Linguagem C++ II

15/12/2025

Ficheiro ZIP

- Está disponível no Moodle um ficheiro ZIP de suporte aos tópicos de hoje
- Diferentes classes simples, exemplificando o overloading de operadores, a criação de classes derivadas, o polimorfismo, e as classes genéricas --- que podem explorar e utilizar

Sumário

- Classes
- Classes Derivadas – Herança
- Polimorfismo
- Classes Genéricas
- Referência

Classes

C++ – Classes e Objetos

- Atributos de instância vs Atributos de classe (**static**)
- Métodos de instância vs Métodos de classe (**static**)
- Visibilidade: **private**, **protected**, **public**
- O ponteiro **this** – referência para o objeto que invoca o método
- O qualificador **const**
- O qualificador **friend**

C++ – Classes e Objetos

- Construtores
- Destrutor – quando é necessário ?
- Construtor de Cópia (**Copy Constructor**) – quando é necessário ?
- Operador de Atribuição (**operator =**) – quando é necessário ?

- Getters e Setters

- Overloaded operators : **operator ==**, **operator <**, etc.

- Output : **friend operator <<**

Exemplo – A classe Fraction

Fraction.h

- Métodos públicos
- Construtores
- Qualificar como const os argumentos e métodos que não alterem atributos
- Passar por referência os objetos que são argumentos

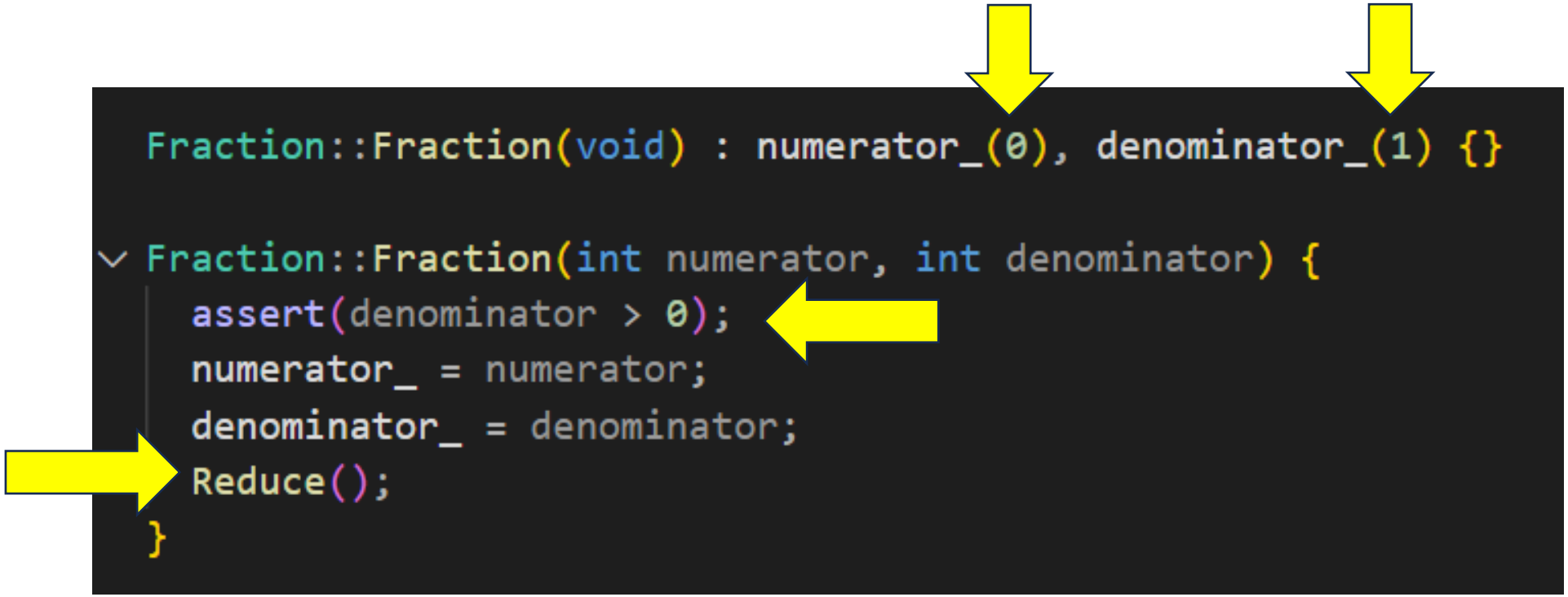
```
class Fraction {
 public:
  Fraction(void);
  Fraction(int numerator, int denominator = 1);

  int GetNumerator(void) const;
  void SetNumerator(int n);

  int GetDenominator(void) const;
  void SetDenominator(int n);

  // Comparison operators
  bool operator==(const Fraction& frac) const;
  bool operator!=(const Fraction& frac) const;
  bool operator<(const Fraction& frac) const;
```

Fraction.h

```
    // Binary operators
    Fraction operator+(const Fraction& frac) const;
    Fraction operator-(const Fraction& frac) const;
    Fraction operator*(const Fraction& frac) const;
    Fraction operator/(const Fraction& frac) const;

    double ToDouble(void) const;

    friend std::ostream& operator<<(std::ostream& out, const Fraction& frac);

  private:
    void Reduce(void);

    int numerator_;
    int denominator_;  // ALWAYS POSITIVE !!!
};
```

- Operadores Aritméticos !
- Método friend !
- Método privado !

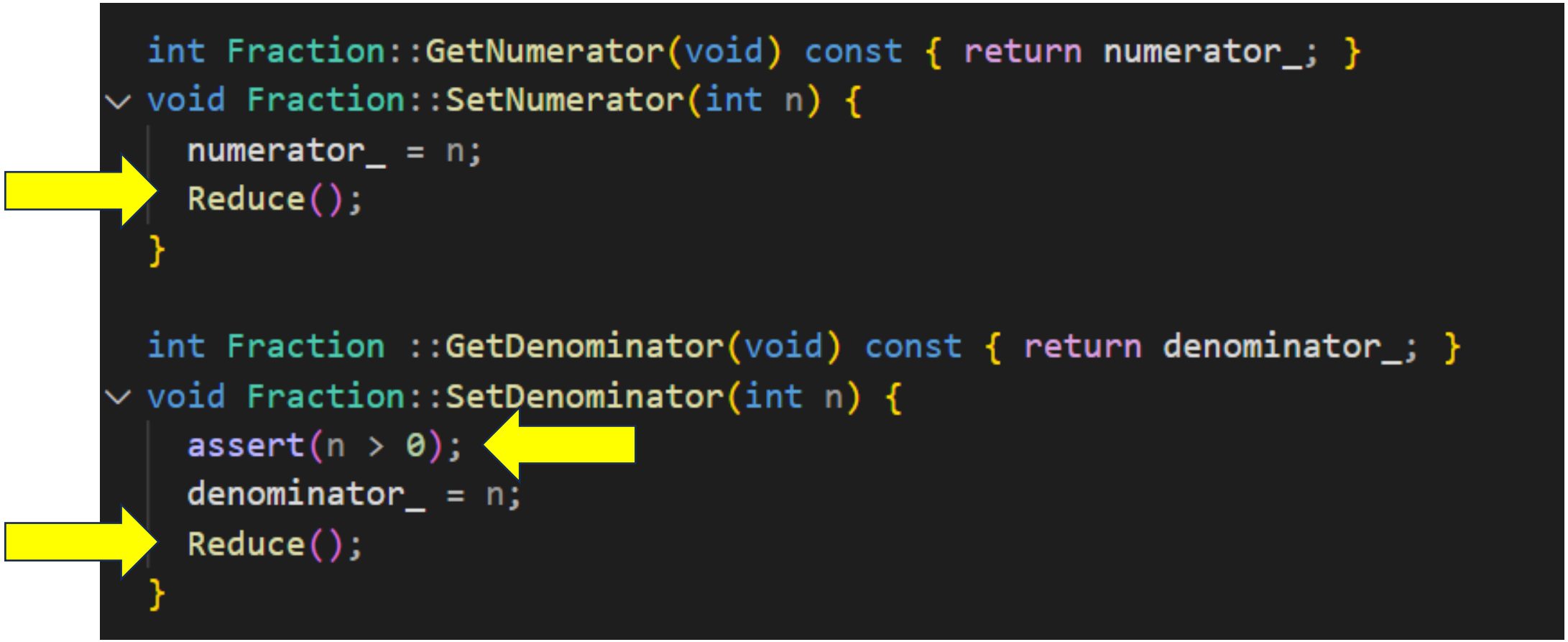
Fraction.cpp – Construtores



```
Fraction::Fraction(void) : numerator_(0), denominator_(1) {}

Fraction::Fraction(int numerator, int denominator) {
  assert(denominator > 0);
  numerator_ = numerator;
  denominator_ = denominator;
  Reduce();
}
```

