Match all things Python:

Advanced parsing of structured data using Python's new match statement

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Speaker Introduction

Marc-André Lemburg

- Studied Mathematics, Computer Science and Physics
- CEO eGenix.com GmbH
- Senior Solution Architect, Consulting CTO and Coach
- EuroPython Society Fellow and former Chair
- Python Software Foundation Fellow and former Director
- Python Core Developer (Unicode, DB-API, platform module, ...)
- Co-founder Python Meeting Düsseldorf
- Based in Düsseldorf, Germany

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Intro: Recap of the new Python match statement

```
match obj:
    case list() as list_obj:
        print (f'found list: {list_obj!r}')

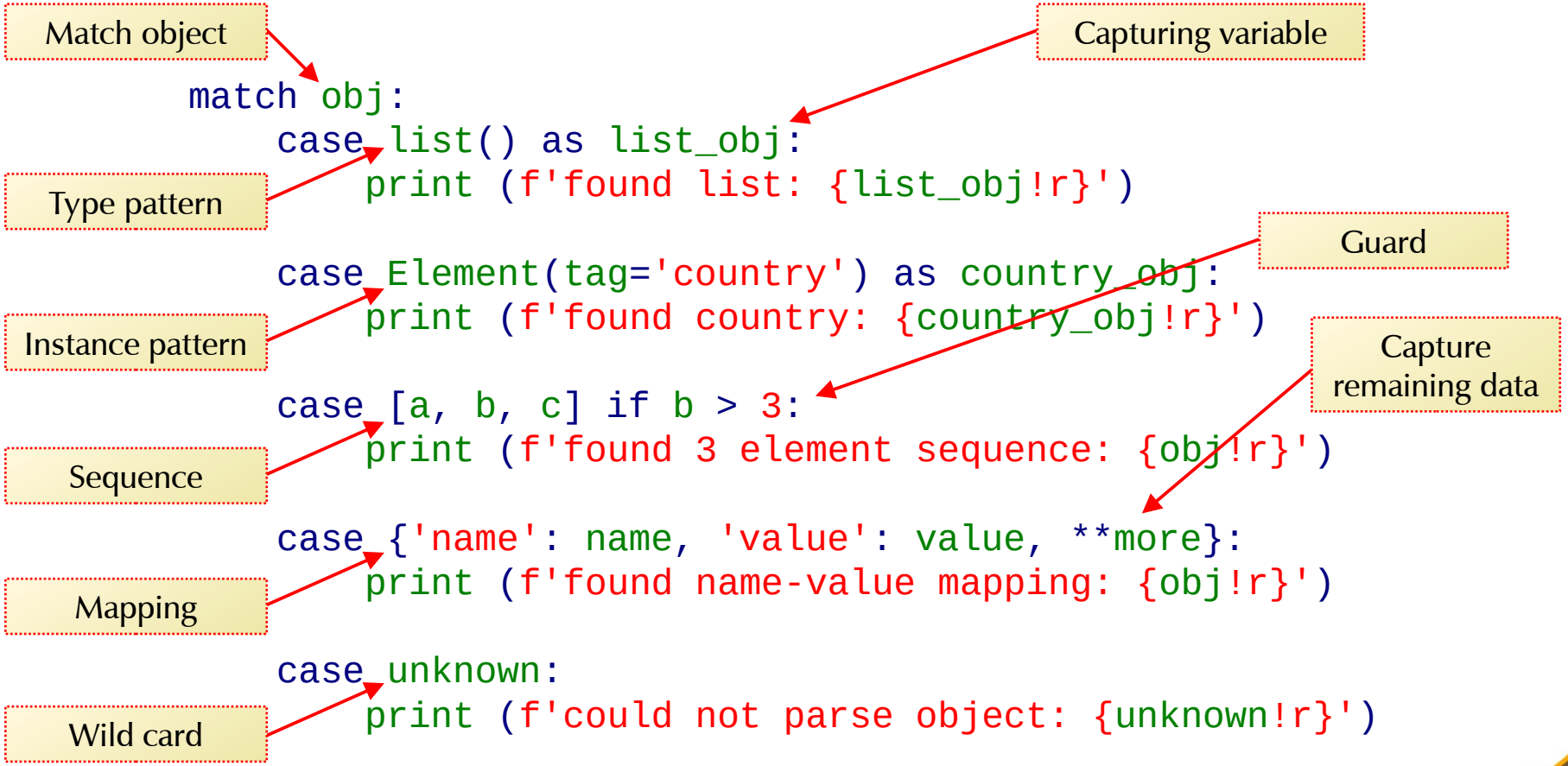
    case Element(tag='country') as country_obj:
        print (f'found country: {country_obj!r}')

    case [a, b, c] if b > 3:
        print (f'found 3 element sequence: {obj!r}')

    case {'name': name, 'value': value, **more}:
        print (f'found name-value mapping: {obj!r}')

    case unknown:
        print (f'could not parse object: {unknown!r}')
```

