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# Hash\_v1.0.0 — Documentation

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# Library Description

This library implements some usefull Hash-Table based Data-Structures, such as Hash-Sets.

In particolar, every **Hash-Structure** has been implemented following two different rules: **Open hashing** and **Close hashing**.

## CONTENTS OF THE LIBRARY

Since the Classes definitions have been made using templates, this is a *header-only* library.

However, in order to be optimized for the most common uses, have also been build some shared-library files `.so`, containing the **explicit template instantiations** of some primitive types.

The only precaution to take when compiling the library headers, is to set the flag `-std=c++20`, since it is needed in order to work properly.

The library is divided in multiple headers:

- "**IF\_Hash.hpp**": here is defined the Interface `LDN::Hash`, with the derived Abstract Class `LDN::HashSet`, which is the Polimorphic Abstract Class for the **Hash-Structure**.
- "**Hash.hpp**": the generic header, which includes all the **Hash-Structure** (it has been designed in order to be included alone).
- "**HashSet.hpp**": the header file whic implements the Specifications for the `LDN::HashSet` Abstract Class.
- "**Specification.tpp**": template implementation for the Specification Classes (such as `LDN::hash_set::Open`).

## INHERITARY STRUCTURE

The library starts with the definition of an Interface, represented by a simple abstract class: *"Hash"*.

Starting from this class, all the derivated ones create a Tree Structure, which allows to manage in a simple way all the Abstract **Hash-Structure**, and makes easy including new ones or derivating more Specifications for the already existing ones.

## ITERATOR IMPLEMENTATION

In order to be used in a simple and secure way, the `LDN::HashSet` Class has been implemented as an *Iterator*, both via Polimorphism and via Specification.

## Classes Documentation

In the "*Hash*" library have been implemented a total of four classes:

IF. **LDN::Hash**: the Root Interface, from which all the other **Hash-Structure** derive from.

1. **LDN::HashSet**: Abstract Class which defines an Hash-Set Data-Structure.

- (a) **LDN::hash\_set::Open**: Hash-Set with Open hashing rule.
- (b) **LDN::hash\_set::Close**: Hash-Set with Close hashing rule.

---

## IF. Hash

---

```
template <typename TYPE>
class Hash {

protected:

    // attributes
    size_t size;
    size_t elements;

    //Method -- Hash Function
    virtual const size_t hash(const TYPE& key) const noexcept = 0;

public:

    // constructor / destructor
    explicit Hash(const size_t& sz) : size(sz), elements(0) {}
    virtual ~Hash() noexcept = default;

    // getters
    inline const size_t& getSize() const noexcept { return this->size; }
    inline const size_t& getElements() const noexcept { return this->elements; }

    // Methods -- clear / contains / toString
    virtual void clear() noexcept = 0;
    virtual bool contains(const TYPE& key) const noexcept = 0;
    virtual std::string toString() const noexcept = 0;

};

// output stream operator «
template <typename TYPE>
inline std::ostream& operator<<(std::ostream& out_stream, const LDN::Hash<TYPE>& hash)
{
    out_stream << hash.toString();
    return out_stream;
}
```

size\_t size;

The **Hash-Structure** size, it is a *protected* member, since the user is not able to modify it.

size\_t elements;

The number of elements currently stored in the **Hash-Structure**, it is a *protected* member, since the user is not able to modify it.

```
explicit Hash(const size_t& sz);
```

This is the *constructor*, which assignes a `size_t` `sz` to the *protected* member `Hash.size`, then sets to 0 the *protected* member `Hash.elements`.

```
virtual ~Hash() noexcept = default;
```

This is the *destructor*, which is automatically invoked when deleting the object. It has been left as a *virtual method*, in order to ensure the Class to be abstract.

```
virtual void clear() noexcept = 0;
```

This *virtual method* imposes that each **Hash-Structure** has to provide a method to clean itself.

```
virtual bool contains(const TYPE& key) const noexcept = 0;
```

This *virtual method* imposes that each **Hash-Structure** has to provide a method to check if an element is stored.

```
virtual std::string toString() const noexcept = 0;
```

This *virtual method* imposes that each **Hash-Structure** has to provide a method to be printed correctly.

```
inline std::ostream& operator<<(std::ostream& out_stream, const LDN::Hash<TYPE>& hash);
```

Operator related to every **Hash-Structure**, which allows to print it via `std::ostream` using its method `Hash.toString()`.

