Evolvability Analysis of Multiple Inheritance and Method Resolution Order in Python

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Marek Suchánek (FIT CTU in Prague, FBE UA)
marek.suchanek@fit.cvut.cz

Robert Pergl (FIT CTU in Prague)

FACULTY OF INFORMATION TECHNOLOGY CTU IN PRAGUE

University of Antwerp

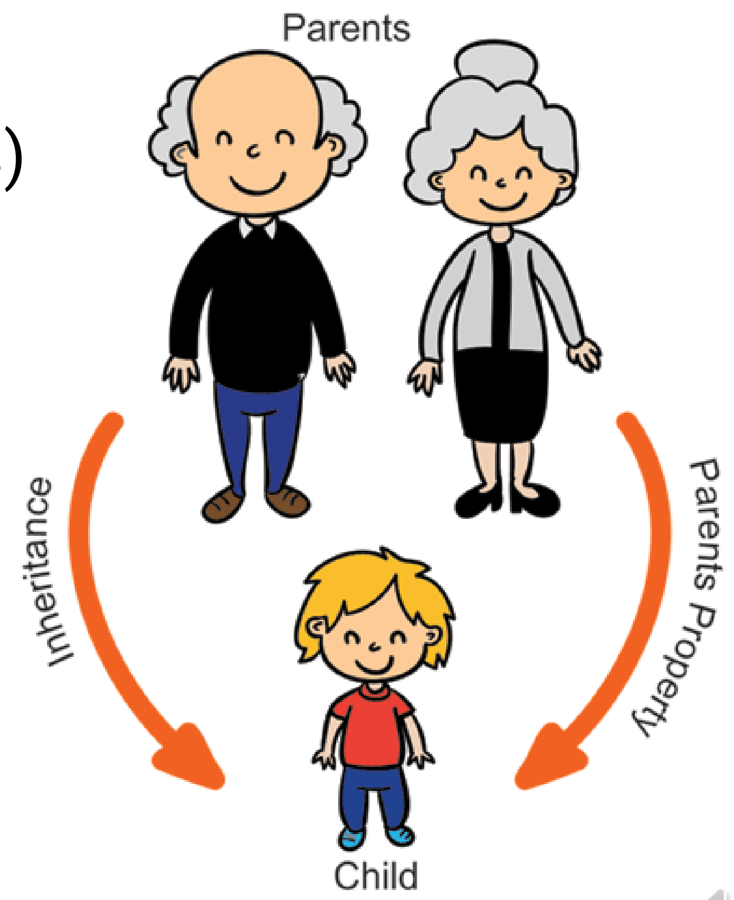
Introduction and Outline

- Speaker: **Marek Suchánek**
  - PhD student at FIT CTU in Prague and FBE University of Antwerp (joint degree)
  - Member of CCMi (Centre for Conceptual Modelling and Implementation)

- Presentation
  1. Concept of Inheritance
  2. Inheritance in Python 3
  3. Inheritance Implementation Patterns
  4. Conclusions and future work

Inheritance in Real-World

- Natural concept in real-world
- Key to evolution (passing properties to next generations)
- Taxonomies (common properties of species)
- Allows us to form abstractions and relate them
- Everyone understands how it works