Intro: Recap of the new Python match statement

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    case list() as list_obj:
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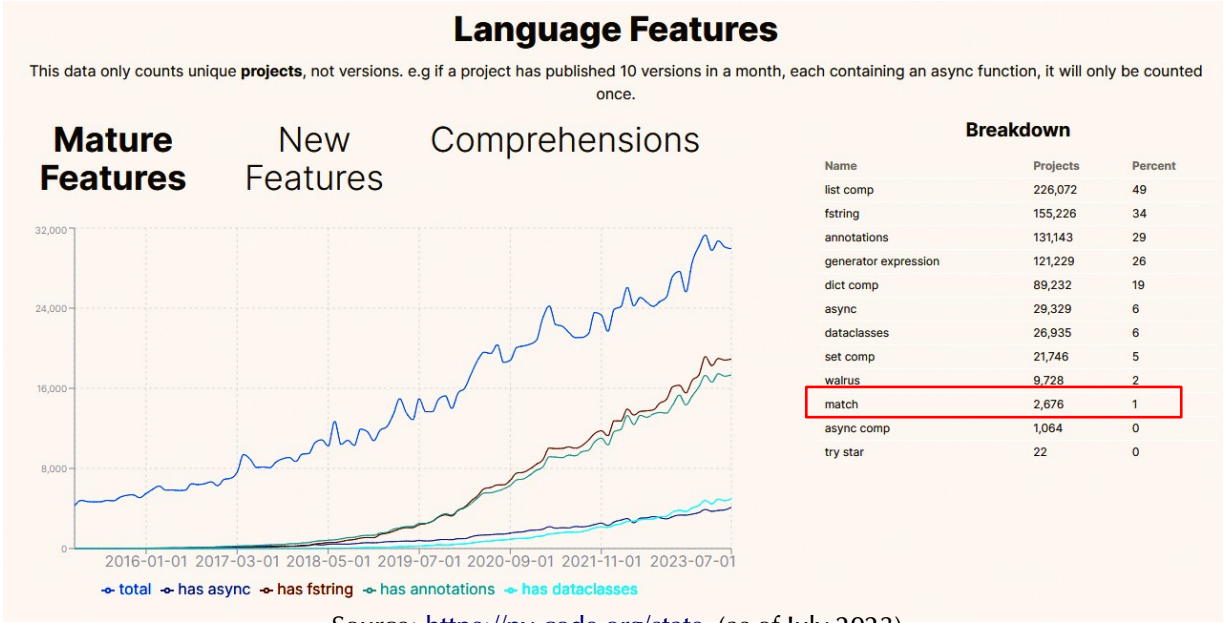
    case [a, b, c] if b > 3:
        print (f'found 3 element sequence: {obj!r}')

    case {'name': name, 'value': value, **more}:
        print (f'found name-value mapping: {obj!r}')

    case unknown:
        print (f'could not parse object: {unknown!r}')
```

Match statement: Popularity

- Introduced in Python 3.10 (Oct 2021)
- How popular is this new feature ?
  - Only 2,676 PyPI packages use the match statement
  - That's about 0.55% of all packages on PyPI



Source: https://py-code.org/stats (as of July 2023)

Match statement: Documentation

- PEPs
  - PEP 635 – Structural Pattern Matching: Motivation and Rationale
    - Discussion about syntax – not a good intro
  - PEP 636 – Structural Pattern Matching: Tutorial
    - Best way to start learning the new syntax
  - PEP 634 – Structural Pattern Matching: Specification
    - In-depth spec for how things work
- Python documentation: match statement
  - Not much different than the PEPs :-(

Some techniques used in advanced parsing

- OR parsing:

