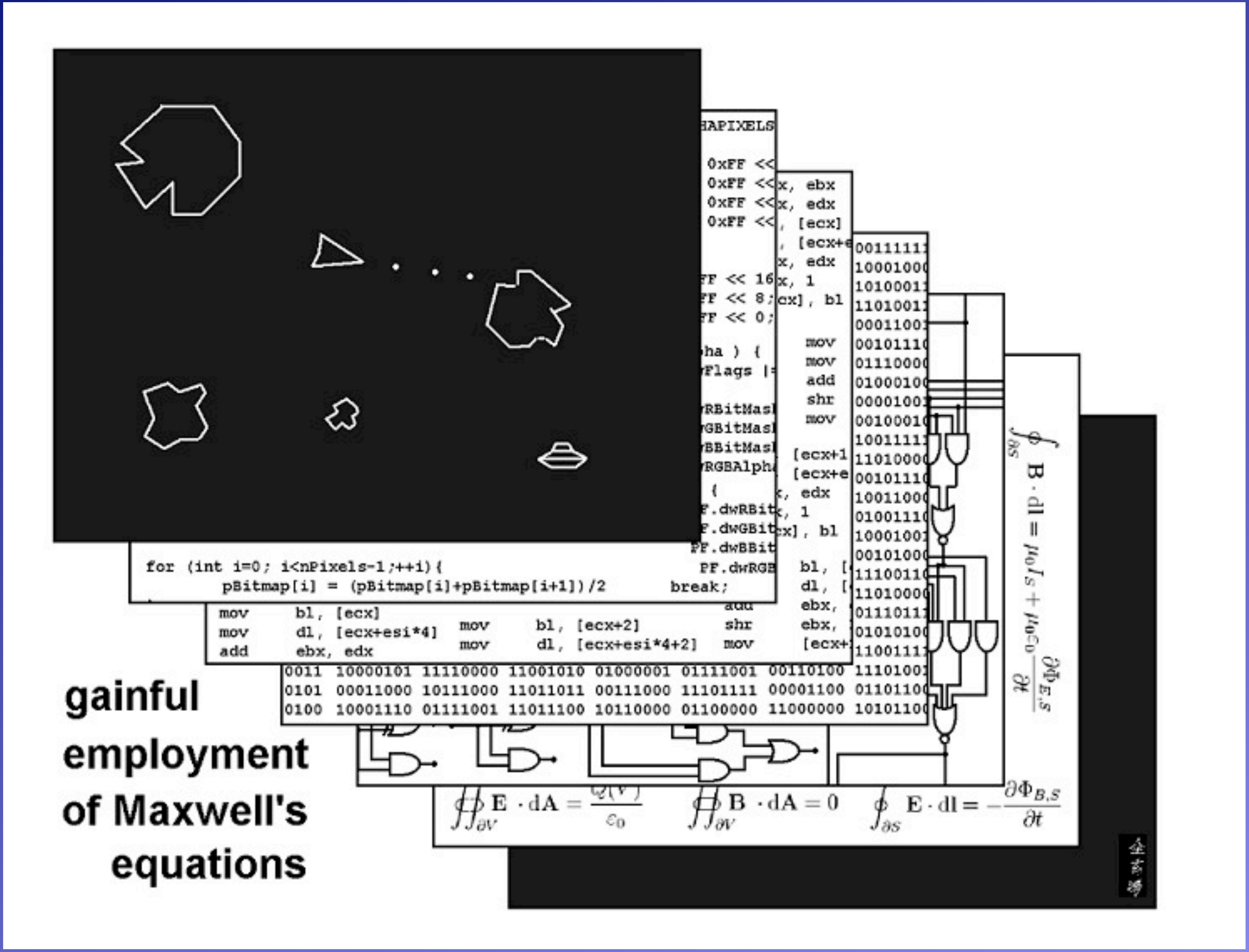
An intro to C++

Francesco Safai Tehrani
francesco.safaitehrani@roma1.infn.it

The root of all evil



http://abstrusegoose.com/307

Software, as seen by a cat fancier

Courtesy of

Özgür Çobanoglu

Non-hierarchical software !..

Object oriented programming

- From functions to objects
  - With functions you have code blocks that accept arguments and process them returning a response
  - With objects you have ‘entities’ that interact with other entities via well defined interfaces
    - Interfaces describe fully what an object can do
- Plenty of different ‘object oriented’ programming approaches
  - Two main ones: static and dynamic
    - Static: objects have a well defined nature which cannot change
    - Dynamics: the object’s nature is detemined by its behavior

From C to C++

- C != C++
  - but this should be abundantly clear by now ;)
- C++ evolved from C as one of the versions of the “C with objects” paradigm
- OOP was invented (according to some) at Xerox PARC during the development of the Alto workstation to design and implement GUIs
  - and then they kind of gave it away...
    - both the OO and the GUIs
    - and the mouse, and the Ethernet, and ...