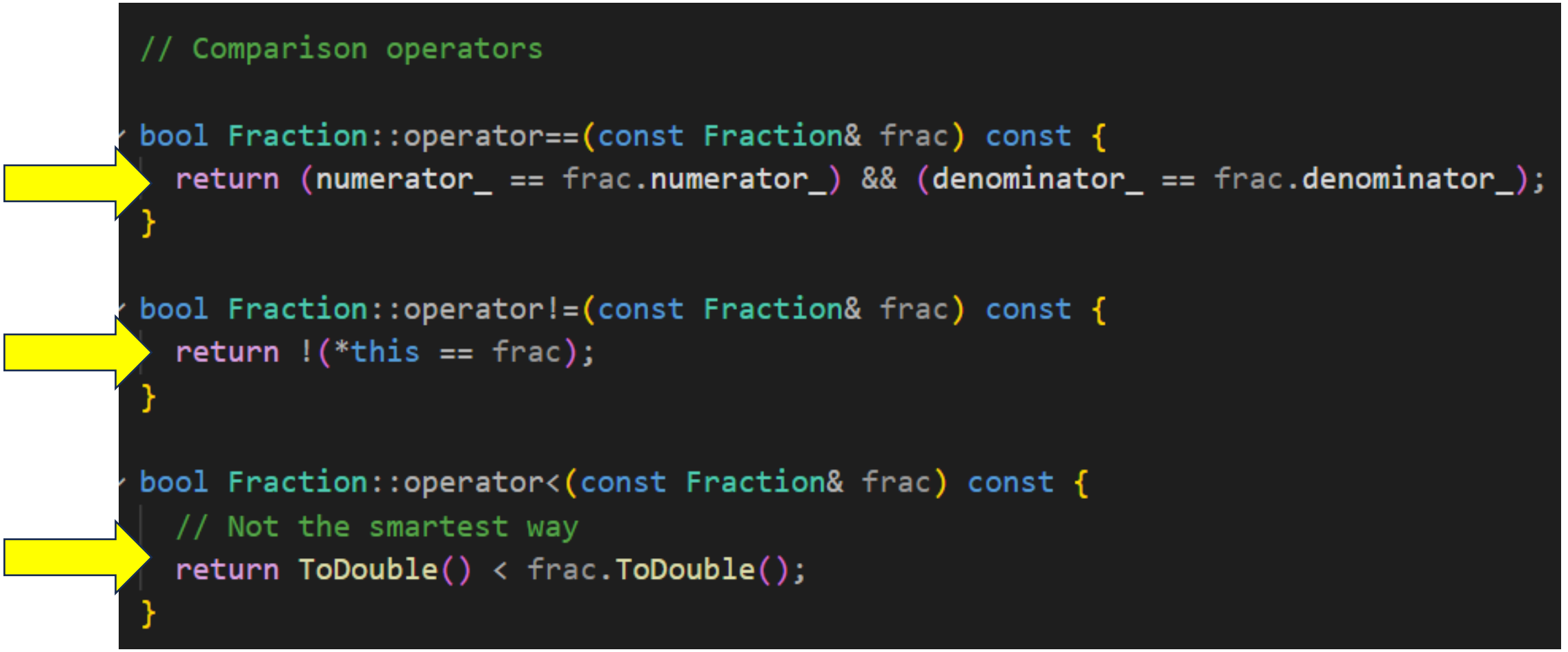
- Lista de inicialização dos atributos
- Representar cada fração usando o menor denominador possível

Fraction.cpp – Getters + Setters



```
int Fraction::GetNumerator(void) const { return numerator_; }
void Fraction::SetNumerator(int n) {
    numerator_ = n;
    Reduce();
}

int Fraction ::GetDenominator(void) const { return denominator_; }
void Fraction::SetDenominator(int n) {
    assert(n > 0);
    denominator_ = n;
    Reduce();
}
```

Fraction.cpp – Operadores de comparação



```cpp
// Comparison operators

bool Fraction::operator==(const Fraction& frac) const {
    return (numerator_ == frac.numerator_) && (denominator_ == frac.denominator_);
}

bool Fraction::operator!=(const Fraction& frac) const {
    return !(*this == frac);
}

bool Fraction::operator<(const Fraction& frac) const {
    // Not the smartest way
    return ToDouble() < frac.ToDouble();
}
```

Fraction.cpp – Operadores aritméticos

```cpp
// Unary operator

Fraction Fraction::operator-(void) const {
  Fraction res(-numerator_, denominator_);
  return res;
}

// Binary operators
Fraction Fraction::operator+(const Fraction& frac) const {
  Fraction res(*this);
  if (res.denominator_ == frac.denominator_) {
    res.numerator_ += frac.numerator_;
  } else {
    res.numerator_ =
        res.numerator_ * frac.denominator_ + frac.numerator_ * res.denominator_;
    res.denominator_ *= frac.denominator_;
  }
  res.Reduce();
  return res;
}
```

- Obter a fração simétrica
- O construtor de cópia foi criado de modo automático

Fraction.cpp – Operadores aritméticos

```
Fraction Fraction::operator-(const Fraction& frac) const {
  return *this + (-frac);
}

Fraction Fraction::operator*(const Fraction& frac) const {
  Fraction res(*this);

  res.numerator_ *= frac.numerator_;
  res.denominator_ *= frac.denominator_;

  res.Reduce();
  return res;
}
```

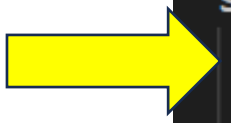
- O operador de subtração é implementado usando operadores já definidos

Fraction.cpp – Operadores aritméticos

```
Fraction Fraction::operator/(const Fraction& frac) const {
  assert(frac.numerator_ != 0);

  Fraction res(*this);

  res.numerator_ *= frac.denominator_;
  res.denominator_ *= frac.numerator_;

  // Ensure the denominator is POSITIVE
  if (res.denominator_ < 0) {
    res.numerator_ *= -1;
    res.denominator_ *= -1;
  }

  res.Reduce();
  return res;
}
```

Fraction.cpp – Métodos auxiliares

```cpp
double Fraction::ToDouble(void) const {
  return (double)numerator_ / (double)denominator_;
}

std::ostream& operator<<(std::ostream& os, const Fraction& frac) {
  os << frac.numerator_ << " / " << frac.denominator_;
  return os;
}

void Fraction::Reduce(void) {
  int gcd = std::gcd(numerator_, denominator_);  // Since C++17

  if (gcd != 1) {
    numerator_ /= gcd;
    denominator_ /= gcd;
  }
}
```




Fraction – Exemplos de utilização

```
Fraction zero;  // Has value ZERO
Fraction fraction_1;
Fraction fraction_2(5);
Fraction fraction_3(2, 4);

std::cout << "1st fraction: " << fraction_1 << " = " << fraction_1.ToDouble()
          << std::endl;

std::cout << fraction_1 << " is equal to " << fraction_3;
std::cout << " : " << std::boolalpha << (fraction_2 == fraction_3)
          << std::endl;

// Arithmetic operations

std::cout << fraction_2 << " + " << fraction_3;
std::cout << " = " << fraction_2 + fraction_3 << std::endl;
```