```
case ["yes" | "y" | "on" | "true" | “1”] as option:
```

- Parsing optional / remaining arguments:

```
case [1, 2, *args]:
case [1, _, _, 4]:
case {'name':name, **more}:
```

- Instance parsing:

```
case Element(tag='country', attrib={'name': name}):
```

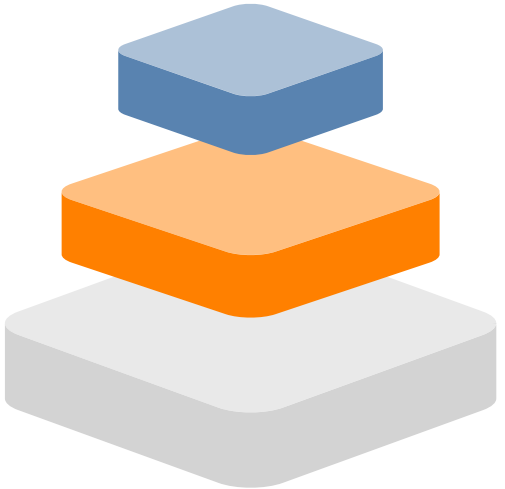
- Mixing local variables and capturing variables:

```
case Call(func=Name(id='isinstance'),
          args=[Name(id=params.varname),
          Name(id=typename)]):
```

more…
see Raymond Hettinger’s PyCon Italia 2022 talk

Examples parsing structured data

- JSON
  - Record lists (tabular data exports)
  - GeoJSON (used for geospatial data)
- XML
  - Country data
- AST
  - *if*-statement to *match*-statement refactoring



Parsing JSON: Tabular data

- Schema:

```
schema = {
   "type" : "object",
   "properties" : {
      "price" : {"type" : "number"},
      "name" : {"type" : "string"},
      },
}
```

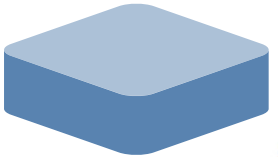
name	price	color
eggs	2.99	
eggs	2	
eggs		
eggs	3.99	brown

- Examples:

```
data_1 = {
   "name" : "eggs",
   "price" : 2.99
}
data_1a = {
   "name" : "eggs",
   "price" : 2
}

table = list(data_1, data_1a, data_2, data_3)
```

```
data_2 = {
   "name" : "eggs"
}
data_3 = {
   "name" : "eggs",
   "price" : 3.99,
   "color": "brown"
}
```

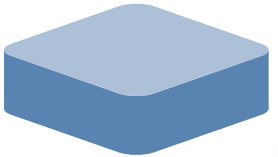


Parsing JSON: Code

- Parse one record:

```
def parse_demo_data(instance):
    match instance:
        case dict() as data_item:
            match data_item:
                case {
                    'name': str() as name,
                    'price': int(price) | float(price),
                    **extra}:
                    if extra:
                        print (f'found extra values: {extra!r}')
                    # Process data
                    print (f'{name}: {price}')
                case wrong_values:
                    print (f'could not parse properties: {wrong_values!r}')
        case wrong_values:
            print (f'could not parse instance: {wrong_values!r}')
```

```
schema = {
    "type" : "object",
    "properties" : {
        "price" : {"type" : "number"},
        "name" : {"type" : "string"},
        },
}
```

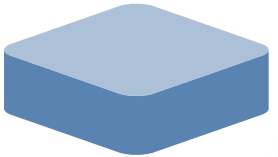


Parsing JSON: Code

- Parse multiple records:

```
def parse_list_data(many_instances):
    match many_instances:
        case list() as data_list:
            for instance in data_list:
                parse_demo_data(instance)
        case wrong_data:
            print (f'unknown data format: {wrong_data!r}')
```