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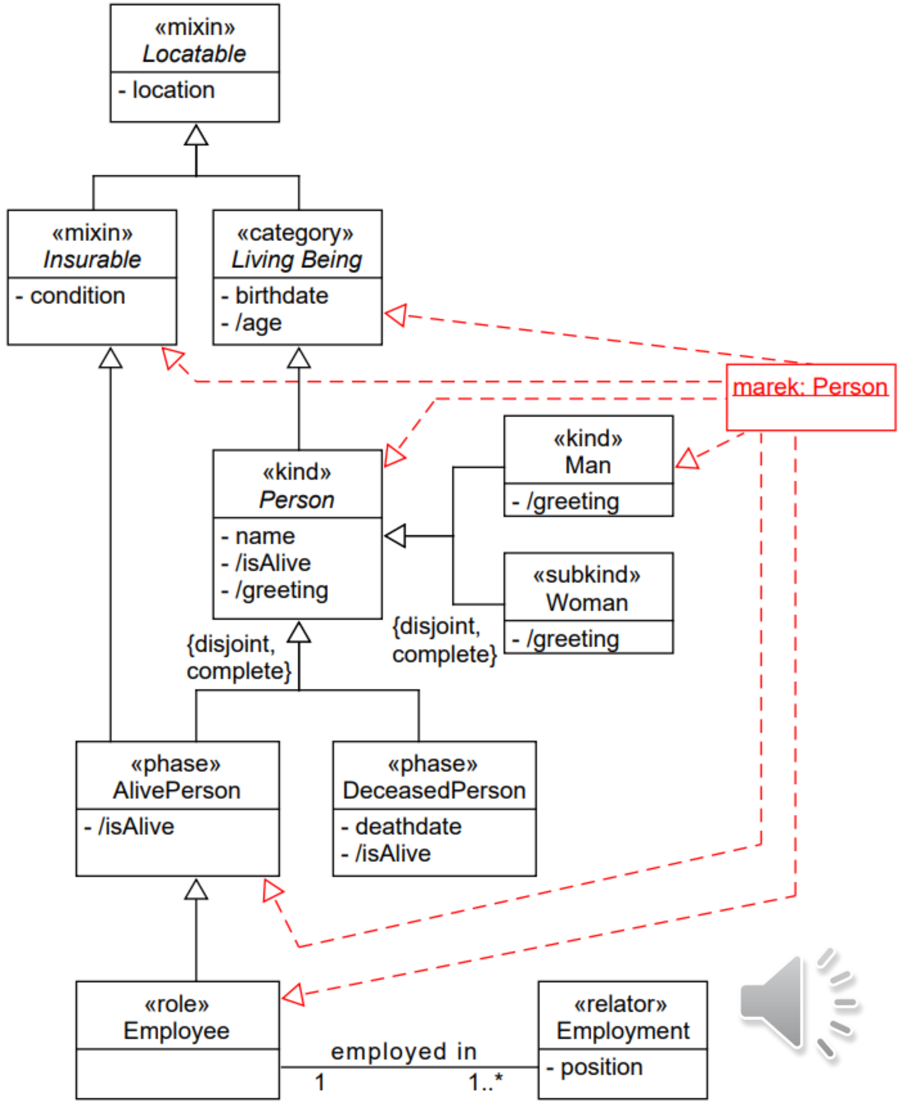
Inheritance in Conceptual Models

- Conceptual models are used to describe reality
- … including inheritance as a key principle
- Different languages provide different/various ways
  - OntoUML
  - UML (class diagram)
  - OWL (owl:subclass)
  - ER (IS-A hierarchies)
- Subtyping, subclassing, etc.
- May be „detached“ from reality, harder to understand



Inheritance in Software Implementation

- In OOP intended to reflect real-world inheritance
- Often abused or mis-used purely for re-use
- DRY principle but with combinatorial effects
- „Composition over inheritance“
- Various implementations and behavior in different languages
- Single inheritance, multiple inheritance, prototyping, interfaces
- Hard to understand (and use correctly)

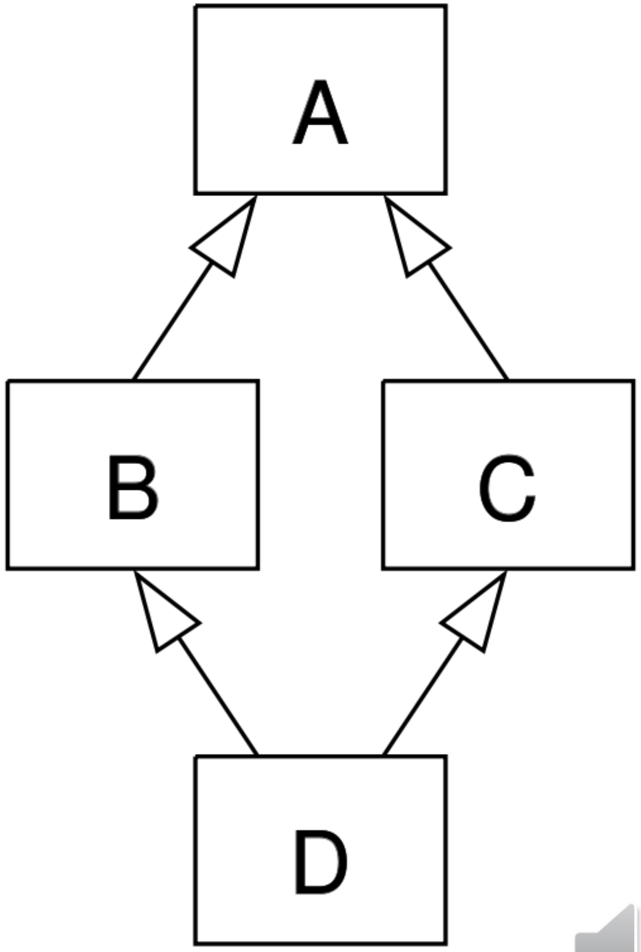
```
class AlivePerson(Person, Insurable):

    def __init__(self, name, birthdate,
        Person.__init__(self, name, birt
        Insurable.__init__(self, conditi

    @property
    def is_alive(self):
        return True
```

