Abstract Classes

Pure-Virtual Members

SoftUni Team

Technical Trainers

Software University

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#cpp-oop

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Pure-virtual Methods and Abstract Classes

Pure-virtual Methods

- Virtual methods are just pointers
  - To function code in memory
  - Pointers can point to `0` / `NULL` / `nullptr`
- Pure-virtual method
  - Points to no code
  - Function pointer to `NULL`
  - Syntax: append = `0;` to virtual method signature

```
virtual void write(string s) = 0;
```

Abstract Classes

- Abstract class – that either defines or inherits at least one pure virtual function
  - Can not be **instantiated**
  - Can not **create objects**

```
class Writer
{
protected: ostringstream log;
public:
  Writer() {}
  virtual void write(string s) = 0;
  string getLog() const {
    return this->log.str();
  }
};
```

```
class FileWriter : public Writer
{
  ofstream fileOut; string filename;
public: FileWriter(string file)
  : fileOut(file), filename(file) {}

  void write(string s) override {
    this->fileOut << s;
    this->log << "wrote " << s.size()
      << " bytes to " << filename;
  }
};
```

```
Writer writer; // compilation error
FileWriter writer("out.txt"); // ok
writer.write("hello");
```

Abstract Classes and Polymorphism

Base declares => Derived defines / implements => Code uses Base

- Usable methods **accessible** from base pointer / reference
- Pointers **guaranteed to point** to derived
- Guaranteed override access – **derived must have override**

```
void writeHello(Writer* writer)
{
  writer->write("hello");
}
```

```
void writeHello(Writer& writer)
{
  writer.write("hello");
}
```

```
FileWriter fileWriter("out.txt");
writeHello(&fileWriter);
```

```
FileWriter fileWriter("out.txt");
writeHello(fileWriter);
```

OOP Interfaces

Declaring Functionality for Others to Implement

OOP Interfaces

- Abstract classes that **only declare public methods**
  - Don't have implementation
  - Derived classes required to implement methods (or be abstract)

```
class Writer
{
 public:
   virtual void write(string s) = 0;
};
```

```
// struct avoids typing public:
struct Writer
{
  virtual void write(string s) = 0;
};
```

OOP Interface - Common Usage

- Derived classes with:
  - **Common methods**
  - **No common base members**
- Extract interface
  - Contains common methods as **pure-virtual methods**
  - Derived **classes inherit** it in addition to their members

OOP Interface - Example

```
class HasInfo {
public:
  virtual string getInfo() const = 0;
};
```

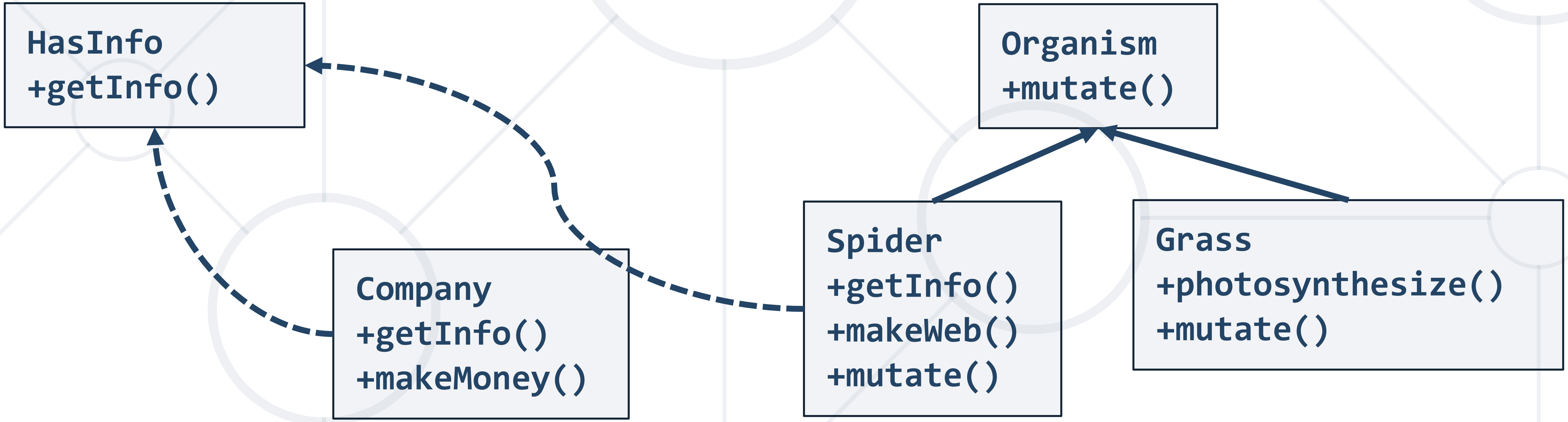
```
class Spider : public Organism, public HasInfo {
...
string getInfo() const override {
...
```

```
class Company : public HasInfo {
...
string getInfo() const override {
...
```

```
Spider spider(...);
Company company(...);
spider.getInfo();
company.getInfo();
```