```
table = [   {'name': 'eggs', 'price': 2.99},
            {'name': 'eggs', 'price': 2},
            {'name': 'eggs'},
            {'color': 'brown', 'name': 'eggs', 'price': 3.99}
]
```



Parsing GeoJSON: Data

- Example:


```
# From https://geojson.org/
GEOJSON_TYPES = (
    'Feature',
    'FeatureCollection',
    'Point',
    # more
)

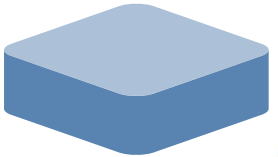

geojson_data_1 = {
    "type": "Feature",
    "geometry": {
        "type": "Point",
        "coordinates": [125.6, 10.1]
    },
    "properties": {
        "name": "Dinagat Islands"
    }
}
```

Parsing GeoJSON: Code

- Parse a GeoJSON record:

```
def parse_geojson_data(instance):
    match instance:
        case {'type': obj_type, **other_members} as obj:
            print (f'new object of type {obj_type!r}')
            if obj_type not in GEOJSON_TYPES:
                print (f'this type is not a valid GeoJSON type')
                return None
            for obj_member in other_members.items():
                match obj_member:
                    case ('geometry', geometry):
                        print (f'found geometry {geometry!r}')
                    case ('properties', properties):
                        print (f'found properties {properties!r}')
                    case wrong_member:
                        print (f'could not parse member: {wrong_member!r}')
        case wrong_values:
            print (f'could not parse object: {wrong_values!r}')
```

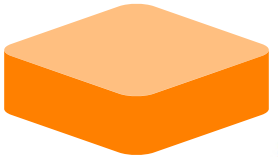
```
geojson_data_1 = {
    "type": "Feature",
    "geometry": {
        "type": "Point",
        "coordinates": [125.6, 10.1]
    },
    "properties": {
        "name": "Dinagat Islands"
    }
}
```



Parsing XML: Data

- Example:

```
<?xml version="1.0"?>
<data>
  <country name="Liechtenstein">
    <rank>1</rank>
    <year>2008</year>
    <gdppc>141100</gdppc>
    <neighbor name="Austria" direction="E"/>
    <neighbor name="Switzerland" direction="W"/>
  </country>
  <country name="Singapore">
    <rank>4</rank>
    <year>2011</year>
    <gdppc>59900</gdppc>
    <neighbor name="Malaysia" direction="N"/>
  </country>
  <country name="Panama">
    <rank>68</rank>
    <year>2011</year>
    <gdppc>13600</gdppc>
    <neighbor name="Costa Rica" direction="W"/>
    <neighbor name="Colombia" direction="E"/>
  </country>
</data>
```



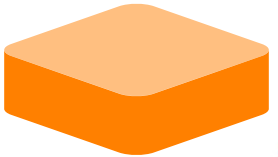
From https://docs.python.org/3/library/xml.etree.elementtree.html

Parsing XML: Code

- Parse countries:

```
def parse_countries_1(tree):
    countries = {}
    for child in tree:
        match child:
            case Element(tag='country',
                         attrib={'name': name}) as country:
                for child in country:
                    neighbors = {}
                    match child:
                        case Element(tag='rank', text=rank):
                            rank = int(rank)
                        case Element(tag='year', text=year):
                            year = int(year)
                        case Element(tag='gdppc', text=gdppc):
                            gdppc = float(gdppc)
                        case Element(
                            tag='neighbor',
                            attrib={'name': nb_name,
                                    'direction': nb_direction}):
                            neighbors[nb_name] = nb_direction
                    case wrong_data:
                        raise TypeError(
                            error_string(wrong_data,
                            'country element'))
                countries[name] = dict(
                    rank=rank,
                    year=year,
                    gdppc=gdppc,
                    neighbors=neighbors,
                )
            case wrong_data:
                raise TypeError(error_string(wrong_data,
                                             'country'))
    return countries
```