Tarefas

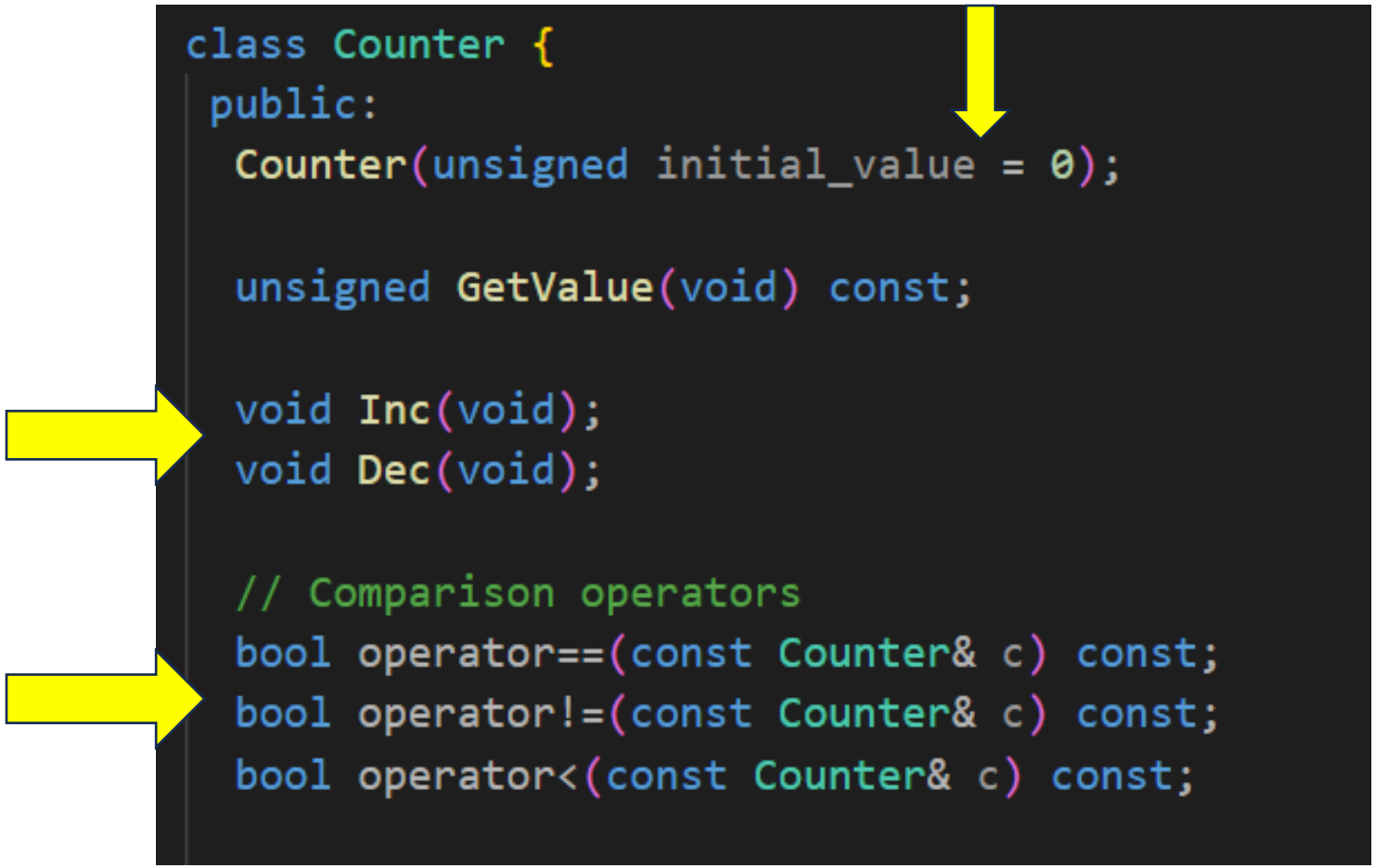
- Analisar o código da classe Fraction
- Desenvolver outros exemplos de utilização

Classes Derivadas

Exemplo
– Counter & LimitedCounter

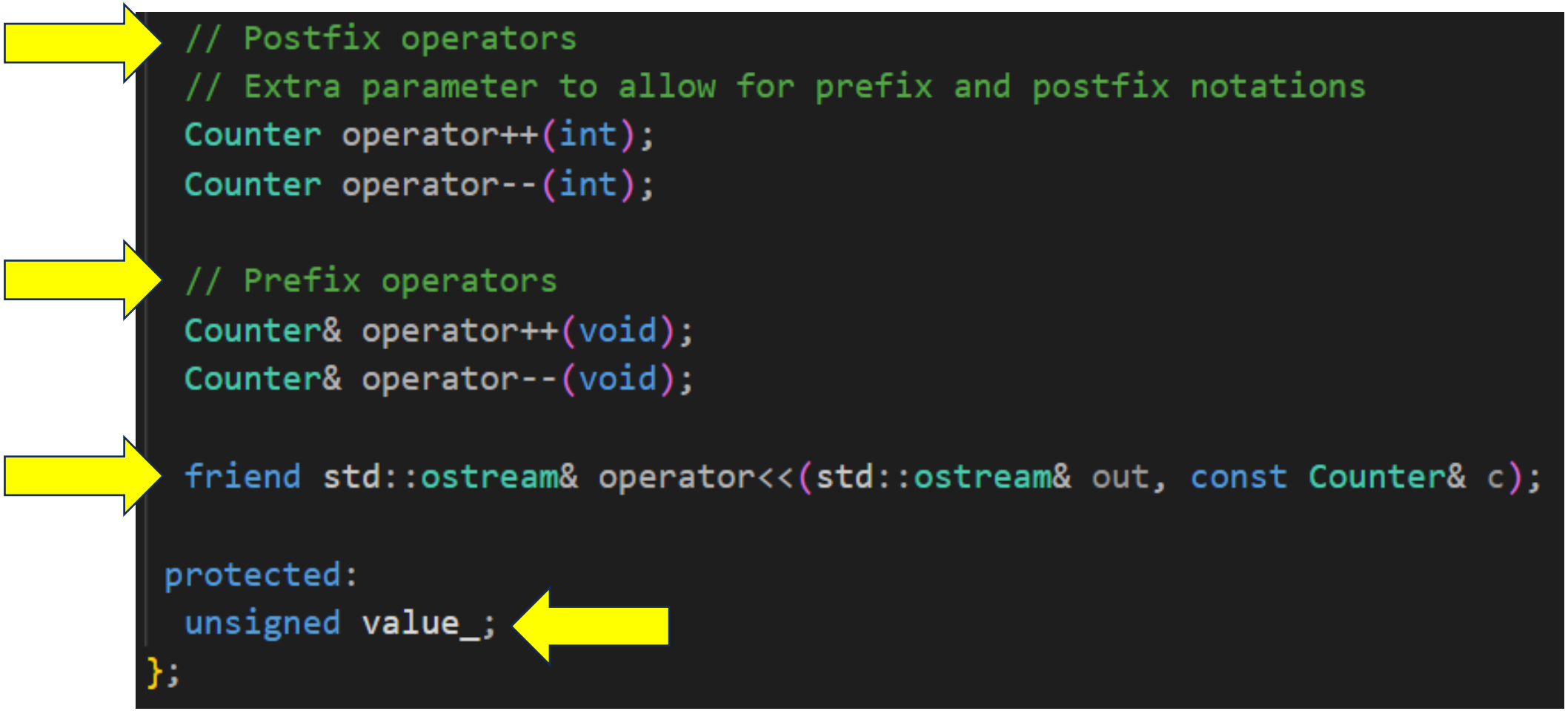
A Classe de Base : Counter

Counter.h – Classe de base



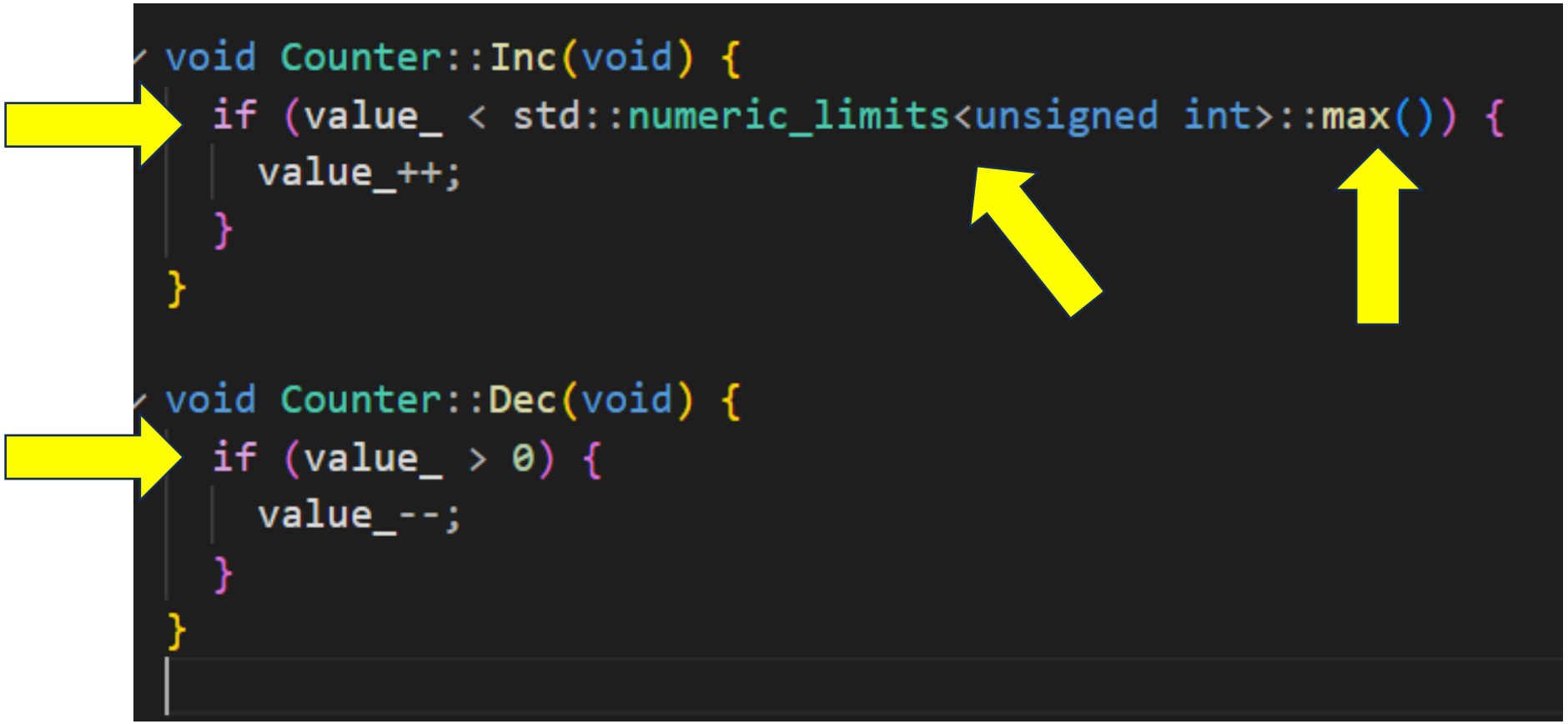
```
class Counter {
 public:
  Counter(unsigned initial_value = 0);

  unsigned GetValue(void) const;

  void Inc(void);
  void Dec(void);

  // Comparison operators
  bool operator==(const Counter& c) const;
  bool operator!=(const Counter& c) const;
  bool operator<(const Counter& c) const;
```

