How FP Deals With Effects

PoolC 양제성

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목차

1st Session

1. 함수형 프로그래밍 Intro
   - Overall Structure
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2. SW 엔지니어링의 목표
   - SW Maintainability
   - FP vs OOP vs PP
3. FP는 정말 순수한가?
   - Purity of Functions
   - File I/O Scenario

`Basic Haskell Knowledge`

2nd Session

1. 함수 합성을 위한 도구들
   - Partial Application
   - Kleisli Composition
2. ...중 하나인 모나드
   - Functor to Monad
   - IO Monad
3. 부수 효과의 관리
   - Action / Calculation / Data
   - Preventing Action Propagation

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Overall Structure

FP is all about **composing pure functions**.

```
int main(void) {
  f(); g(); h(); ..
}
```

[Procedural Promramming]

VS

```
f(g(h(..)))
```

[Functional Programming]

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Overall Structure

How?

FP is all about **composing pure functions**.

```c
int main(void) {
  f(); g(); h(); ..
}
```

VS

```
f(g(h(..)))
```

[Procedural Promramming]

[Functional Programming]

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Overall Structure

Sum all. [`stdin <- "5\n1 2 3 4 5"`]

C++ (imperative)

```cpp
int main() {
  int n, result;
  std::cin >> n;
  for (size_t i = 0; i < n; ++i) {
    int a;
    std::cin >> a;
    result += a;
  }
  std::cout << result << '\n';
  return 0;
}
```

[Procedural Promramming]

Haskell (declarative)

```haskell
main =
  interact
    (show . sum .
      map read . drop 1 . words)
```

Python3 (declarative)

```python
from sys import stdin

print(sum(map(
  int, stdin.read().split()[1:]
)))
```

[Functional Programming]

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Overall Structure

1. Purity
   - Side Effect
   - Referential Transparency
   - Significance of …

2. Immutability
   - Recursion (feat. Tail Call Optimization)
   - C vs Haskell in File IO

3. First Class Function
   - Currying
   - Linked List

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Overall Structure

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<Let’s code!>

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Historical Review (CS + Math)

Lambda Calculus

1. Very Basics
2. Boolean in Action

Category Theory

1. Very Basics
2. Functor in Action

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Lambda Calculus

Function Encoding

1. Variables (Immutable)
2. Functions (Curried)
3. Application

⇔ `Turing Machine`

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Lambda Calculus

Function Encoding

1. Variables (Immutable)
2. Functions (Curried)
3. Application

$\Leftrightarrow$ `Turing Machine`

$$\lambda x.fx$$

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Lambda Calculus

Function Encoding

1. Variables (Immutable)
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3. Application

$\Leftrightarrow$ `Turing Machine`

$$\underline{\lambda x.fx}$$

Lambda Abstraction

`Py ver. lambda x: f(x)  |  JS ver. (x) => f(x)`

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Lambda Calculus

Function Encoding

1. Variables (Immutable)
2. Functions (Curried)
3. Application

$\Leftrightarrow$ `Turing Machine`

Function Signifier $\longleftarrow$ $\underline{\lambda x . f x}$

Lambda Abstraction

`Py ver. lambda x: f(x) | JS ver. (x) => f(x)`

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Lambda Calculus

Function Encoding

1. Variables (Immutable)
2. Functions (Curried)
3. Application

$\Leftrightarrow$ `Turing Machine`

Parameter Variable

Function Signifier $\longleftarrow$ $\underbrace{\lambda x . f x}_{\text{Lambda Abstraction}}$

Py ver. `lambda x: f(x)` | JS ver. `(x) => f(x)`

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Lambda Calculus

Function Encoding

1. Variables (Immutable)
2. Functions (Curried)
3. Application

$\Longleftrightarrow$ `Turing Machine`

Parameter Variable

Function Signifier $\longleftarrow$ $\underbrace{\lambda x . f x}_{\text{Lambda Abstraction}}$ $\longrightarrow$ Return <u>Expression</u>

Lambda Abstraction

`Py ver. lambda x: f(x)  |  JS ver. (x) => f(x)`

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Lambda Calculus

Function Encoding

1. Variables (Immutable)
2. Functions (Curried)
3. Application

$\Leftrightarrow$ `Turing Machine`

$$
\begin{aligned}
\text{expression} ::= &\ \text{variable} && \textit{identifier} \\
|&\ \text{expression expression} && \textit{application} \\
|&\ \lambda\ v_1 v_2 \cdots .\ \text{expression} && \textit{abstraction} \\
|&\ (\ \text{expression}\ ) && \textit{grouping}
\end{aligned}
$$