C++ by examples

- I am not going to try to teach you all of C++
  - yeah, right ;)
- I'll give some examples...
  - hopefully you'll be able to glimpse the truth from these
- I am NOT going to talk about complex stuff
  - just basic C++
    - "C++ for the masses"
- Lots of talking, little writing
  - there's plenty of good books out there... no need to replicate them

1D CA

I will use this example in the C++ lecture, hence the longer description.

Let's give some nomenclature.

The cellular automaton lives on a playground of N spaces.
The playground is circular (its leftmost element and its rightmost element are next to each other).
Each 'space' in the playground is called a cell.
A cell can be dead (0) or alive (1).
Time flows in discrete steps. At each given step the cell state can change or remain the same.
The cell state changes depending on its own state and the state of its first neighbors (usually known as a neighborhood).

Each automaton is completely defined by its initial state and its evolution rules.

Since there are eight possible configurations for a neighborhood, each with a possible outcome of 0 or 1 in the next state, there is a total of 256 possible evolution rules.

State	111	110	101	100	011	010	001	000
Outcome	0	0	1	1	0	1	0	0

As an example, this is rule 52 (2^2 + 2^4 + 2^5).

The implementation

- 4 versions of the same program, with increasing technology.
- The program is EXTREMELY simple, and frankly overkill for C++.
    - ... but I hope it'll help you figure out a few things
- Once we lay down the infrastructure it will pretty much stay the same throughout the various versions...
- I have no plan, nor hope (nor desire) to try to cram all of C++ into a 1h lecture
- The code is written to be plain and understandable, which implies I didn't use many advanced features of C++
    - e.g. I use loops instead of iterators...

Code structure

- I’ve broken down the problem into two separate entities:
    - the Playground class which abstracts the notion of the arena where the cells ‘live’
    - the Cell entity which abstracts ... well, the cell.
- In such a simple case, I expect most people would agree with me on my ‘design’
    - and still I expect plenty would disagree
        - the long debated issue: “should an event be an object?”
    - different people will design their programs differently...
        - “different people have different needs” (Depeche Mode, deep 80s)

V.1

```
#ifndef _CELL_H_
#define _CELL_H_

using namespace std;

class Cell {
private:
  int state;
  int RuleSet[8];

public:
  Cell() { state = 0; }

  Cell(int aState): state(aState) {}

  Cell(int aState, int* aRuleSet) {
    state = aState;
    for(int i=0; i<8; i++) {
      RuleSet[i] = aRuleSet[i];
    }
  }

  virtual ~Cell() {}

  int evolve(Cell* neighbors[]);

  int getState() {
    return state;
  }

  int setState(int aState) {
    state = aState;
  }
};

#endif
```

Constructor: the method that is invoked when instantiating an object

Overloading: a kind of polymorphism where a method can have different signatures. The choice of the correct method to invoke is performed based on the invocation signature

Overloaded constructors (ctors)

Destructor

Destructor: the method that is invoked when releasing an object

Virtual: a big can of worm that has to do with what method gets invoked when. (A bit) more on this later...

Destructors HAVE to be virtual, unless you really know what you're doing.

Cell.hh [v1]

```cpp
#include "Cell.hh"

int Cell::evolve(Cell* neighbors[]) {
  int stateInfo = 4*(neighbors[0])->getState() + 2 * state + (neighbors[1])->getState();
  return RuleSet[stateInfo];
}
```

In C++:

headers contain the interface of a class
.c files contain the implementation of a class

Okay, what the heck is a class?
A class is a logical entity representing a part that contributes to the solution of your problem. Different people have different classes (one man's constant is another man's variable).

A class is the blueprint of the actual entity (the project for a car versus the actual car). A class gets instantiated into an object.

An object is an instance of a class, that is it conforms to the class interface while providing a state.

A class, being a blueprint, does not have a state.
An interface fully defines what an object can do, or (using the messaging model) what messages can it answer?

The object is the core entity of C++ programming. A C++ programming can be seen as a 'network' of 'objects' which interact with each other exchanging 'messages'

Or, using an 'active' view: each object can ask another object to perform a service and return a result (this is known as 'delegation').