---

## 1. HashSet

---

```
template <typename TYPE>
class HashSet : public Hash<TYPE> {

public:

    // constructor / destructor
    explicit HashSet(const size_t& sz) : Hash<TYPE>(sz) {}
    virtual ~HashSet() noexcept = default;

    // Methods -- insert / remove / resize /loadFactor
    virtual void insert(const TYPE& key) = 0;
    virtual void insert(const TYPE& key) noexcept = 0;
    virtual void resize() noexcept = 0;
    inline const double loadFactor() const {
        return static_cast<double>(this->elements) / static_cast<double>(this->size)
    }

    // ----- Iterator Interface -----
    ...

    // Iterator Methods -- begin / end
    virtual Iterator begin() noexcept = 0;
    virtual Iterator end() noexcept = 0;

};
```

```
explicit HashSet(const size_t& sz);
```

This is the *constructor*, which calls back the constructor of the Interface `LDN::Hash<TYPE>`.

```
virtual ~HashSet() noexcept = default;
```

This is the *destructor*, which is automatically invoked when deleting the object.  
It has been left as a *virtual method*, in order to ensure the Class to be abstract.

```
virtual void insert(const TYPE& key) = 0;
```

This *virtual method* imposes that each **Hash-Set** has to provide a method to insert and store correctly a key (if possible).

```
virtual void remove(const TYPE& key) noexcept = 0;
```

This *virtual method* imposes that each **Hash-Set** has to provide a method to remove a key (if already stored).

```
virtual void resize() noexcept = 0;
```

This *virtual method* imposes that each **Hash-Set** has to provide a method to resize itself.

```
inline const double loadFactor() const
```

Method which allows to calculate the current *load factor* of the **Hash-Set**.

```
// ----- Iterator Interface -----
```

Technical implementation of the **Hash-Set** as an *Iterator*, if you want to see the technicalities, check the header "*IF\_Hash.hpp*".

```
virtual Iterator begin() noexcept = 0;  
virtual Iterator end() noexcept = 0;
```

Method which allows the **Hash-Set** to be used as an *Iterator*, the user does not need to call them directly. They have been left as *virtual methods* since the implementation differs depending on the Specification.

---

## 1.1 HashSet -> Open

---

```
template <typename TYPE>
class Open : public LDN::HashSet<TYPE> {

private:

    // helper Bucket definition
    struct Bucket{

        TYPE value;
        struct Bucket* next;

        explicit Bucket(const TYPE& key): value(key), next(nullptr) {}
        ~Bucket() noexcept = default;

    };

    // attributes
    std::unique_ptr<Bucket*[]> table;

    // Method -- Hash Function
    const size_t hash(const TYPE& key) const noexcept override;

public:

    // constructor / destructor
    explicit Open(const size_t& sz);
    ~Open() noexcept override;

    // Hash Methods -- implementation
    ...

    // HashSet Methods -- implementation
    ...

    // ----- Iterator Implementation -----
    ...

    // Iterator Methods -- begin / end
    LDN::HashSet<TYPE>::Iterator begin() noexcept override {
        SpecificationIterator it(this->table.get(), this->size, 0);
        return typename LDN::HashSet<TYPE>::Iterator(it.clone());
    }
    LDN::HashSet<TYPE>::Iterator end() noexcept override {
        SpecificationIterator it(this->table.get(), this->size, this->size);
        return typename LDN::HashSet<TYPE>::Iterator(it.clone());
    }

};
```

```
struct Bucket{...};
```

Definition of an helper struct `LDN::hash_set::Open::Bucket`, private to the **Hash-Set** Specification, which allows to use the Hash-Structure with chaining (following the **Open hashing** rule).

```
std::unique_ptr<Bucket*[]> table;
```

Implementation of the Hash-Table used for the **Hash-Set**, it has been used a `std::unique_ptr<>` in order to keep the user from accessing the table directly (due to the concept of **Hash-Set**).

```
const size_t hash(const TYPE& key) const noexcept override;
```

Implementation of the *hash function*, it is based on the standard-library struct `std::hash<>`, allowing correct and complete management of the hashing rule following C++ standard.

```
explicit Open(const size_t& sz);
```