++/-- – Pré- vs Pós-Incrementar/Decrementar



```
  // Postfix operators
  // Extra parameter to allow for prefix and postfix notations
  Counter operator++(int);
  Counter operator--(int);

  // Prefix operators
  Counter& operator++(void);
  Counter& operator--(void);

  friend std::ostream& operator<<(std::ostream& out, const Counter& c);

 protected:
  unsigned value_;
};
```

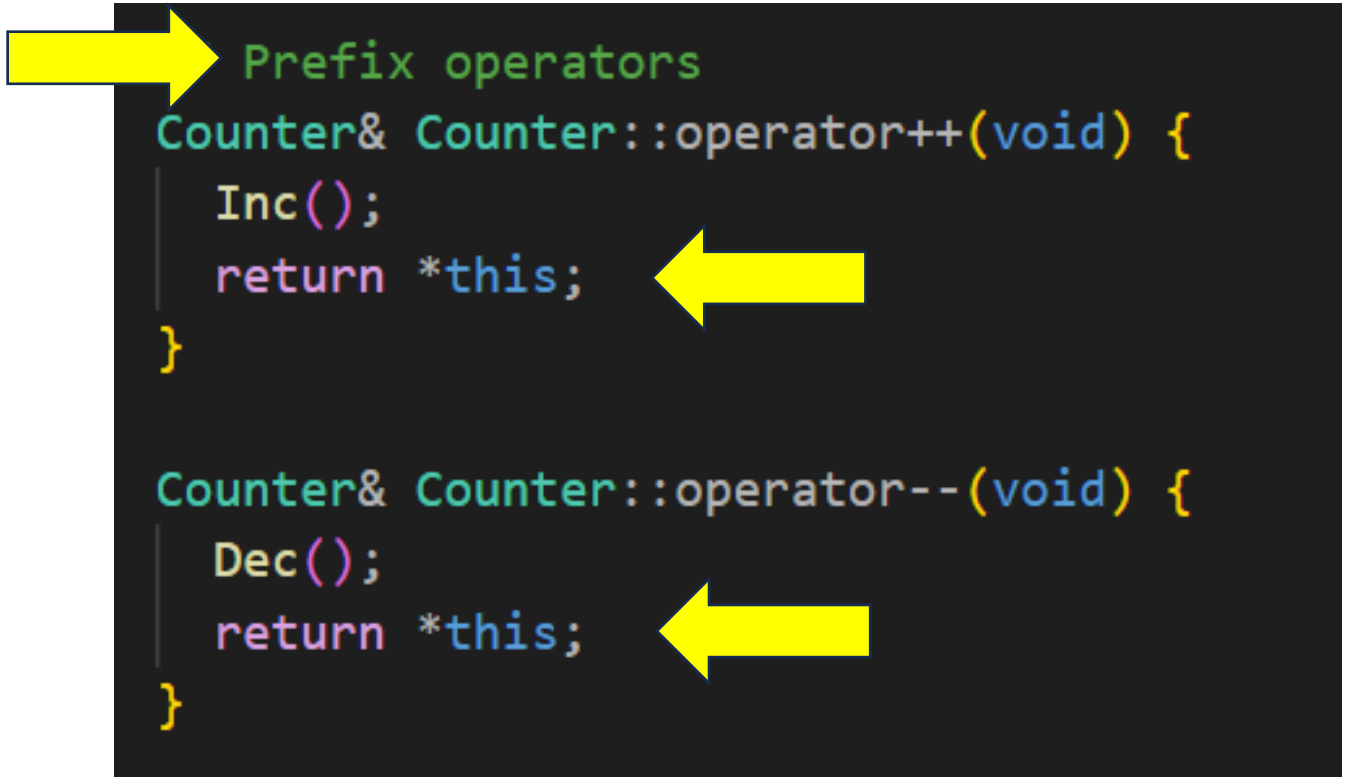
Counter.cpp – Valores no intervalo [0, max()[



++/-- – Pós-Incrementar/Decrementar

```
// Postfix operators
// Extra parameter to allow for prefix and postfix notations

Counter Counter::operator++(int) {
  Counter old_counter = *this;
  Inc();
  return old_counter;
}

Counter Counter::operator--(int) {
  Counter old_counter = *this;
  Dec();
  return old_counter;
}
```

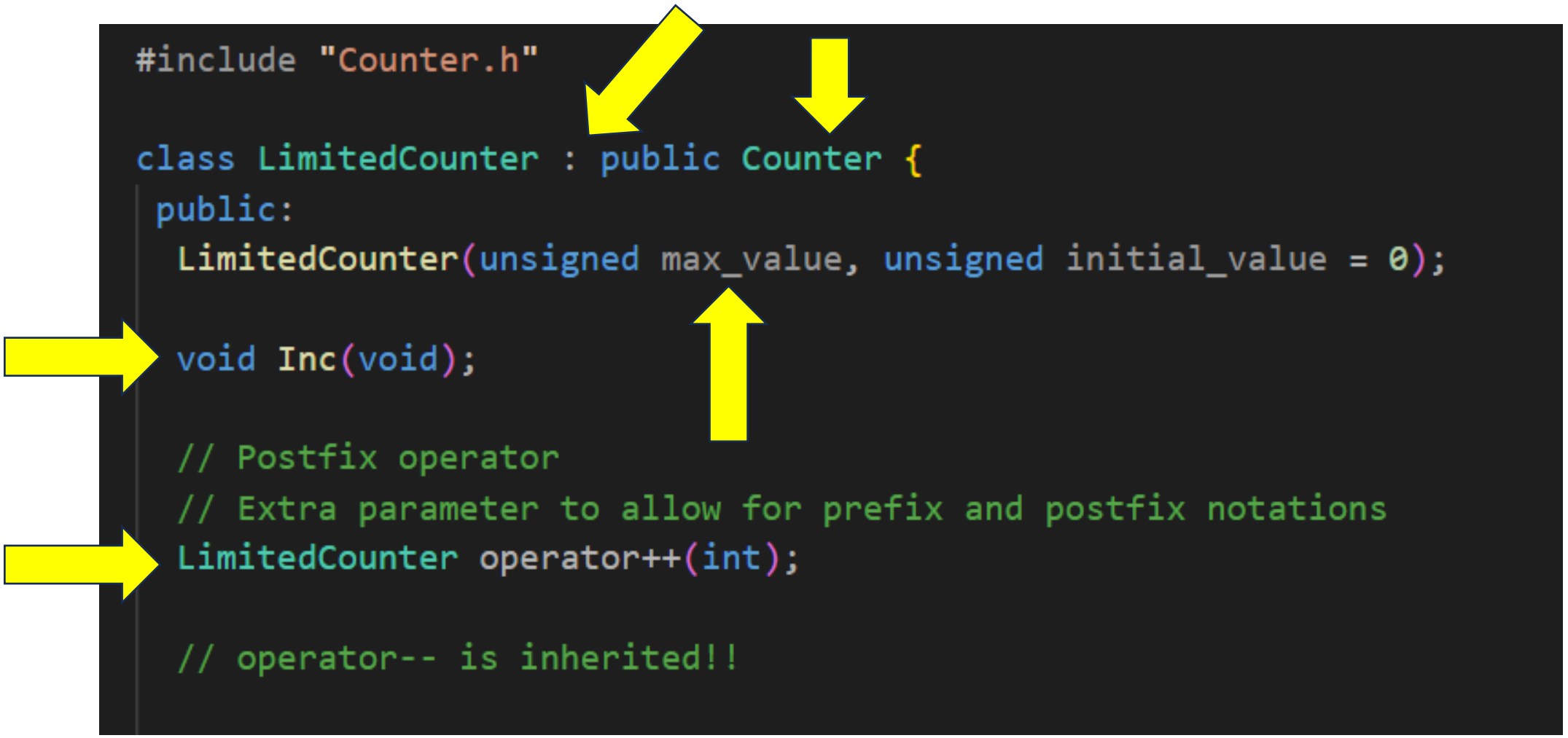
++/-- – Pré-Incrementar/Decrementar



```
// Prefix operators
Counter& Counter::operator++(void) {
  Inc();
  return *this;
}

Counter& Counter::operator--(void) {
  Dec();
  return *this;
}
```