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Lambda Calculus

β-reduction

$$((\lambda a.a)\lambda b.\lambda c.b)(x)\lambda e.f$$
$$= (\lambda b.\lambda c.b)(x)\lambda e.f$$
$$= (\lambda c.x)\lambda e.f$$
$$= x \ (\beta\text{-normal form})$$

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Lambda Calculus

Function Encoding

1. Variables (Immutable)
2. Functions (Curried)
3. Application

⇔ Turing Machine

ex) Church Encoding: Boolean JS

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Category Theory

"Mathematics is the art of giving
the **same name** to **different things**"

Henri Poincaré

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Category Theory

Abstraction!

"Mathematics is the art of giving
the **same name** to **different things**"

Henri Poincaré

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Category Theory

Abstraction of numbers	→	Elementry Algebra
Abstraction of relationships	→	Graph Theory
Abstraction of vectors and their linear relationships	→	Linear Algebra

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Category Theory

Abstraction of composition	→	**Category Theory**
Abstraction of numbers	→	Elementry Algebra
Abstraction of relationships	→	Graph Theory
Abstraction of vectors and their linear relationships	→	Linear Algebra

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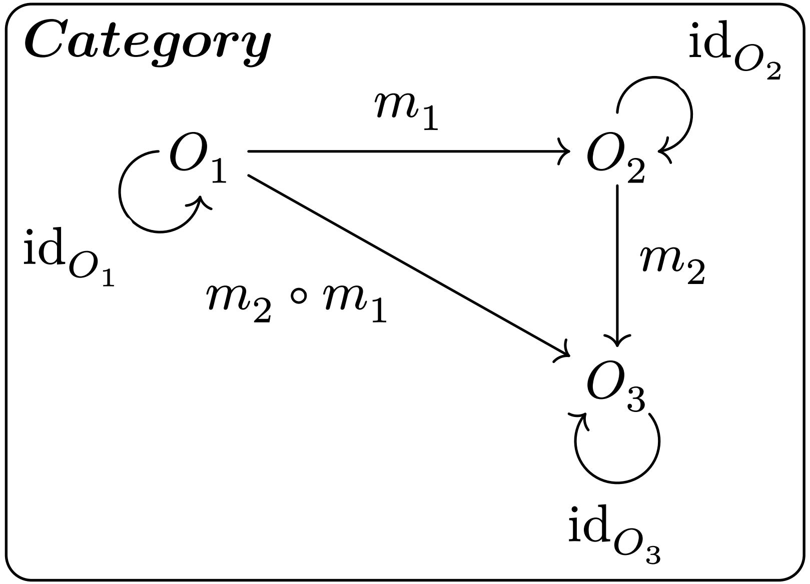
Category Theory

A **category** is a collection of...

Components
Objects
Morphisms (a.k.a. Arrows)
Composition of morphisms



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Category Theory

A **category** is a collection of...

Components	**For example...**
Objects	$\mathbb{Q},\ \mathbb{P} = \mathbb{R} - \mathbb{Q},\ i\mathbb{R} = \mathbb{C} - \mathbb{R}$
Morphisms (a.k.a. Arrows)	$f : \mathbb{Q} \to \mathbb{P},\ g : \mathbb{P} \to i\mathbb{R}$
Composition of morphisms	$g \circ f : \mathbb{Q} \to i\mathbb{R}$

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Category Theory

$\boldsymbol{C}$

$$
\begin{tikzcd}
\mathbb{Q} \arrow[r, "f(x) = x + \pi"] \arrow[dr, "g \circ f"'] \arrow[loop left, "\mathrm{id}_{\mathbb{Q}}"] & \mathbb{P} \arrow[d, "g(x) = xi"] \arrow[loop right, "\mathrm{id}_{\mathbb{P}}"] \\
& i\mathbb{R} \arrow[loop below, "\mathrm{id}_{i\mathbb{R}}"]
\end{tikzcd}
$$