OOP Interface - Usage Diagram

- **Company** and **Spider** are in different "trees"
  - **Company** is a "root", **Spider** is "under" the **Organism** "root"
  - Share members through **HasInfo** interface



- OOP hierarchies are often described with diagrams

Multiple Inheritance

Multiple Inheritance

- In the previous slides, we demonstrated multiple inheritance
  - But we used the "safe" way – interfaces
- C++ allows a derived class to have multiple bases

```
class Derived : public Base1, public Base2, ...
```

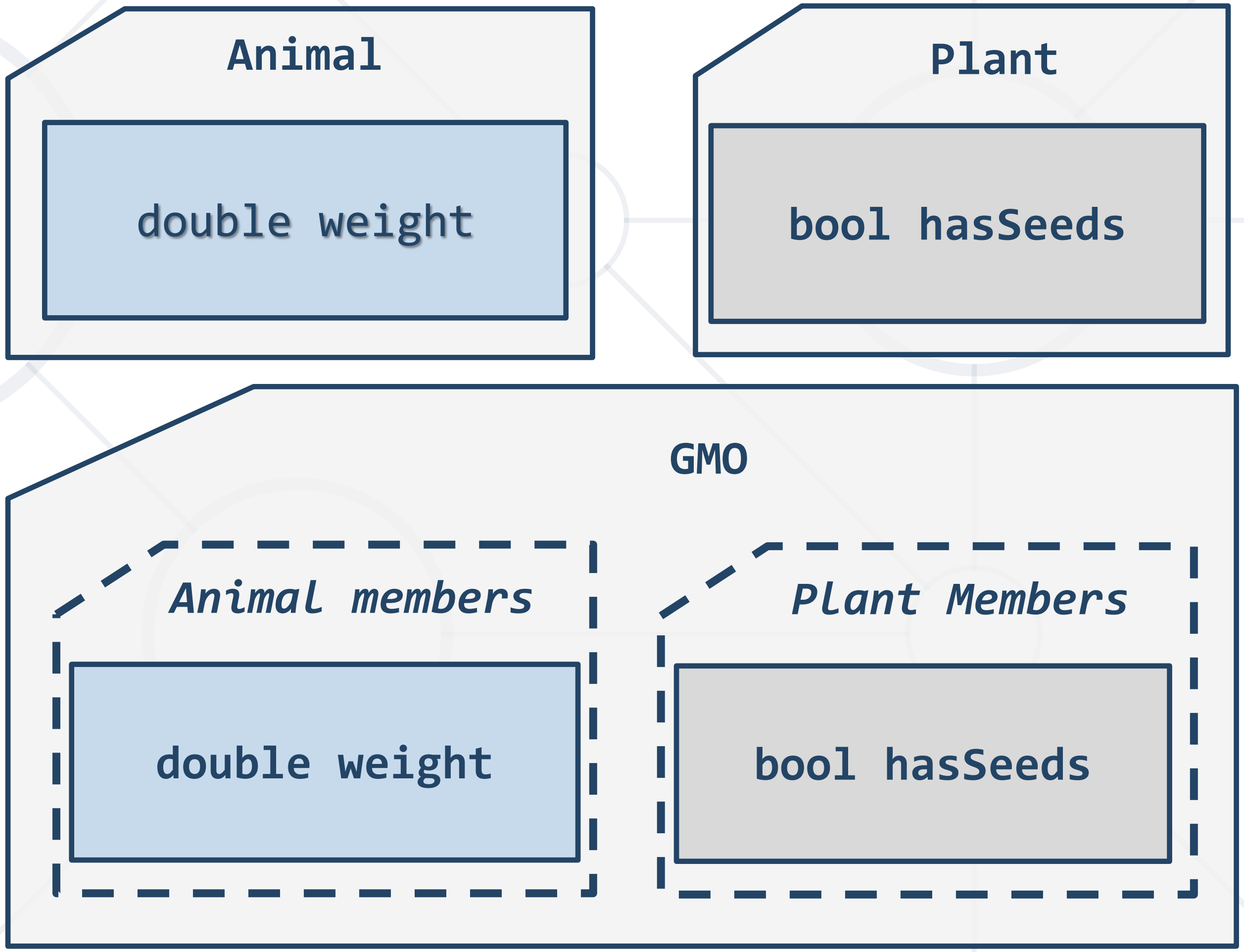
- Can cause member conflicts – if member names match
  - Internal code uses `Base1::member` vs. `Base2::member`
  - External code can be cast to `(Base1*)` or `(Base2&)`, etc.