```
<country name="Panama">
  <rank>68</rank>
  <year>2011</year>
  <gdppc>13600</gdppc>
  <neighbor name="Costa Rica" direction="W"/>
  <neighbor name="Colombia" direction="E"/>
</country>
```



Note: This does not detect missing child elements. See repo for a version which does.

Parsing ASTs: Data

- Example function and AST:

```
def example(x):
    if isinstance(x, int) and x > 12:
        print ('Int > 12: {x}')
    elif isinstance(x, float):
        print ('Float: {x}')
    elif isinstance(x, str) and len(x) > 5:
        print ('String with more than 5 chars: {x}')
    else:
        print ('Unknown type: {x}')
```

- Idea: Programmatically refactor this into an equivalent function using the *match* statement

```
Module(
  body=[
    FunctionDef(
      name='example',
      args=arguments(
        posonlyargs=[],
        args=[
          arg(arg='x')],
        kwonlyargs=[],
        kw_defaults=[],
        defaults=[]),
      body=[
        If(
          test=BoolOp(
            op=And(),
            values=[
              Call(
                func=Name(id='isinstance', ctx=Load()),
                args=[
                  Name(id='x', ctx=Load()),
                  Name(id='int', ctx=Load())],
                keywords=[]),
              Compare(
                left=Name(id='x', ctx=Load()),
                ops=[
                  Gt()],
                comparators=[
                  Constant(value=12)])]),
          body=[
            Expr(
              value=Call(
                func=Name(id='print', ctx=Load()),
                args=[
                  Constant(value='Int > 12: {x}')],
                Keywords=[]))],
... lots more
```

Parsing ASTs: Code

- Parse function AST & refactor:

```
def if_match_refactor(fct):
    source = inspect.getsource(fct)
    tree = ast.parse(source) # AST.Module
    # Find functions
    for node in tree.body:
        match node:
            case FunctionDef(
                name,
                args=arguments(args=[arg(arg=varname)])):
                # Refactor function name with variable varname
                function_refactor(node, name, varname)
            case _:
                # skip
                pass
    return tree
```

```
def function_refactor(fct_node, name, varname):
    # Find if-elif-else
    new_body = []
    for node in fct_node.body:
        match node:
            case If(test, body, orelse):
                # Scan for match cases written as if-elif chain
                cases, orelse = scan_if(node, varname,
                                        test, body, orelse)
                if cases:
                    # Refactor to use match instead
                    node = if_refactor(node, varname,
                                       cases, orelse)
            case _:
                # Not an if node
                break
        new_body.append(node)
    fct_node.body = new_body
```

Parsing ASTs: Code

- Scan *if-elif-else* chains recursively:

```
def scan_if(node, varname, test, body, orelse, cases=None):
    # Trick for non-capturing vars
    class params:
        pass
    params.varname = varname
    # Check for possible match refactoring if-candidate
    match test:
        case Call(func=Name(id='isinstance'),
                  args=[Name(id=params.varname),
                        Name(id=typename)]):
            # isinstance(varname, typename)
            new_case = (varname, typename, None, body)
        case BoolOp(op=And(),
                    values=[
                        Call(func=Name(id='isinstance'),
                             args=[Name(id=params.varname),
                                   Name(id=typename)]),
                        condition
                    ]):
            # isinstance(varname, typename) and condition
            new_case = (varname, typename, condition, body)
        case _:
            # Unsupported if-variant
            return cases, node
    # Add new case
    if cases is None:
        cases = []
    cases.append(new_case)
    # Recursively check whether there are more if-elif cases
    match orelse:
        case [If(elif_test, elif_body, elif_orelse) as elif_node]:
            cases, orelse = scan_if(
                elif_node, varname,
                elif_test, elif_body, elif_orelse,
                cases)
        case _:
            pass
    return cases, orelse
```

Parsing ASTs: Code

- Refactor *if-elif-else* into *match* statements:

```
def if_refactor(if_node, varname, cases, orelse):
    # Build match_cases
    case_nodes = [
        match_case(
            pattern=MatchClass(
                cls=Name(id=typename),
                patterns=[],
                kwd_attrs=[],
                kwd_patterns=[]),
                guard=condition,
                body=body)
        for (varname, typename, condition, body) in cases
    ]
    case_nodes.append(
        match_case(
            pattern=MatchAs(),
            body=orelse)
    )