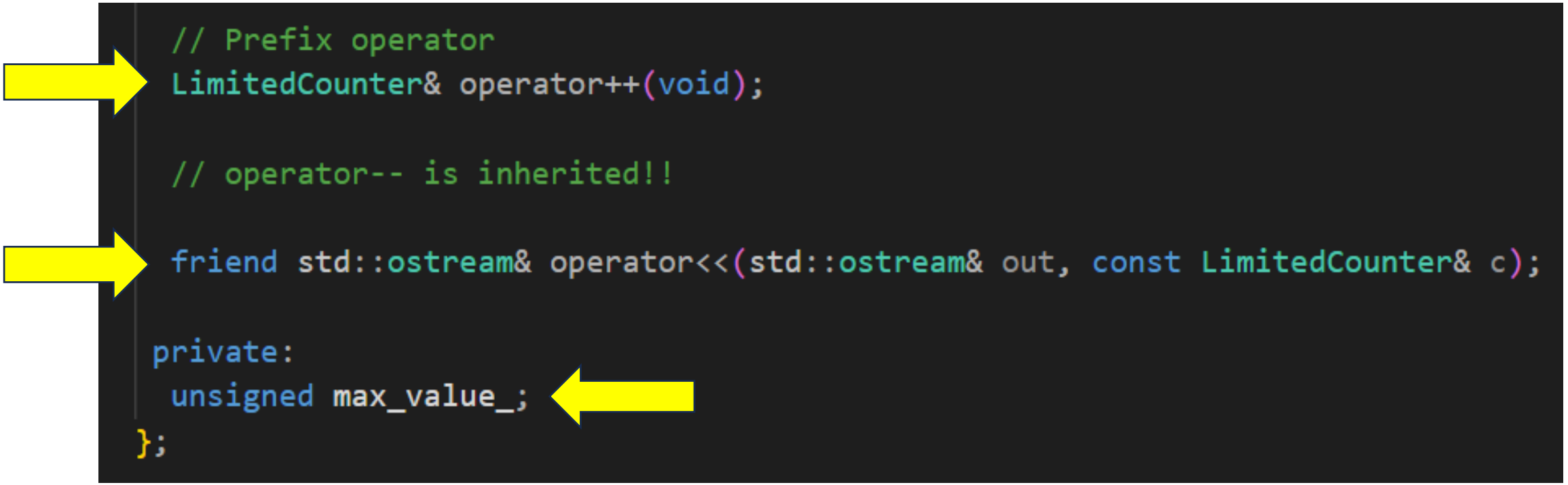
A Classe Darivada : LimitedCounter

LimitedCounter.h – Classe derivada



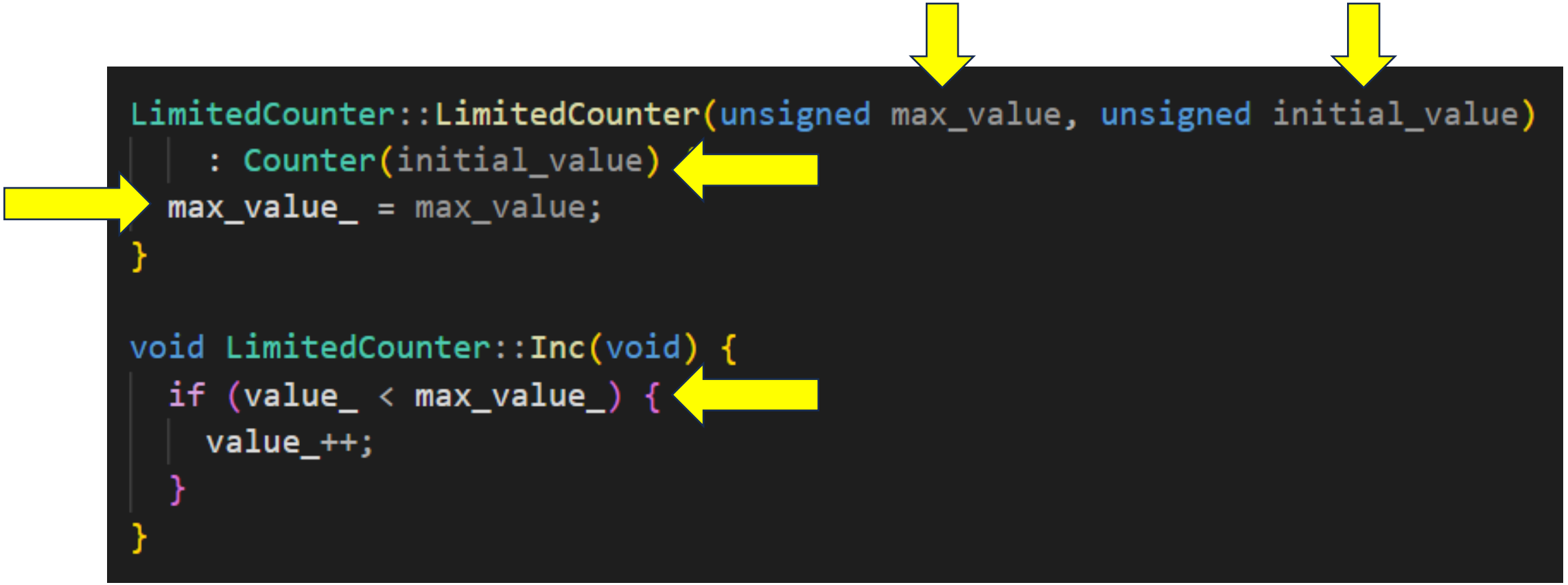
```
#include "Counter.h"

class LimitedCounter : public Counter {
 public:
  LimitedCounter(unsigned max_value, unsigned initial_value = 0);

  void Inc(void);

  // Postfix operator
  // Extra parameter to allow for prefix and postfix notations
  LimitedCounter operator++(int);

  // operator-- is inherited!!
```

LimitedCounter.h – Atributo adicional



```
  // Prefix operator
  LimitedCounter& operator++(void);

  // operator-- is inherited!!

  friend std::ostream& operator<<(std::ostream& out, const LimitedCounter& c);

 private:
  unsigned max_value_;
};
```

LimitedCounter.cpp – Construtor - Inc()