Multiple Inheritance - Example

```
class Animal {
  double weight;
};

class Plant {
  bool hasSeeds;
};

class GMO : public Animal,
            public Plant {
};
```



Multiple Inheritance - Error Prone

- With C++ multiple inheritance come multiple pitfalls
  - Name conflicts, casting, base member calls, memory, ...
  - Interfaces are mostly **immune** to the above (except name conflicts)
- The diamond problem – the root of most pitfalls
  - `class Top;`
  - `class Left : Top; class Right : Top;`
  - `class Bottom : Left, Right;`
  - Bottom has 2 copies of each Top member

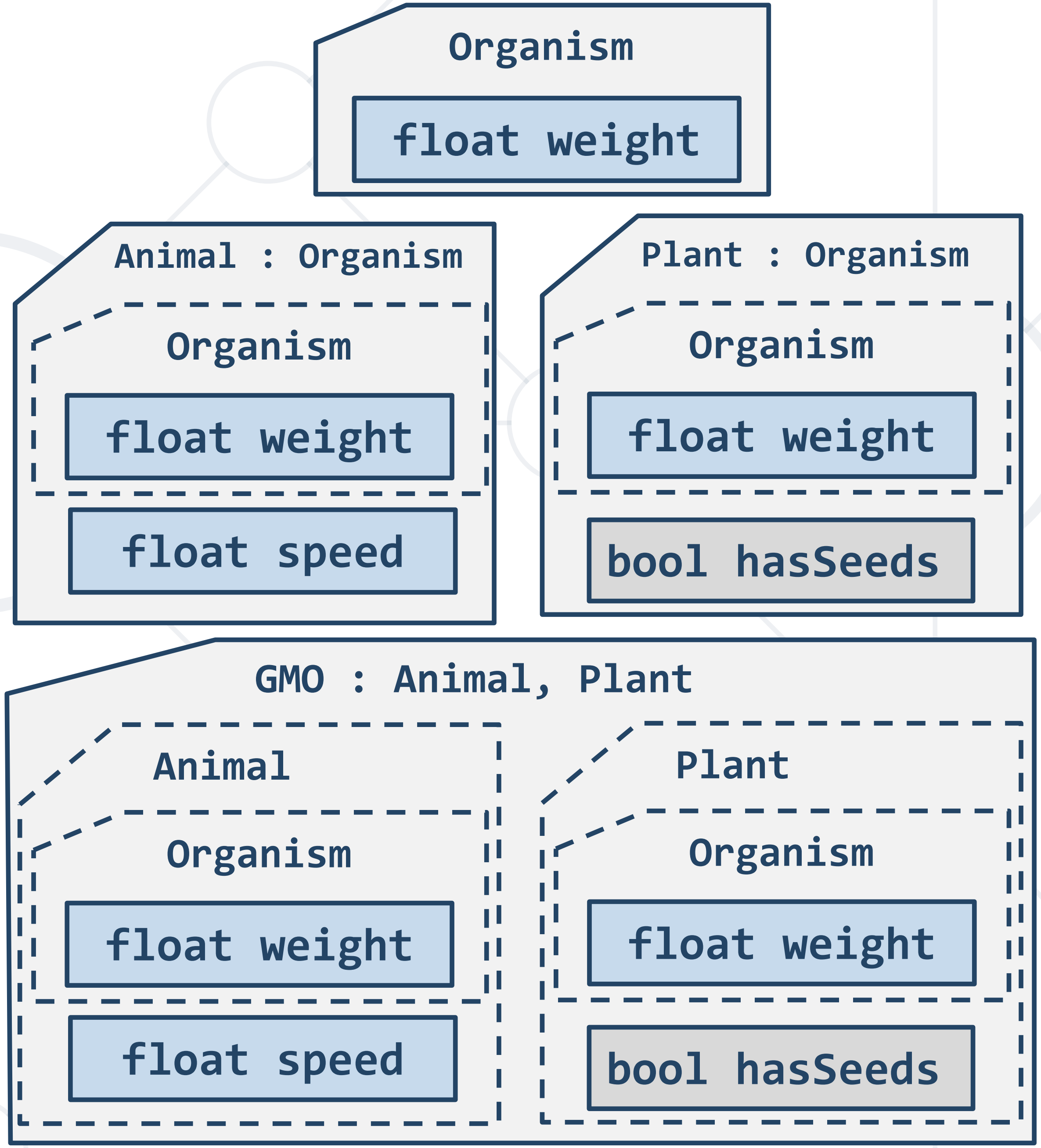
The Diamond Problem

```
class Organism {
  double weight;
};

class Animal : Organism {
  double movementSpeed;
};

class Plant : Organism {
  bool hasSeeds;
};

class GMO : Animal, Plant {
};
```