Cell.cc [v1]

```
#ifndef _PLAYGROUND_H_
#define _PLAYGROUND_H_

#include "Cell.hh"

using namespace std;

class Playground {
private:
  Cell** currentArena;
  Cell** nextArena;
  Cell** tmpArena;
  int RuleSet[8];
  int rule;
  int size;

public:
  Playground(int aSize, int aRule) {
    size = aSize;
    rule = aRule;

    currentArena = new Cell*[size];
    nextArena    = new Cell*[size];

    createRuleSet();

    for(int idx=0; idx<size; idx++) {
      currentArena[idx] = new Cell(0, RuleSet);
      nextArena[idx]    = new Cell(0, RuleSet);
    }
    initCurrentArena();
  }

  virtual ~Playground() {
    delete[] currentArena;
    delete[] nextArena;
  }

  void createRuleSet();
  void initCurrentArena();
  void nextGeneration();
  void printArena();
};

#endif
```

Playground.hh [v1]

```
#include <iostream>
#include "Playground.hh"

using namespace std;

void Playground::createRuleSet() {
  for(int idx=0; idx<8; idx++) {
    RuleSet[idx] = (rule & (1 << idx)) / (1 <<idx);
  }
}

void Playground::nextGeneration() {
  Cell* neighborhood[2];

  for(int idx=0; idx<size; idx++) {
    int pidx = (idx-1)<0?(size-1):(idx-1);
    neighborhood[0] = currentArena[pidx];
    neighborhood[1] = currentArena[(idx+1)%size];
    (nextArena[idx])->setState((currentArena[idx])->evolve(neighborhood));
  }
  tmpArena     = currentArena;
  currentArena = nextArena;
  nextArena    = tmpArena;
}

void Playground::initCurrentArena() {
  // impulse
  (currentArena[size/2])->setState(1);
}

void Playground::printArena() {
   for(int idx=0; idx<size; idx++) {
      if((currentArena[idx])->getState()) {
        cout << "o";
      } else {
        cout << " ";
      }
   }
   cout << endl;
}
```

Playground.cc [v1]

```
#include<iostream>
#include "Cell.hh"
#include "Playground.hh"

#define PLAYGROUND_SIZE 80
#define GENERATIONS     100
#define RULE            30

int main (int argc, const char * argv[]) {
  Playground* myPlayground = new Playground(PLAYGROUND_SIZE, RULE);

  for(int idx=0; idx<GENERATIONS; idx++) {
    myPlayground->nextGeneration();
    myPlayground->printArena();
  }
  return 0;
}
```

```
Compile like this:

g++ -c Cell.cc
g++ -c Playground.cc
g++ -o ca1d ca1d.cc Cell.o Playground.o
```

V.2

```
#ifndef _ABSCELL_H_
#define _ABSCELL_H_

class AbsCell {

public:
  virtual ~AbsCell() {};

  virtual int evolve(AbsCell* neighbors[])=0;
  virtual int getState()=0;
  virtual int setState(int)=0;
};

#endif
```

purely virtual functions

This is an abstract class. A class that cannot be instantiated.
It is just an interface, no behavior whatsoever.

The trick is that purely abstract methods HAVE TO BE implemented before the a class can be instantiated.

The other tools you need is inheritance.

Inheritance is a property of OO where I can declare that a class ‘inherits’ from another class, that is the new class takes all the behaviors of the parent class and ‘specializes’ them, that is it changes the behavior to adapt for its specific needs.

AbsCell.hh [v2]

```
#ifndef _CELL_H_
#define _CELL_H_

#include <iostream>
#include "AbsCell.hh"

using namespace std;

class Cell: public AbsCell {
private:
  int state;
  int RuleSet[8];

public:
  Cell() { state = 0; }

  Cell(int aState): state(aState) {}

  Cell(int aState, int* aRuleSet) {
    state = aState;
    for(int i=0; i<8; i++) {
      RuleSet[i] = aRuleSet[i];
    }
  }

  virtual ~Cell() {}

  virtual int evolve(AbsCell* neighbors[]);

  virtual int getState() {
    return state;
  }

  virtual int setState(int aState) {
    state = aState;
  }
};

#endif
```

Inheritance: the class Cell inherits the interface (and the behavior if any) from AbsCell.
You can also say that Cell conforms to the AbsCell interface.

and here I specialize the evolve method defined in the AbsCell interface...