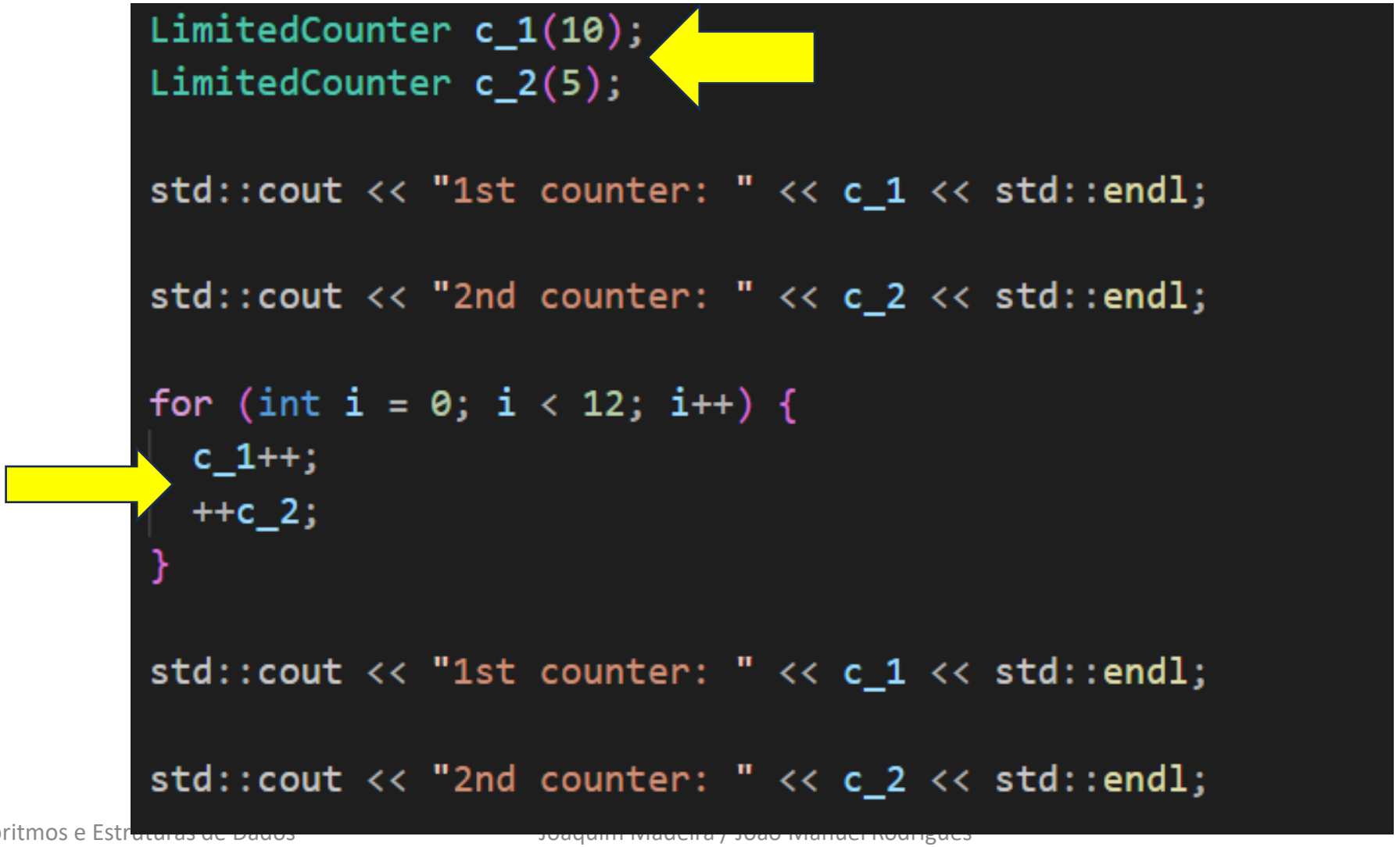


```
LimitedCounter::LimitedCounter(unsigned max_value, unsigned initial_value)
    : Counter(initial_value)
  max_value_ = max_value;
}

void LimitedCounter::Inc(void) {
  if (value_ < max_value_) {
    value_++;
  }
}
```

LimitedCounter.cpp – Method Overriding

```cpp
// Postfix operators
// Extra parameter to allow for prefix and postfix notations

LimitedCounter LimitedCounter::operator++(int) {
  LimitedCounter old_LimitedCounter = *this;
  Inc();
  return old_LimitedCounter;
}

// Prefix operators
LimitedCounter& LimitedCounter::operator++(void) {
  Inc();
  return *this;
}
```

LimitedCounter – Exemplos de utilização



```
LimitedCounter c_1(10);
LimitedCounter c_2(5);

std::cout << "1st counter: " << c_1 << std::endl;

std::cout << "2nd counter: " << c_2 << std::endl;

for (int i = 0; i < 12; i++) {
  c_1++;
  ++c_2;
}

std::cout << "1st counter: " << c_1 << std::endl;

std::cout << "2nd counter: " << c_2 << std::endl;
```

Tarefas

- Analisar o código das classes Counter e LimitedCounter
- Desenvolver outros exemplos de utilização

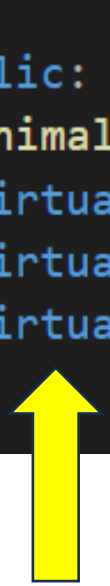
Polimorfismo

Exemplo – Animais & Zoo

A Classe Abstrata : Animal

Animal – A classe de base é abstrata

```
class Animal
{
private:
  std::string name;                    // Name of the animal
  unsigned weight;                     // Weight of the animal

public:
  Animal(std::string_view theName, unsigned wt);   // Constructor
  virtual ~Animal() = default;                     // Very important: a virtual destructor!
  virtual std::string who() const;                 // Return string containing name and weight
  virtual std::string_view sound() const = 0;      // Return the sound of an animal
};
```

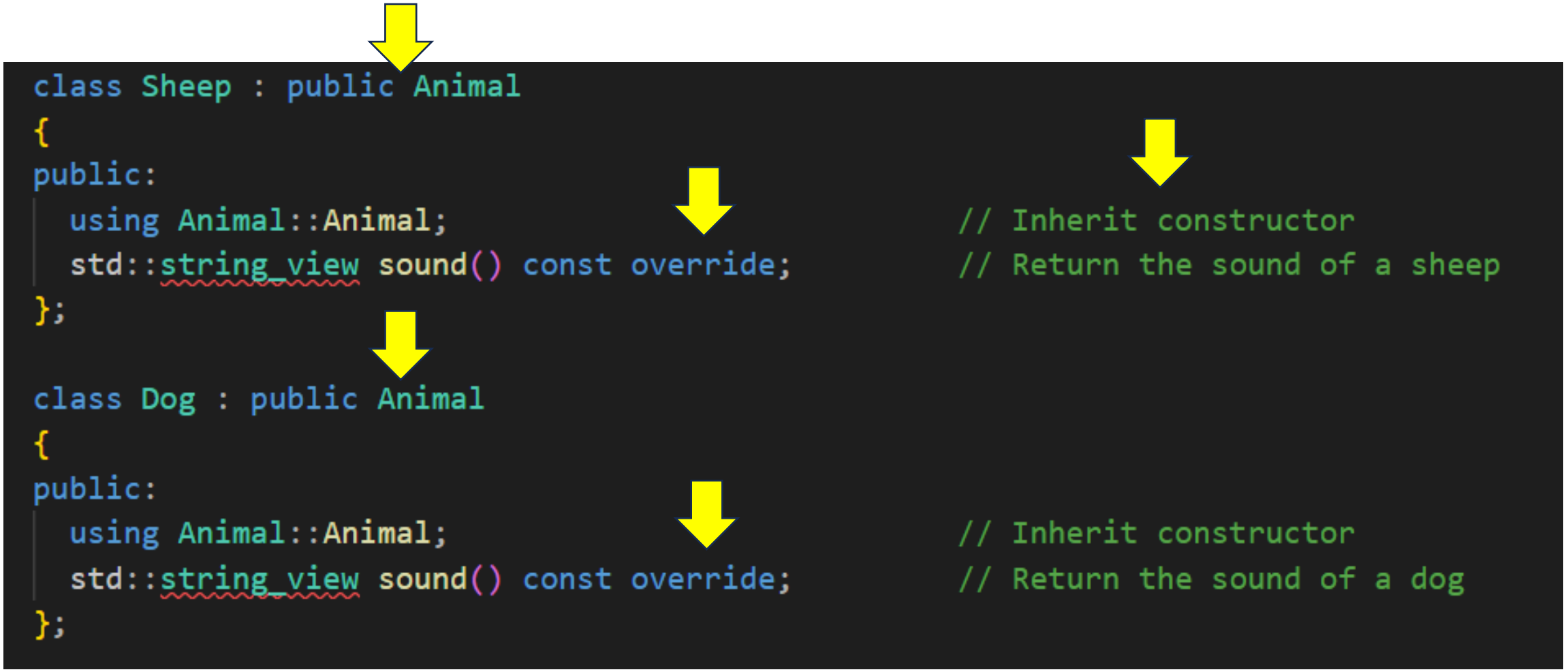



Animal – Método who() vai ser herdado

```
// Constructor
Animal::Animal(std::string_view theName, unsigned wt)
    : name(theName), weight(wt)
{}

// Return string describing the animal
std::string Animal::who() const
{
  return "My name is " + name + ". My weight is " + std::to_string(weight) + " lbs.";
}
```

Classes Derivadas

Classes Derivadas – Diferentes animais



```
class Sheep : public Animal
{
public:
  using Animal::Animal;                          // Inherit constructor
  std::string_view sound() const override;       // Return the sound of a sheep
};

class Dog : public Animal
{
public:
  using Animal::Animal;                          // Inherit constructor
  std::string_view sound() const override;       // Return the sound of a dog
};
```

Classes Derivadas – Overriding

```
// Make like a sheep
std::string_view Sheep::sound() const
{
  return "Baaaa!!";
}

// Make like a dog
std::string_view Dog::sound() const
{
  return "Woof woof!!";
}

// Make like a cow
std::string_view Cow::sound() const
{
  return "Mooooo!!";
}
```