Virtual Inheritance - Solving the Diamond

- Virtual Inheritance – "override" instead of copy same members
  - `class Top;`
  - `class Left : virtual Top`
  - `class Right : virtual Top`
  - `class Bottom : Left, Right`
  - `Bottom` gets single `Top`, that both `Left` and `Right` point to

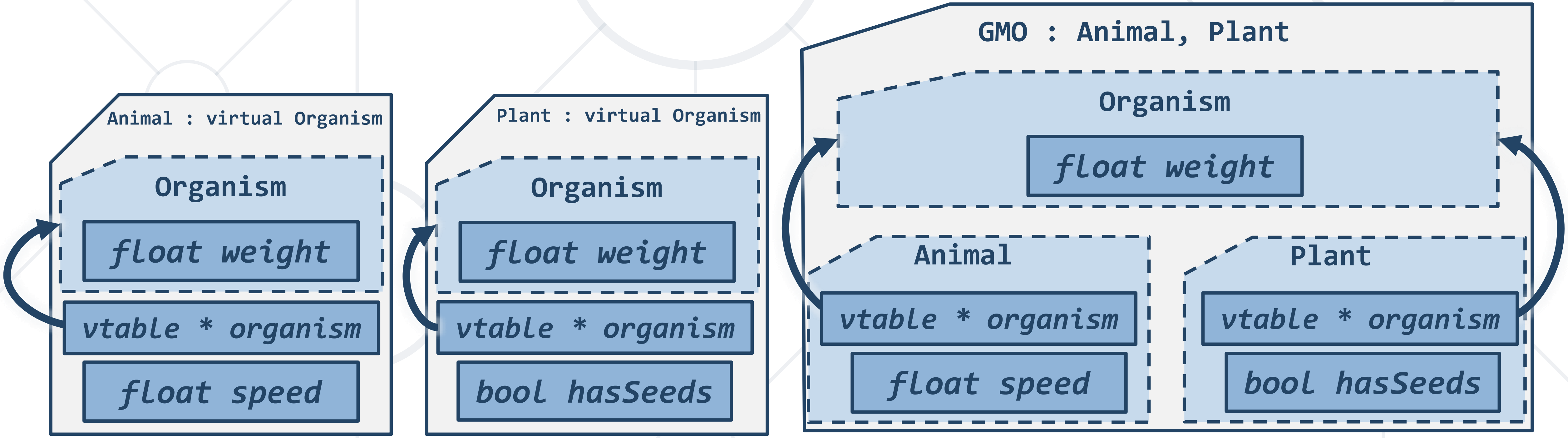
```
class Animal : public virtual Organism
```

```
class Plant  : public virtual Organism
```

```
class GMO : public Animal, public Plant
```

Solving the Diamond - Diagram

```
class Organism { ... };
class Animal : virtual Organism { ... };
class Plant : virtual Organism { ... };
class GMO : Animal, Plant { ... };
```



Runtime Type Checking

Dynamic Casting

`dynamic_cast<T>(value)`

- Casts `value` to `T`, `value` must be a pointer / reference
- `T` must be a pointer/reference to a class

- If a cast is not possible – returns `nullptr` if casting to pointer
  - Runtime error if casting to reference

`std::dynamic_pointer_cast<T>(smartPtr)`

- Similar to `dynamic_cast<T>`, but used for smart pointers

Runtime Type Checking

- dynamic_cast allows type checking of base pointers
  - Cast and check if the result is non-null

```
Spider spider(...);
Organism* upcast1 = dynamic_cast<Organism*>(&spider);
Company* toCompany = dynamic_cast<Company*>(&spider); // null
Organism* upcast2 = dynamic_cast<Organism*>(&spider);
```

Avoiding Runtime Type Checking

- Needing **runtime type checks** may indicate bad design
- Prefer using **overrides to define special behavior**
  - If not possible, why?
  - Do we need more classes?
  - Do we need "wider" or better base classes?
  - Is the function handling more than it is responsible for?