This is the *constructor*, which calls back the constructor of the Generalization `LDN::HashSet<TYPE>` and makes an unique Hash-Table.

```
~Open() noexcept override;
```

This is the *destructor*, which is automatically invocated when deleting the object.

```
// Hash Methods -- implementation
```

Implementation of the Methods declared by the Interface `LDN::Hash<TYPE>`.

```
// HashSet Methods -- implementation
```

Implementation of the Methods declared by the Generalization `LDN::HashSet<TYPE>`.

```
// ----- Iterator Implementation -----
```

Technical implementation of the **Hash-Set** as an *Iterator*, if you want to see the technicalities, check the header "`HashSet.hpp`".

```
LDN::HashSet<TYPE>::Iterator begin() noexcept override;
LDN::HashSet<TYPE>::Iterator end() noexcept override;
```

Method which allows the **Hash-Set** to be used as an *Iterator*, the user does not need to call them directly. They implement the Polimorphic **Hash-Set** ones, so that both Generalization and Specification can be used as *Iterators*.

---

## 1.2 HashSet -> Close

---

```
template <typename TYPE>
class Close : public LDN::HashSet<TYPE> {

private:

    // helper fake-constants declaration
    TYPE EMPTY;
    TYPE TOMBSTONE;

    // attributes
    std::unique_ptr<TYPE[]> table;
    bool quadratic;

    // Method -- Hash Function
    const size_t hash(const TYPE& key) const noexcept override;

public:

    // constructor / destructor
    explicit Close(const size_t& sz, bool probing, TYPE empty, TYPE tombstone);
    ~Close() noexcept override = default;

    // Hash Methods -- implementation
    ...

    // HashSet Methods -- implementation
    ...

    // ----- Iterator Implementation -----
    ...

    // Iterator Methods -- begin / end
    LDN::HashSet<TYPE>::Iterator begin() noexcept override {...}
    LDN::HashSet<TYPE>::Iterator end() noexcept override {...}

};
```

```
TYPE EMPTY;
```

Declaration of an helper fake-constant, private to an instance of the **Hash-Set** Specification, which allows to use the Hash-Structure as a single array (following the **Close hashing** rule).

It is set by the *constructor*.

```
TYPE TOMBSTONE;
```

Declaration of an helper fake-constant, private to an instance of the **Hash-Set** Specification, which allows to use the Hash-Structure as a single array (following the **Close hashing** rule).

It is set by the *constructor*.

```
std::unique_ptr<TYPE[]> table;
```

Implementation of the Hash-Table used for the **Hash-Set**, it has been used a `std::unique_ptr<>` in order to keep the user from accessing the table directly (due to the concept of **Hash-Set**).

```
bool quadratic;
```

Flag which represents the method of probing (linear if set to *false*, quadratic is set to *true*).

```
const size_t hash(const TYPE& key) const noexcept override;
```

Implementation of the *hash function*, it is based on the standard-library struct `std::hash<>`, allowing correct and complete management of the hashing rule following C++ standard.

```
explicit Close(const size_t& sz, bool probing, TYPE empty, TYPE tombstone);
```

This is the *constructor*, which calls back the constructor of the Generalization `LDN::HashSet<TYPE>` and makes an unique Hash-Table.

It also set for the only time the fake-constants `EMPTY` and `TOMBSTONE`.

```
~Close() noexcept override = default;
```

This is the *destructor*, which is automatically invocated when deleting the object.

It is set to *default*, since the `std::unique_ptr<>` delete itself automatically, and there are no other deletions (like chaining-related ones).

```
// Hash Methods -- implementation
```

Implementation of the Methods declared by the Interface `LDN::Hash<TYPE>`.

```
// HashSet Methods -- implementation
```

Implementation of the Methods declared by the Generalization `LDN::HashSet<TYPE>`.

```
// ----- Iterator Implementation -----
```

Technical implementation of the **Hash-Set** as an *Iterator*, if you want to see the technicalities, check the header "*HashSet.hpp*".

```
LDN::HashSet<TYPE>::Iterator begin() noexcept override;  
LDN::HashSet<TYPE>::Iterator end() noexcept override;
```

Method which allows the **Hash-Set** to be used as an *Iterator*, the user does not need to call them directly. They implement the Polimorphic **Hash-Set** ones, so that both Generalization and Specification can be used as *Iterators*.