Category Theory

Ivan Murashko

July 18, 2018

Contents

Introduction

There is an introduction to Category Theory.

Chapter 1

Base definitions

1.1 Definitions

1.1.1 Object

Definition 1.1 (Class)**.** A class is a collection of sets (or sometimes other mathematical objects) that can be unambiguously defined by a property that all its members share.

Definition 1.2 (Object)**.** In category theory object is considered as something that does not have internal structure (aka point) but has a property that makes different objects belong to the same Class

Remark 1.3 (Class of Objects)**.** The Class of Objects will be marked as $\mathrm{ob}(C)$

1.1.2 Morphism

Morphism is a kind of relation between 2 Objects.

Definition 1.4 (Morphism)**.** A relation between two Objects a and b

$$f_{ab} : a \to b$$

is called *morphism*. Morphism assumes a direction i.e. one Object (a) is called *source* and another one (b) *target*.

Morphisms have several properties. [1]

[1] The properties don't have any proof and postulated as axioms

Property 1.5 (Composition)**.** *If we have 3 Objects a, b and c and 2 Morphisms*

$$f_{ab} : a \to b$$

and

$$f_{bc} : b \to c$$

then there exists Morphism

$$f_{ac} : a \to c$$

such that

$$f_{ac} = f_{bc} \circ f_{ab}$$

Remark 1.6 (Composition)**.** The equation

$$f_{ac} = f_{bc} \circ f_{ab}$$

means that we apply f_{ab} first and then we apply f_{bc} to the result of the application i.e. if our objects are sets and $x \in a$ then

$$f_{ac}(x) = f_{bc}(f_{ab}(x)),$$

where $f_{ab}(x) \in b$.

Property 1.7 (Associativity)**.** *The Morphisms Composition (Property 1.5) s should follow associativity property:*

$$f_{ce} \circ (f_{bc} \circ f_{ab}) = (f_{ce} \circ f_{bc}) \circ f_{ab} = f_{ce} \circ f_{bc} \circ f_{ab}.$$

Definition 1.8 (Identity morphism)**.** For every Object a we define a special Morphism $\mathbf{1}a : a \to a$ with the following properties: $\forall f_{ab} : a \to b$

$$\mathbf{1}a \circ f_{ab} = f_{ab}$$

and $\forall f_{ba} : b \to a$

$$f_{ba} \circ \mathbf{1}a = f_{ba}.$$

This morphism is called *identity morphism.*

Definition 1.9 (Commutative diagram)**.** A commutative diagram is a diagram of Objects (also known as vertices) and Morphisms (also known as arrows or edges) such that all directed paths in the diagram with the same start and endpoints lead to the same result by composition

The following diagram commutes if $f_{ab} = f_{cb} \circ f_{ac}$.

$$\begin{tikzcd} A \arrow[rr, "f_{ab}"] \arrow[dr, "f_{ac}"'] & & B \\ & C \arrow[ur, "f_{cb}"'] & \end{tikzcd}$$

Remark 1.10 (Class of Morphisms)**.** The Class of Morphisms will be marked as hom(C)

Definition 1.11 (Monomorphism)**.** If $\forall g_1, g_2$ the equation

$$f \circ g_1 = f \circ g_2$$

leads to

$$g_1 = g_2$$

then f is called *monomorphism*.

Definition 1.12 (Epimorphism)**.** If $\forall g_1, g_2$ the equation

$$g_1 \circ f = g_2 \circ f$$

leads to

$$g_1 = g_2$$

then f is called *epimorphism*.

1.1.3 Category

Definition 1.13 (Category)**.** A category **C** consists of

- Class of Objects ob(C)
- Class of Morphisms hom(C) defined for ob(C), i.e. each morphism f_{ab} from hom(C) has both source a and target b from ob(C)

Equality of objects

via unique isomorphism

Equality of morphisms

TBD

1.2 Examples

There are several examples of categories that will also be used later

1.2.1 Set category

Example 1.14 (Set category)**.** *In the set category we consider a set of sets where Objects are sets and Morphisms are functions between the sets.*

Remark 1.15 (Set vs Category)**.** There is an interesting relation between sets and categories. In both we consider objects(sets) and relations between them(morphisms/functions).

In the set theory we can get info about functions by looking inside the objects(sets) aka use “microscope” [1]

Contrary in the category theory we initially don’t have info about object internal structure but can get it using the relation between the objects i.e. using Morphisms. In other words we can use “telescope” [1] there.

Definition 1.16 (Surjection)**.** The function $f : X \to Y$ is surjective (or onto) if $\forall y \in Y$, $\exists x \in X$ such that $f(x) = y$.

Remark 1.17 (Surjection vs Epimorphism)**.** TBD

Definition 1.18 (Injection)**.** The function $f : X \to Y$ is injective (or one-to-one function) if $\forall x_1, x_2 \in X$, such that $x_1 \neq x_2$ then $f(x_1) \neq f(x_2)$.

Remark 1.19 (Injection vs Monomorphism)**.** TBD

1.2.2 Hask category

TBD

Chapter 2

Initial and terminal objects

TBD

Chapter 3

Product and sum

TBD

Chapter 4

Functors

TBD

Chapter 5

Monads

TBD

Index

Bibliography

[1] Milewski, B. Category Theory for Programmers / B. Milewski. — Bartosz Milewski, 2018. — https://github.com/hmemcpy/milewski-ctfp-pdf/releases/download/v0.7.0/category-theory-for-programmers.pdf.