A Classe Zoo

Zoo – Coleção de (ponteiros para) Animais

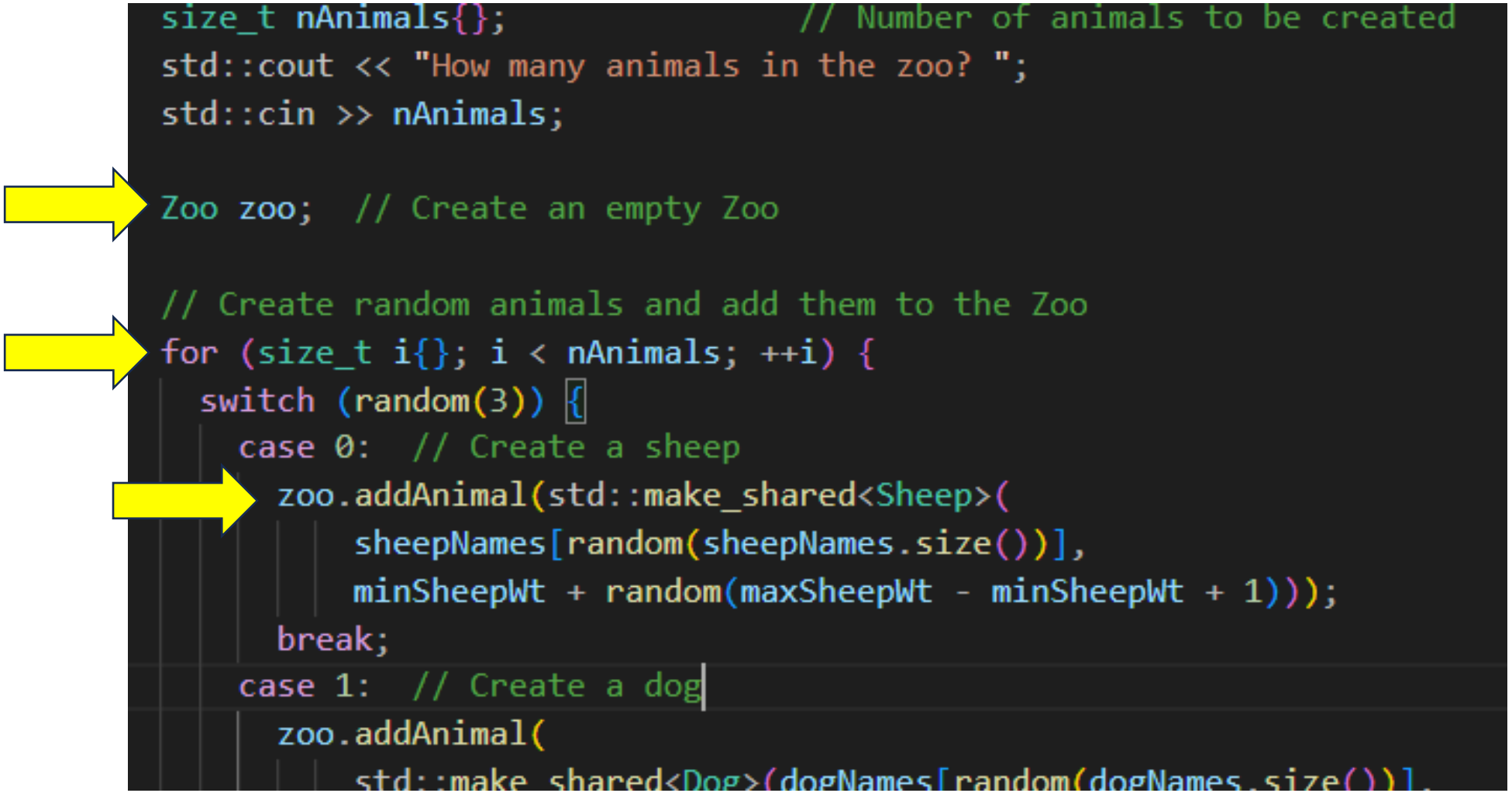
```
using AnimalPtr = std::shared_ptr<Animal>;          // Define a type alias for convenience

class Zoo
{
private:
  std::vector<AnimalPtr> animals;      // Stores pointers to the animals

public:
  Zoo() = default;                                  // Default constructor for an empty zoo
  Zoo(const std::vector<AnimalPtr>& new_animals);  // Constructor from a vector of animals
  virtual ~Zoo() = default;                         // Add a virtual destructr to allow classes to safely derive from
                                                    // possible examples of Zoo specializations include SafariPark, Pe
  void addAnimal(AnimalPtr animal);                 // Add an animal to the zoo
  void showAnimals() const;                         // Output the animals and the sound they make
};
```

Zoo – Polimorfismo

```
// Add an animal to the z
void Zoo::addAnimal(AnimalPtr animal)
{
  animals.push_back(animal);
}

// Output the animals and the sound they make
void Zoo::showAnimals() const
{
  for (auto animal : animals)
  {
    std::cout << animal->who() << ' ' << animal->sound() << std::endl;
  }
}
```

- Ponteiros para instâncias da classe de base
- Iterar sobre a coleção
- São invocados os métodos da correspondente classe derivada

Animals & Zoo – Exemplo de utilização



```
size_t nAnimals{};                    // Number of animals to be created
std::cout << "How many animals in the zoo? ";
std::cin >> nAnimals;

Zoo zoo;  // Create an empty Zoo

// Create random animals and add them to the Zoo
for (size_t i{}; i < nAnimals; ++i) {
  switch (random(3)) {
    case 0:  // Create a sheep
      zoo.addAnimal(std::make_shared<Sheep>(
          sheepNames[random(sheepNames.size())],
          minSheepWt + random(maxSheepWt - minSheepWt + 1)));
      break;
    case 1:  // Create a dog
      zoo.addAnimal(
          std::make_shared<Dog>(dogNames[random(dogNames.size())],
```

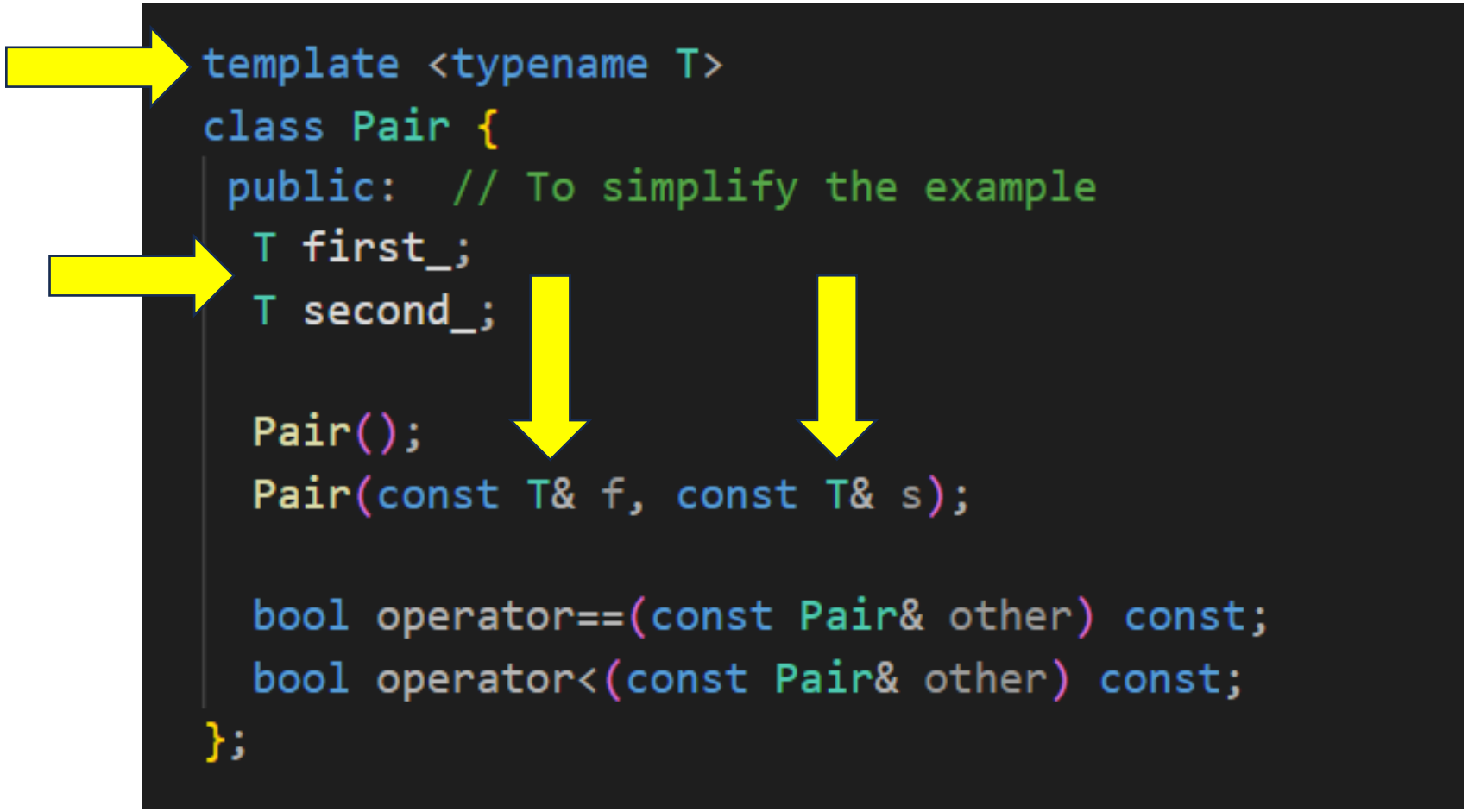
Tarefas

- Analisar o código da classe de base (Animal) e das classes derivadas (Cow, Dog, Sheep)
- Criar classes derivadas adicionais: p. ex., Cat, Tiger, Elephant, etc.
- Modificar o exemplo de utilização para usar também essas classes adicionais