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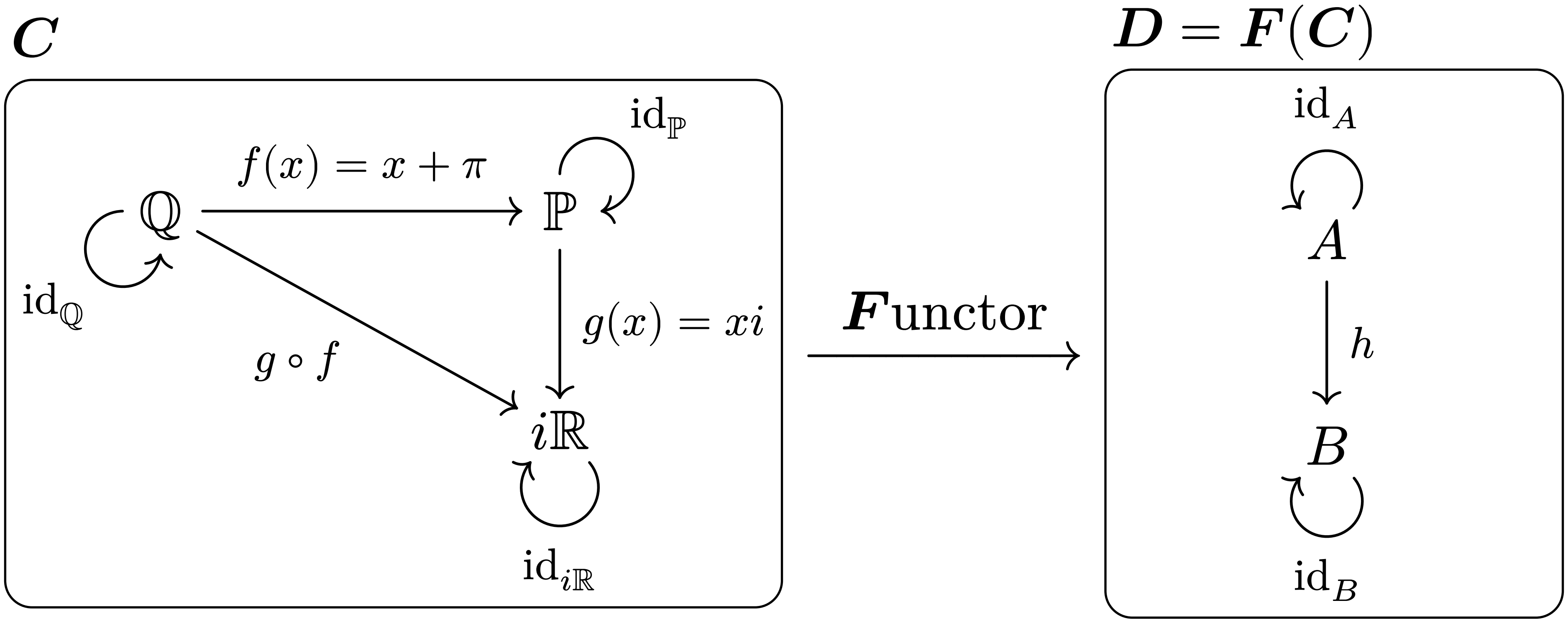
Category Theory



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Category Theory

$\boldsymbol{C}$

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\mathbb{Q} \arrow[loop left, "\mathrm{id}_{\mathbb{Q}}"] \arrow[r, "f(x) = x + \pi"] \arrow[dr, "g \circ f"'] & \mathbb{P} \arrow[loop right, "\mathrm{id}_{\mathbb{P}}"] \arrow[d, "g(x) = xi"] \\
 & i\mathbb{R} \arrow[loop below, "\mathrm{id}_{i\mathbb{R}}"]
\end{tikzcd}
$$

$$\xrightarrow{\boldsymbol{F}\text{unctor}}$$

$\boldsymbol{F}(\boldsymbol{C})$

$$
\begin{tikzcd}
F(\mathbb{Q}) \arrow[loop above, "F(\mathrm{id}_{\mathbb{Q}})"] \arrow[r, "F(f)"] \arrow[dr, "F(g \circ f)"'] & F(\mathbb{P}) \arrow[loop above, "F(\mathrm{id}_{\mathbb{P}})"] \arrow[d, "F(g)"] \\
 & F(i\mathbb{R}) \arrow[loop below, "\mathrm{id}_{i\mathbb{R}}"]
\end{tikzcd}
$$