    # Build Match node
    match_node = Match(
        subject=Name(id=varname),
        cases=case_nodes,
    )
    return match_node
```

Parsing ASTs: Fully automatic refactoring

- Example:

```
def example(x):
    if isinstance(x, int) and x > 12:
        print ('Int > 12: {x}')
    elif isinstance(x, float):
        print ('Float: {x}')
    elif isinstance(x, str) and len(x) > 5:
        print ('String with more than 5 chars: {x}')
    else:
        print ('Unknown type: {x}')
```

```
def example(x):
    match x:
        case int() if x > 12:
            print('Int > 12: {x}')
        case float():
            print('Float: {x}')
        case str() if len(x) > 5:
            print('String with more than 5 chars: {x}')
        case _:
            print('Unknown type: {x}')
```

What about performance ?

Name	Match Variant	If Variant	Notes
Int	91	42	
Int capvars	98 (generic) 587 (inlined)	45	*Avoid inlined capvars (?)*
List ints	50	71	
Str	94	43	
Int guards	144	42	
Complex obj with capvars	684 (generic) 3650 (inlined)	274	*Avoid inlined capvars (?)*
Float or int	95	52	

Using Python 3.12. All numbers refer to nanoseconds. See repo for benchmark details

What about performance ?

Name	Match Variant	If Variant	Notes
Int	91	42	
Int capvars	98 (generic) 587 (inlined)	45	*Avoid inlined capvars (?)*
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Int guards	144	42	
Complex obj with capvars	684 (generic) 3650 (inlined)	274	*Avoid inlined capvars (?)*
Float or int	95	52	

Generic: `case int() as a:`
Inlined: `case int(a):`

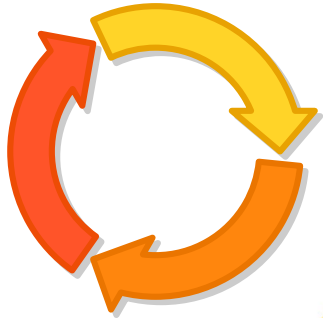
Using Python 3.12. All numbers refer to nanoseconds. See repo for benchmark details

Benchmarking: Conclusions

- *match* is about 2 times slower than *if* in most cases
- *match* shines for sequence matching

```
match obj:
    case [a, b, c]:
        do_something()
```

- Python 3.10 – 3.13: still first implementation of the PEPs
  - No significant optimizations have been applied since
  - Some parts appear to have performance bugs (inlined capvars)



Overall conclusion: Advanced parsing with *match*

- *match* isn't fast (yet)
  - Lot's of room for improvements
- *match* is great for complex parsing tasks where readability counts:

```
if isinstance(obj, int) and obj > 20:
    value = obj
elif (isinstance(obj[0], int) and
      isinstance(obj[1], int) and
      isinstance(obj[2], dict) and
      ('abc' in obj[2]) and
      isinstance(obj[2]['abc'], int) and
      isinstance(obj[3], tuple) and
      isinstance(obj[3][0], int) and
      isinstance(obj[3][1], int) and
      isinstance(obj[3][2], int)):
    [a, b, q1, (d, e, f)] = obj
    c = q1['abc']
else:
    pass
```

```
match obj:
    case int() as value if value > 20:
        pass
    case [int() as a, int() as b,
          {'abc': int() as c},
          (int() as d, int() as e, int() as f)]:
        pass
    case _:
        pass
```

Main takeaway: Never stop learning and trying out new things

Resources

- Talk slides and examples:
  - Github: https://github.com/eGenix/egenix-advanced-match-parsing

- Micro Benchmark Package:
  - Github: https://github.com/eGenix/egenix-micro-benchmark
  - PyPI: https://pypi.org/project/egenix-micro-benchmark/

Thank you for your attention !

Time for discussion

Contact

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References

- Some content taken from:
  - https://py-code.org/stats
  - https://de.wikipedia.org/wiki/Tango_Desktop_Project
- Several photos taken from Pixabay and Unsplash
- Some screenshots taken from the mentioned websites
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