, TypeAliasRHS, AugmentedAssignmentLHS, AugmentedAssignmentRHS, VarDefVarName (target field of AnnAssign), VarDefType (annotation field of AnnAssign), VarDefInitValue (value field of AnnAssign), ForElement (target), ForEnumerable (iter), ForBody, ForElseBody, AsyncForElement (target), AsyncForEnumerable (iter), AsyncForBody, AsyncForElseBody, WhileCondition, WhileBody, WhileElseBody, IfCondition, IfBody, IfElseBody, WithElement (withitem plus context\_expr), WithAs (withitem plus optional\_vars), WithBody, AsyncWithElement (withitem plus context\_expr), AsyncWithAs (withitem plus optional\_vars), AsyncWithBody, MatchCondition (subject), CaseGuard (guard, either left or comparators), CaseBody, Raise (exc), RaiseFrom (cause), TryBody, ExceptType, ExceptBody, TryElse, FinallyBody, AssertCondition, AssertMessage, Logical (both binary and unary), AssignExpLHS, AssignExpRHS, Arithmetic (both binary and unary), Pow, Shift, BWLogical (both binary and unary), MatMult, LambdaBody, TernaryCondition, TernaryIfBody, TernaryElseBody, SetLiteral, ListLiteral, TupleLiteral, DictionaryLiteralKey, DictionaryLiteralValue, ComprehensionElement, ComprehensionTarget, ComprehensionIter, ComprehensionIf, Await, Yield, YieldFrom, Relational, Is, In, CallFuncName, CallArg, FString, Dot, Slice, Indexing, Star, TypeAnnotation, DefaultParamValue, TypeVar.

The following are weak entities derived from Expressions.

**Comprehensions**:

| **Name** | **Description** | **Domain** |
| --- | --- | --- |
| Category | Kind of comprehension | ListComp, SetComp, DictComp, GenComp |
| Number of ifs | Number of elements in the ifs field | Integer |
| Number of generators | Number of generators in the comprehension (generators field) | Integer |
| IsAsync | Whether the comprehension is async | Boolean |
| ExpressionIDψ | Primary key of the corresponding expression | Unique ID (Integer) |

**CallArgs**:

| **Name** | **Description** | **Domain** |
| --- | --- | --- |
| NumberArgs | The number of all the arguments | Integer |
| NamedArgsPct | Proportion of arguments with the syntax: name=arg\_value | Real [0, 1] |
| DoubleStarArgsPct | Proportion of arguments with the following syntax: \*\*args (there could be more than one) | Real [0, 1] |
| ExpressionIDψ | Primary key of the corresponding expression | Unique ID (Integer) |

**Fstrings**:

| **Name** | **Description** | **Domain** |
| --- | --- | --- |
| NumberOfElements | Number of elements in the f-string (values that are Constant plus values that are FormattedValue) | Integer |
| ConstantsPct | Proportion of string literal fragments in the f-string (number of values that are Constant in the ast) | Real [0, 1] |
| ExpressionsPct | Proportion of expressions in the f-string (number of FormattedValues in the values list of the ast node) | Real [0, 1] |
| ExpressionIDψ | Primary key of the corresponding expression | Unique ID (Integer) |

**Variables**:

| **Name** | **Description** | **Domain** |
| --- | --- | --- |
| NameConvention | Its naming convention | NamingConvention2 |
| NumberOfCharacters | The number of characters of the variable ID | Integer |
| IsPrivate | Whether the variable name starts with the “\_” character | Boolean |
| IsMagic | Whether the variable name starts and ends with two “\_” characters. In that case, IsPrivate must be false. | Boolean |
| ExpressionIDψ | Primary key of the corresponding expression | Unique ID (Integer) |

2 NamingConvention:

* Lower: all the letters are lowercase.
* Upper: all the letters are uppercase, and \_ could be included.
* CamelLow: camel case, starting with a lowercase letter.
* CammelUp: camel case, starting with an uppercase letter.
* SnakeCase: snake case (everything lowercase but with \_s).
* Discard: just the \_ character.

**Vectors**:

| **Name** | **Description** | **Domain** |
| --- | --- | --- |
| Category | Kind of literal | ListLiteral, SetLiteral, DictLiteral, GeneratorLiteral |
| NumberOfElements | The number of elements in the literal | Integer |
| Homogeneous | Whether the elements in the literal are the same type of not. Notice that [1, 1.2] are different (IntLiteral and FloatLiteral), whereas [my\_int, my\_float] are not (syntactically, my\_int and my\_float are both Variables) | Boolean |
| ExpressionIDψ | Primary key of the corresponding expression | Unique ID (Integer) |

**Parameters**:

| **Name** | **Description** | **Domain** |
| --- | --- | --- |
| NumberOfParams | Number of all the parameters | Integer |
| PosOnlyParamPct | Proportion of positional only parameters (see the / char in [here](https://peps.python.org/pep-0570/#origin-of-as-a-separator)). | Real [0, 1] |
| VarParamPct | Proportion of var params | Real [0, 1] |
| HasVarParam | Whether it has a vararg value | Boolean |
| TypeAnnotationPct | Proportion of parameters with type annotations | Real [0, 1] |
| KwOnlyParamPct | Proportion of parameters with keyword only option (kwonlyargs) | Real [0, 1] |
| DefaultValuePct | Proportion of parameters with default values (defaults plus kw\_defaults) | Real [0, 1] |
| HasKWParam | Whether it has a kwarg | Boolean |
| NameConvention | The naming convention used for most parameters | NamingConvention2 |

1. BT stands for bitwise. [↑](#footnote-ref-1)