Object Morphology – A Protean Generalization of Object-Oriented Paradigm

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**Abstract.** The abstract should summarize the contents of the paper and should contain at least 70 and at most 150 words. It should be set in 9-point font size and should be inset 1.0 cm from the right and left margins. There should be two blank (10-point) lines before and after the abstract. This document is in the required format.

**Keywords:** We would like to encourage you to list your keywords in this section.

1 Introduction

Philosophical Background

Goals

Literature Review

Methods

Chosen methods reflect the character of the problem, which lies on the border between basic and applied science:

Case studies (one structural, one behavioral)

Evaluation of three OOP languages (Java, Scala, Groovy)

Analysis of problematic aspects identified in the case studies

Generalization of the existing paradigms and methods (OOP, UML, Liskov principle)

Verification through development of P-o-C and its application on a set of problematic scenarios (discussed further)

Theoretical Foundations of OM

This section presents the theoretical foundations of Object Morphology. With respect to its limited scope, this paper introduces the concepts in a rather brief manner with emphasis on intuition. Wherever it is possible, the explanations are accompanied by simple illustrations.

Morph Models

When modeling a protean phenomenon in the outer world, the modeler focuses on the description of the features exhibited by individual instances of the phenomenon. The individual instances may or may not share a set of common features, and even a single instance may not exhibit the same set of features during its existence. A typical example of such a phenomenon is a butterfly and its development; there is little or nothing in common between individual developmental stages, except the butterfly’s identity.

In Object Morphology, the concept of a *fragment* is used to describe a feature of a modeled phenomenon. A fragment can be likened to a potentially complex attribute with possible behavior. In contrast to fragments, attributes hold data only and do not define any behavior, nor do they possess identity. On the other hand, a fragment should not be mistaken for a part of a phenomenon. The reason is that a fragment, in contrast to a part, may constitute or contribute to the identity of its phenomenon, while a part possesses its own identity distinct from its owner’s identity.

A collection of fragments describing a given phenomenon at certain moment is called *alternative*. The individual fragments in the alternative may be *passive* or *active*. A passive fragment’s behavior cannot be influenced by the presence of other fragments, while the behavior of an active fragment can be overridden by other fragments (it is an analogy to final/non-final classes). An instance of an alternative is called a *morph*, which is a representation of a modeled phenomena instance (an analogy to an object).

The collection of all alternatives describing a given phenomenon is called a *morph model*. A morph model is in fact an expression of the concept of the phenomenon. A morph model may describe a phenomenon whose instances are either *immutable* or *mutable*. The immutable instances exhibit the same features until they cease to exist. The individual immutable instances differ in the composition of the fixed feature set, while the diversity of this set among the instances is governed by the morph model. On the other hand, the mutable instances may undergo many mutations during their lifetime, while the only possible mutations are dictated by the morph model.

There may exist one or more disjoint groups of alternatives sharing a certain collection of fragments. These common fragments are called *prototypes* of the morph model and the group sharing a given prototype is called the prototype’s *attractor*. It should be remarked that there may exist more ways to partition a morph model to attractors. Then, it is on the modeler to select the best partitioning.

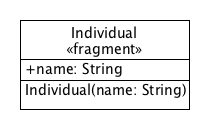
Examples

The rest of this section presents a couple of examples illustrating the-above mentioned concepts. The models in the examples are expressed using the R-Algebra, a mathematical formalism developed in the thesis [REF], used to construct morph model expressions.

The *Person* model in (**1**) represents a person and consists of a single fragment – *Individual*. Such singular models consisting of only one alternative with one fragment virtually correspond to the traditional concept of class.

|  |  |
| --- | --- |
| Person = Individal | (**1**) |

The notation of fragments follows the notation of classes (**Figure** 1). To distinguish the two concepts the fragment notation applies the *fragment* stereotype. It should be reminded that despite the notation similarity, the two concepts are fundamentally different, as a fragment should be seen rather as an attribute on steroids.