Classes Genéricas
– Template Classes

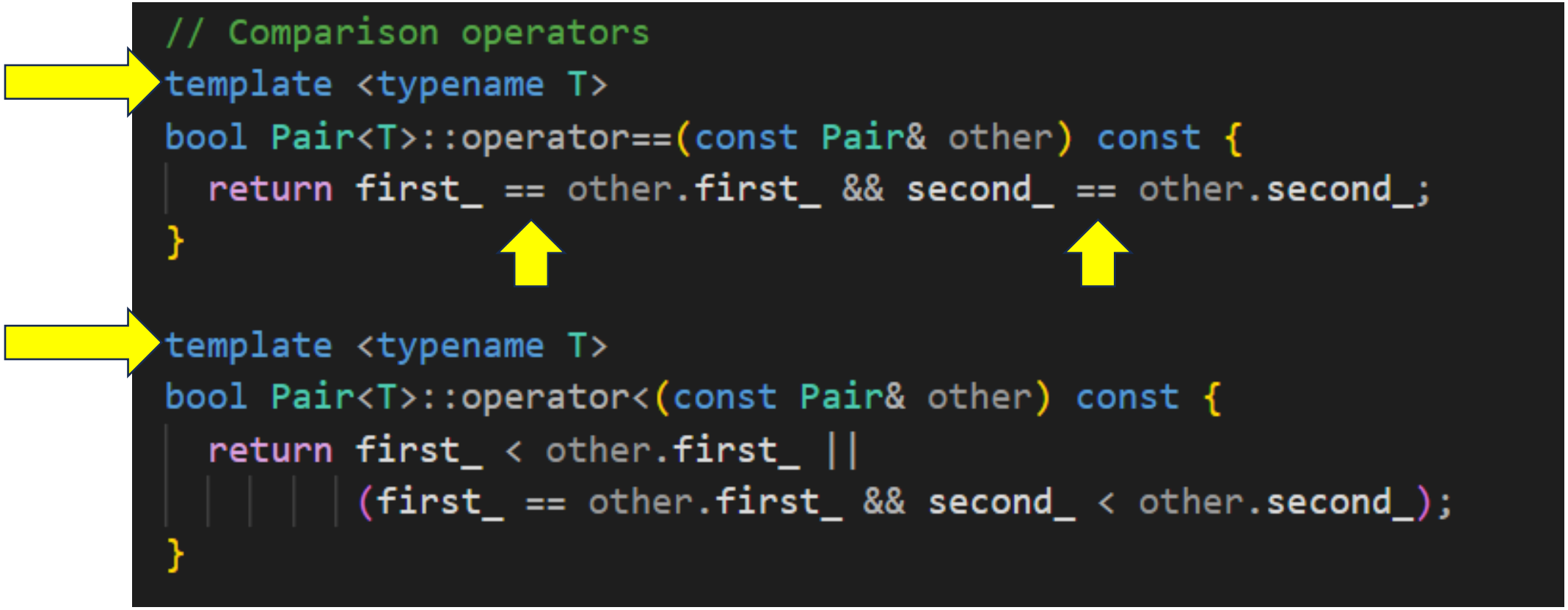
Exemplo
– A classe genérica Pair<T>

Pair.h – Par de elementos do mesmo tipo



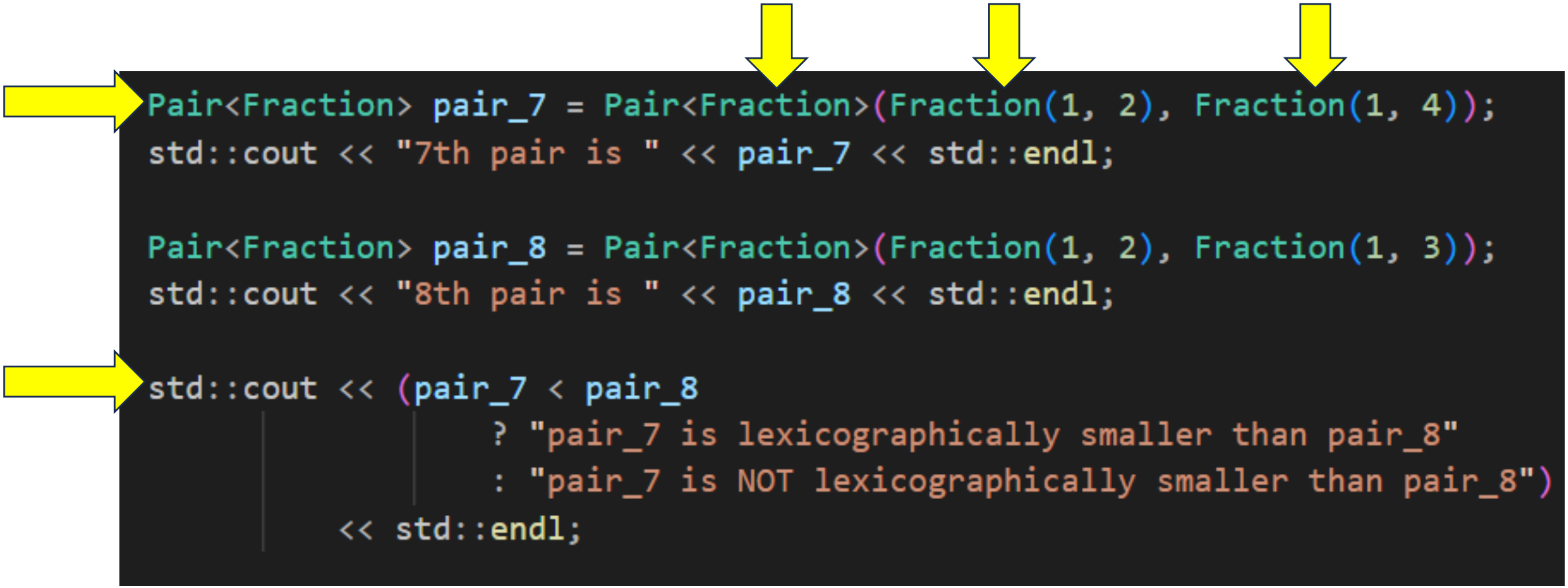
```
template <typename T>
class Pair {
 public:  // To simplify the example
  T first_;
  T second_;

  Pair();
  Pair(const T& f, const T& s);

  bool operator==(const Pair& other) const;
  bool operator<(const Pair& other) const;
};
```

Pair.h – Operadores de comparação



```
// Comparison operators
template <typename T>
bool Pair<T>::operator==(const Pair& other) const {
    return first_ == other.first_ && second_ == other.second_;
}

template <typename T>
bool Pair<T>::operator<(const Pair& other) const {
    return first_ < other.first_ ||
           (first_ == other.first_ && second_ < other.second_);
}
```

Exemplo de utilização – Pair<Fraction>



```
Pair<Fraction> pair_7 = Pair<Fraction>(Fraction(1, 2), Fraction(1, 4));
std::cout << "7th pair is " << pair_7 << std::endl;

Pair<Fraction> pair_8 = Pair<Fraction>(Fraction(1, 2), Fraction(1, 3));
std::cout << "8th pair is " << pair_8 << std::endl;

std::cout << (pair_7 < pair_8
                  ? "pair_7 is lexicographically smaller than pair_8"
                  : "pair_7 is NOT lexicographically smaller than pair_8")
          << std::endl;
```

Tarefas

- Analisar o código da classe genérica
- Analisar os exemplos de utilização
- Criar uma nova classe genérica, que permita instanciar famílias de pares de elementos, em que o tipo do 1º elemento é diferente do tipo do 2º elemento
- Modificar o exemplo de utilização para usar também essa nova classe genérica

Referência

Referência

Tomás Oliveira e Silva, *AED Lecture Notes*, 2022