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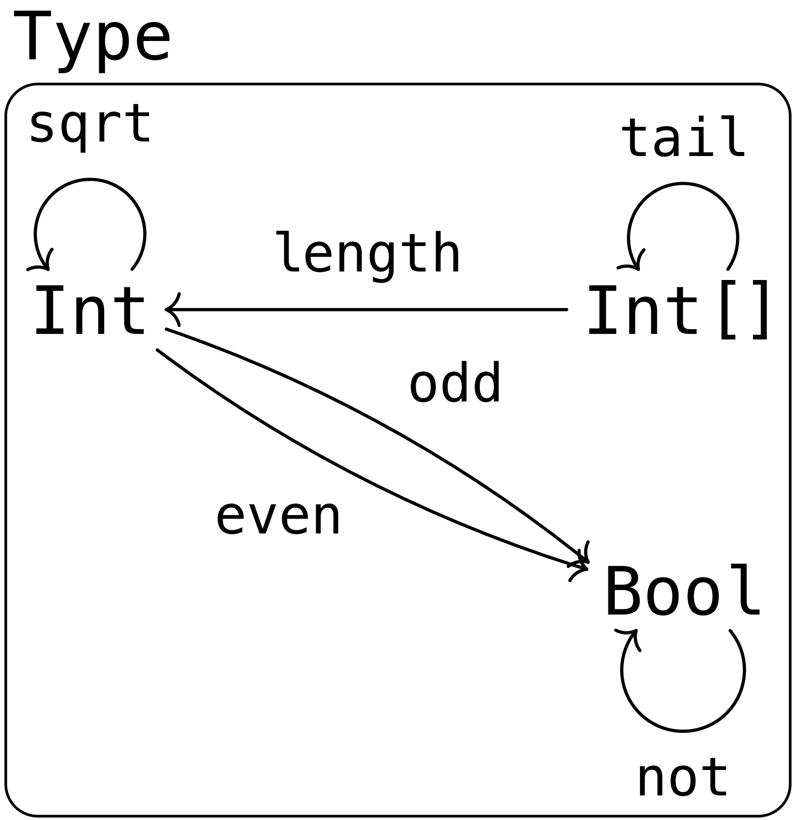
Category Theory



... let's ignore undefined situations

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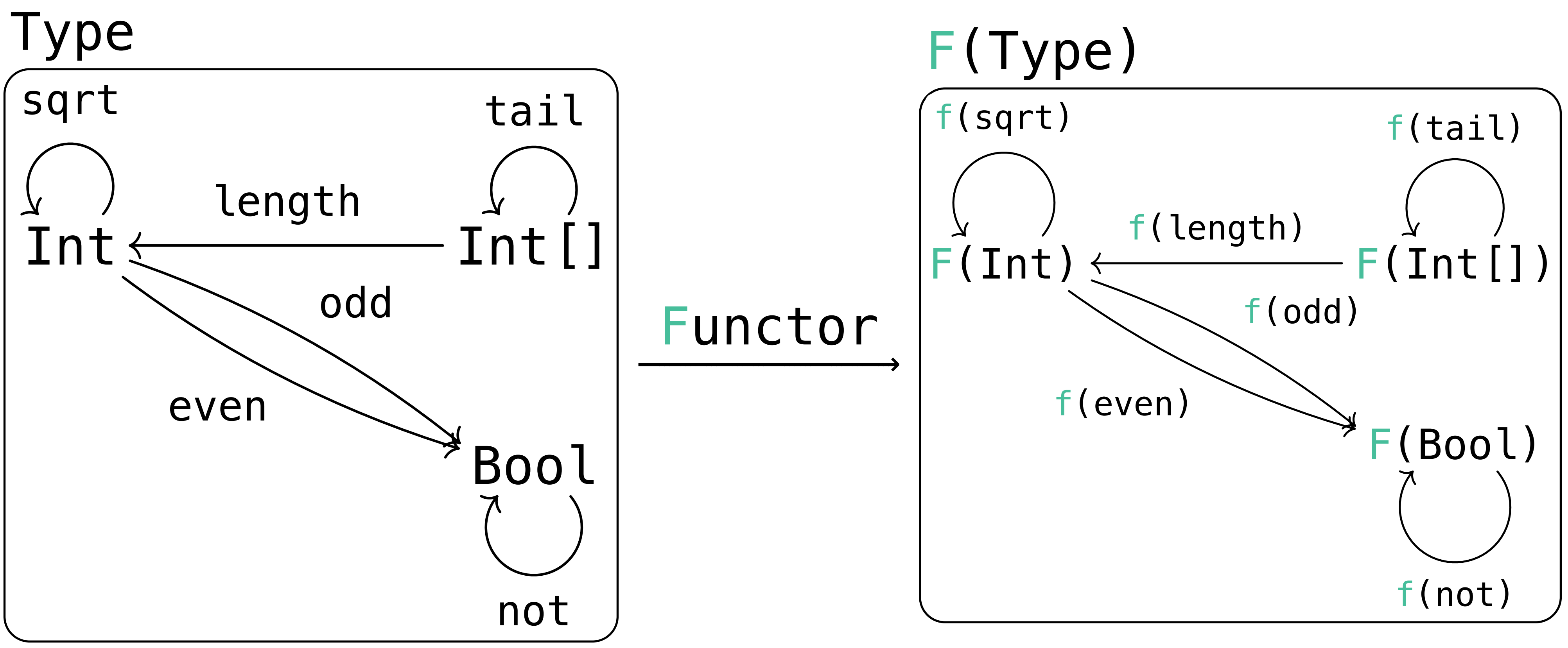
Category Theory