Mutliple Inheritance in Python 3

- Python 3 = language suitable for prototyping
- Allows to re-define behaviour of almost everything
- Method Resolution Order
- Concept of metaclasses
- Easy transition to other OOP languages in „production-ready“ stacks such as Java



Inheritance Implementation Patterns

- We described patterns how to implement inheritance based on related work:
  - Union pattern
  - Composition pattern
  - Generalization Set pattern
- Evaluated only on the conceptual-level
- Next goal was to investigate how to use them in implementation:
  - Elimination of combinatorial effects
  - Ease of implementation (overhead)
  - Flexibility for various use cases

Inheritance Implementation Patterns

- **Traditional Inheritance** (multiple with MRO)
- Order of subclassing matters, but the order is usually not modelled
- Changing a class affects all the (direct and indirect) subclasses
- Object can be instance only of a single class
- Imminent combinatorial effect (leading to „combinatorial explosion“)

```
class AlivePerson(Person, Insurable):

    def __init__(self, name, birthdate, location, condition):
        Person.__init__(self, name, birthdate, location)
        Insurable.__init__(self, condition)
```

```
class Woman(Person):

    @property
    def greeting(self):
        return f'Mrs. {self.name}'
```

Inheritance Implementation Patterns

- **Union Pattern**
- Merges whole hierarchy into a single class
- The „order“ is captured while merging
- Changes contained in the class
- Discriminators to toggle subclasses
- To share behavior, delegation can be used
- Can be generated but causes issues when union classes should be split or merged

```
class Person:

    def __init__(self, name, birthdate, location, condition):
        self.location = location
        self.condition = condition
        self.birthdate = birthdate
        self.name = name
        # optional-subclass attributes
        self.employment = None
        self.deathdate = None
        # discriminators
        self._d_man_woman = None
        self._d_alive_deceased = None
        self._d_employee = None
        # superclasses with behaviour
        self._x_living_being = LivingBeing
```

Inheritance Implementation Patterns

- **Composition Pattern**
- Replaces inheritance with delegation
- Easy to generate from a model (may need order)
- Additional rules for generalization sets must be handled using custom code

```
class Delegation:

    def __init__(self, p_name, a_name):
        self.p_name = p_name
        self.a_name = a_name

    def __get__(self, instance, owner):
        p = getattr(instance, f'_parent_{self.p_name}')
        a = getattr(p, self.a_name) if p else None
        return a(instance) if callable(a) else a

    def __set__(self, instance, value):
        p = getattr(instance, f'_p_{self.p_name}')
        setattr(p, self.a_name, value)
```

```
class Person:

    condition = Delegation('insurable', 'condition')
    age = Delegation('living_being', 'age')

    def __init__(self, *, name, **kwargs):
        self._p_living_being = LivingBeing(_c_person=self, **kwargs)
        self._c_man = None
        self._c_woman = None
        self.name = name
```

Inheritance Implementation Patterns

- **Generalization Set Pattern**
- Strives to include GS with composition
- For a set of classes, special GS class may be added
- It holds additional GS constraints and maintains integrity
- Special treatment of overlapping generalization sets
- More complex navigation for delegation

Comparison

Implementation	Classes*	Extra constructs	CE-handling	Issue(s)
Traditional	$N + 2^N$	none	none	initialization, order of superclasses, uncontrolled change propagation
Traditional + `init_bases`	$N + 2^N$	`Init_bases` function	shared initialization	shared attributes across hierarchy, order of superclasses, uncontrolled change propagation
Union	2	`Delegation` class	shared class (merged)	Separation of Concerns violated, maintainability, discriminators
Composition	N	`Delegation` class	shared initialization, delegation	manual handling of GS constraints, added complexity (for humans)
GS	$N + 1$	`Delegation` class, GS helpers	shared initialization, delegation	added complexity (for humans)

*) per single hierarchy of N classes, worst case (all combinations needed)

Conclusions and Future Work

- We revisited and prototyped the inheritance implementation patterns
- Focused on generation from model and maintainability
- Avoid order-related combinatorial effects by solving it upon transformation
- Other change-related combinatorial effect are partially avoided by delegation

- Future work:
  - Prototype and test expansion for inheritance with production-ready stack
  - Inheritance in UI/UX (i.e., how to create instances for hierarchy)

Questions & Discussion