**Figure** : Fragment *Person*

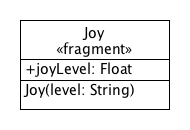
A morph creation can be schematically expressed as shown in the pseudo-code[[1]](#footnote-1) (**2**). The *p* morph can be used in the same way as if it were an instance of a class having the same structure as fragment *Individual*.

|  |  |
| --- | --- |
| p: Person = Individual(“Peter”) | (**2**) |

The model in formula (**3**) models the six basic human emotions. The vertical bar is the *union* operator delimiting mutually exclusive emotions (in terms of this model).

|  |  |
| --- | --- |
| Emotion = Joy | Surprise | Fear | Sadness | Disgust | Anger | (**3**) |

**Figure** 2 shows the structure of the *Joy* fragment. The structure of the remaining emotion fragments is analogous.



**Figure** : Fragment *Joy*

The listing (**4**) sketches two instantiations of emotion morphs.

|  |  |
| --- | --- |
| e1: Emotion = Joy(0.7) e2: Emotion = Surprise(0.2) | (**4**) |

Besides the union operator, the R-Algebra formalism introduces the *join* (.) operator, by which two sub-expressions are declared as co-occurring. To illustrate the join operator let us suppose that the modeler comes to conclusion that the original model is too coarse-grained since it does not include mixed emotions. A finer-grained model may be constructed by joining the original model with itself, as shown in (**5**).

|  |  |
| --- | --- |
| Emotion = (Joy | Surprise | Fear | Sadness | Disgust | Anger). (Joy | Surprise | Fear | Sadness | Disgust | Anger) =  (Joy | Surprise | Fear | Sadness | Disgust | Anger)*2* | (**5**) |

In case of the emotion fragments, both operators fulfill the associativity, commutativity and distributivity law with the join operator as the one being distributed. Besides those, for any two emotion fragments holds that *F.F* = *F* and *F* | *F* = *F*. Applying these rules results in the following *canonical* form of the model.

|  |  |
| --- | --- |
| Emotion = Joy | Surprise | Fear | Sadness | Disgust | Anger | Joy.Surprise | Joy.Fear | Joy.Sadness | Joy.Disgust | Joy.Anger | Surprise.Fear | Surprise.Sadness | Surprise.Disgust | Surprise.Anger | Fear.Sadness | Fear.Disgust | Fear.Anger | Sadness.Disgust | Sadness.Anger | Disgust.Anger | (**6**) |

A morph consisting of *Joy* and *Surprise* emotions may be instantiated as shown in the following pseudo-code:

|  |  |
| --- | --- |
| e1: Emotion = Joy(0.6).Surprise(0.2) | (**7**) |

So far, the example models have dealt with the fragments for which the above-mention R-Algebra rules hold. Such fragments are called *entities*. An important consequence of those rules is that no alternative in a model may consist of two occurrences of the same entity fragment. Besides entities there is another kind of fragments, which are governed by different rules. Such fragment are called *wrappers*, which owe their name to the fact that they can be stacked on top of entity fragments and override their behavior. As a wrapper example, let us consider the morph model in (**8**), which models a path.

|  |  |
| --- | --- |
| Path = Origin.(1 | Move | Left | Right) *N* | (**8**) |

The model includes the *Origin* entity fragment, which encapsulates the origin of the path. The other three fragments *Move*, *Left* and *Right* represent the three basic movement steps. A composition of those three steps results in the transformation of the origin into the end point of the path. For wrappers, the distributive and associative laws still hold, but the commutative law and the rule *F*.*F* = *F* are not guaranteed. A sample path morph evolution is in the listing (**9**).

|  |  |
| --- | --- |
| Origin Origin.Move Origin.Move.Left Origin.Move.Left.Move | (**9**) |

The *1* element in the model represents the so-called *unit fragment*, which plays the role of the unit element in the R-Algebra, for which the rules *1* | *F* = *F* a *1.F* = *F* hold.

The *N* parameter in the exponent determines the maximum number of steps of the paths modeled by the Path model. As long as the model should be able to describe paths consisting of unlimited number of steps, the model would have to be designed recursively, as shown in (**10**).

|  |  |
| --- | --- |
| Path = Origin.(1 | Move | Left | Right).Path | (**10**) |

The morph model of a compass in (**11**) illustrates a use of the so-called *inverse fragments*. The inverse fragment of fragment *F* represents the antipodal feature to the feature represented by *F*. For a fragment and its inverse fragment it holds that *F.~F*=*0*, where 0 is the *null* fragment playing the role of the zero element in R-Algebra.

|  |  |
| --- | --- |
| Compass = (N.~S | W.~E | S.~N | E.~W)*N* | (**11**) |

The fragments *N*, *W*, *S* and *E* represent the four cardinal directions. Unsurprisingly, these fragments are modeled as wrappers, as they can be stacked to express directions more precisely. The fragments prefixed by the tilde correspond to the inverse fragments of the respective directions. Hence, the sub-expression *N*.*~S* expresses the fact that the north fragment may not occur in the same alternative as S. This formula prohibits invalid compositions, such as N.S or W.E.S. These combinations simply cancel out from the model due to the rule *F.~F* = *0*. Just as in (**8**), the *N* coefficient determines the resolution of the compass.