Summary

- C++ uses **memory layout** to handle inheritance
  - Base is at beginning of the memory block
  - Derived continues after base in memory
- Pure-virtual methods **force implementation**
  - Derived defining them guaranteed to be called due to **virtual**
  - Allows pure-virtual classes – **OOP Interfaces**
- Multiple inheritances allows combining multiple bases

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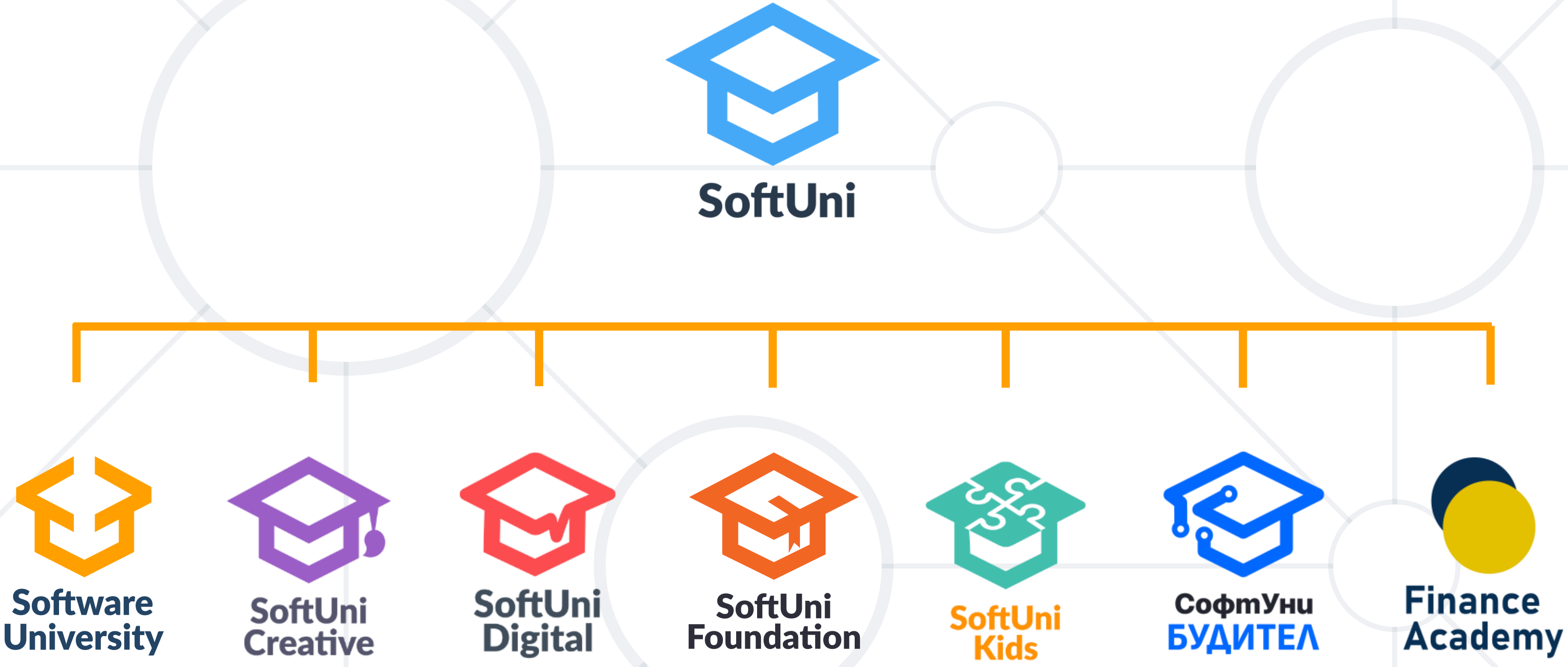
Questions?



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