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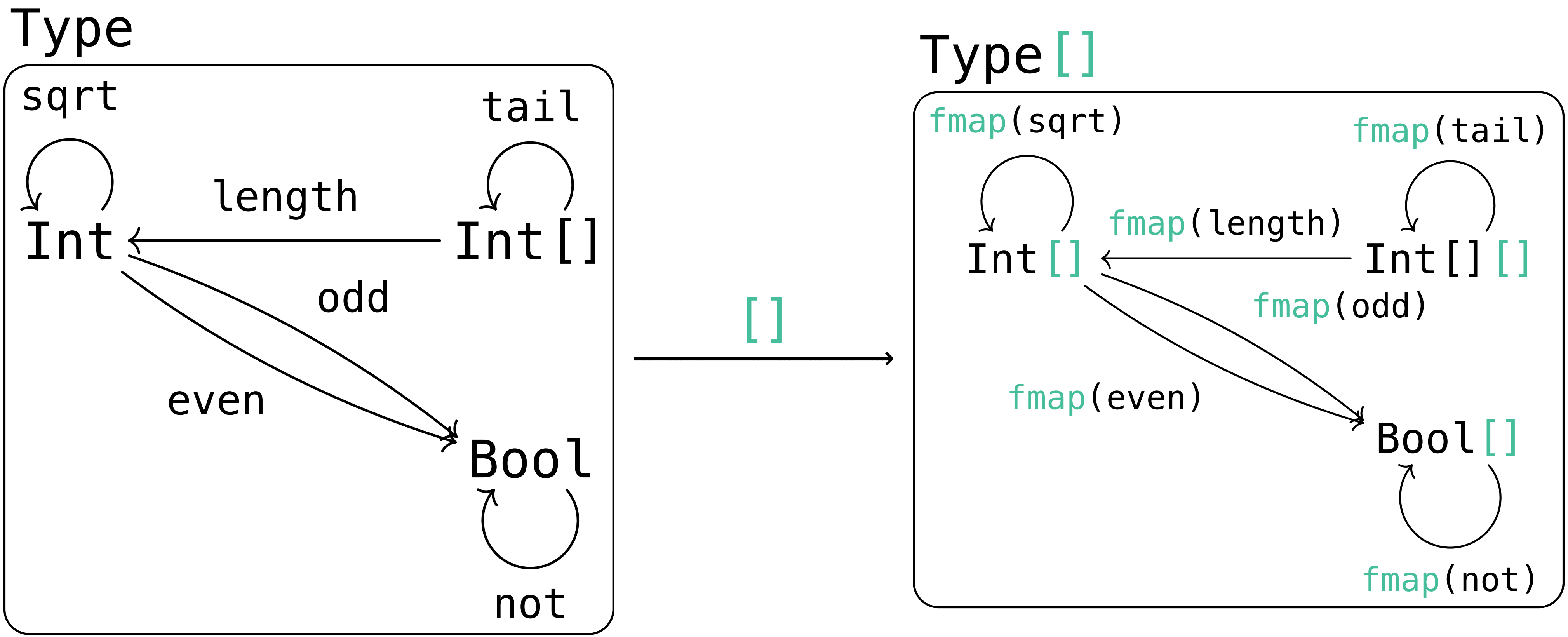
Category Theory



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