Having constructed the four morph models, it is possible to compose those models and model so a traveller’s mind, as shown in (**12**).

|  |  |
| --- | --- |
| Traveller = Person.Destination.Path.Compass.Emotion | (**12**) |

A traveller’s state of mind includes the concept of the “self” represented by the *Person* model. The traveller is aware of his or her destination represented by the additional entity fragment *Destination*. In contrast to the two preceding models, which may be considered immutable per a traveller’s instance, the remaining models are mutable. The ongoing journey is represented by an evolution of the *Path* model and the current direction to the destination is represented by an alternative of the *Compass* model. The current compass state (alternative) influences the traveller’s decisions and hence the path. The Emotion model reflects various factors, such as the distance from the destination, the weather condition (outer condition example) etc. Its presence may also influence the path decisions. [REF: Řepa]

Morphing Strategies

A morphing strategy is a key concept in OM, which determines the composition of morphs. Whenever a new morph is created or re-morphed, a morphing strategy must be supplied. The morphing strategy is responsible for selecting the model alternative fitting best the outer or inner conditions of the modeled object. Together with a morph model, a morphing strategy forms the so-called *recognizer*. In other words, while a morph model represents the static part of a recognizer, a morphing strategy is its dynamic part. Although it is possible to implement custom strategies, there are three general implementations: *promoting*, *masking* and *rating* strategies [REF].

A key property of morphing strategies is their composability; they do not have to provide the definite decision on which alternative is the winner. Instead, a strategy may constrain its decision on a certain sub-model of the main morph model. The final strategy then may be composed of several partial strategies.

Prototypical Analysis

As mentioned in the introduction, one of the main motivations of this work is the inability of object-oriented programming to provide a prototypical conceptual framework that would be more suitable for modeling every-day phenomena. It has also been suggested that object morphology could help close that gap.

So far only the theoretical aspects of object morphology have been examined without explicit connection to any prototypical conceptual framework. Although it is too early to establish a full-blown methodical manual for prototypical analysis through object morphology, some essential guidelines may already be recognized and formulated. The following list outlines the basic steps of performed when analyzing and modeling a protean phenomenon.

1. Understanding Phenomena
2. Identifying Prototypes
3. Property Analysis
4. Morph Model Construction
5. Binding Properties to Context
6. Morphing Strategy Construction
7. Creating Recognizer

The steps 1-4 constitute conceptual analysis, as they establish the analyzed concept. On the other hand, the remaining steps represent contextual analysis that captures the relationship between the morph model and its context. The result artifact of this process is the recognizer, which is a composition of the morph model and the morphing strategy. The recognizer serves to create morphs according to outer conditions, i.e. the context. It is also responsible for reshaping the morphs as a result of changes in their inner state or in the context.

Reference Implementation

The goal of the presented thesis is not only to develop the theoretical concept of object morphology but also to provide a reference implementation (RI) as a proof-of-concept prototype [REF]. The RI is developed as an extension of the Scala programming language and consists of two main components: compile-time and run-time. The compile-time component parses and validates morph models expressed by means of a special type, while the run-time component instantiates objects according to morph models. Because of the chosen language, developers may enjoy the interoperability with other code developed in any language running on the Java Virtual Machine platform.

Applications

Onto UML

DCI

Square-Rectangle Problem

Modeling Facial Emotions

Further Work

Theoretical aspects: identity, R-Algebra for wrappers, recursive models

Practical aspects: a type system based on the generalized LSP, quantitative aspects (i.e. not only what-it-is, but also how-much-it-is)

Discussion

1. The pseudo-code in this section is inspired by Scala, which is the language on top of which the proof-of-concept implementation of OM is developed. [↑](#footnote-ref-1)