`Cell.hh [v2]`

```
#ifndef _PLAYGROUND_H_
#define _PLAYGROUND_H_
#include "Cell.hh"

using namespace std;

class Playground {
private:
  AbsCell** currentArena;
  AbsCell** nextArena;
  AbsCell** tmpArena;
  int RuleSet[8];
  int rule, size;

public:
  Playground(int aSize, int aRule) {
    size = aSize;
    rule = aRule;

    currentArena = new AbsCell*[size];
    nextArena    = new AbsCell*[size];

    createRuleSet();

    for(int idx=0; idx<size; idx++) {
      currentArena[idx] = new Cell(0, RuleSet);
      nextArena[idx]    = new Cell(0, RuleSet);
    }
    initCurrentArena();
  }

  virtual ~Playground() {
    delete[] currentArena;
    delete[] nextArena;
  }

  void createRuleSet();
  void initCurrentArena();
  void nextGeneration();
  void printArena();
};
```

in this class I need to substitute most of the Cell variables with AbsCell variables

The reason will become clear later...

Liskov substition principle:
Let q(x) be a property provable about objects x of type T. Then q(y) should be true for objects y of type S where S is a subtype of T.

```
#include <iostream>
#include "Playground.hh"

using namespace std;

void Playground::createRuleSet() {
  for(int idx=0; idx<8; idx++) {
    RuleSet[idx] = (rule & (1 << idx)) / (1 <<idx);
  }
}

void Playground::nextGeneration() {
  AbsCell* neighborhood[2];

  for(int idx=0; idx<size; idx++) {
    int pidx = (idx-1)<0?(size-1):(idx-1);
    neighborhood[0] = currentArena[pidx];
    neighborhood[1] = currentArena[(idx+1)%size];
    (nextArena[idx])->setState((currentArena[idx])->evolve(neighborhood));
  }
  tmpArena     = currentArena;
  currentArena = nextArena;
  nextArena    = tmpArena;
}

void Playground::initCurrentArena() {
  // impulse
  (currentArena[size/2])->setState(1);
}

void Playground::printArena() {
   for(int idx=0; idx<size; idx++) {
      if((currentArena[idx])->getState()) {
        cout << "o";
      } else {
        cout << " ";
      }
   }
   cout << endl;
}
```

Okay, now which evolve method is being called?

The one from AbsCell or the one from Cell? Why? How does C++ do the right thing?

Virtualization and late binding!

V.3

Okay, great but there are other CAs out there... what if I want to define a different kind of cell conforming to the AbsCell interface? Do I need to rewrite the Playground every time I have a different kind of cell?

Naturally not, and this question has an (almost) infinite amount of answers in terms of what you can do.

For this particular tasks I've chosen to use a template: a structure that has one or more parametric arguments whic can be classes or types.

Templates are extremely powerful tools and constitute a kind of language within the language. I'm not even going to scrape its surface.

Just FYI, templates are the base of generic programming.

```
#ifndef _PLAYGROUND_H_
#define _PLAYGROUND_H_

#include "AbsCell.hh"

using namespace std;

template <class T> class Playground {
private:
  AbsCell** currentArena;
  AbsCell** nextArena;
  AbsCell** tmpArena;
  int RuleSet[8];
  int rule, size;

public:

  Playground(int aSize, int aRule) {
    size = aSize;
    rule = aRule;

    currentArena = new AbsCell*[size];
    nextArena    = new AbsCell*[size];

    this->createRuleSet();

    for(int idx=0; idx<size; idx++) {
      currentArena[idx] = new T(0, RuleSet);
      nextArena[idx]    = new T(0, RuleSet);
    }
    this->initCurrentArena();
  }

  virtual ~Playground() {
    delete[] currentArena;
    delete[] nextArena;
  }

  void createRuleSet();
  void initCurrentArena();
  void nextGeneration();
  void printArena();
};
```

Template definition: I'm informing the compiler that T is going to be a class.
The compiler knows NOTHING about T until I actually 'instantiate' the template with a real class

Playground.hh [template version, v3][1/2]

```
template <class T> void Playground<T>::createRuleSet() {
  for(int idx=0; idx<8; idx++) {
    RuleSet[idx] = (rule & (1 << idx)) / (1 <<idx);
  }
}

template <class T> void Playground<T>::nextGeneration() {
  AbsCell* neighborhood[2];

  for(int idx=0; idx<size; idx++) {
    int pidx = (idx-1)<0?(size-1):(idx-1);
    neighborhood[0] = currentArena[pidx];
    neighborhood[1] = currentArena[(idx+1)%size];
    (nextArena[idx])->setState((currentArena[idx])->evolve(neighborhood));
  }
  tmpArena     = currentArena;
  currentArena = nextArena;
  nextArena    = tmpArena;
}

template <class T> void Playground<T>::initCurrentArena() {
  // impulse
  (currentArena[size/2])->setState(1);
}

template <class T> void Playground<T>::printArena() {
   for(int idx=0; idx<size; idx++) {
      if((currentArena[idx])->getState()) {
        cout << "o";
      } else {
        cout << " ";
      }
   }
   cout << endl;
}
#endif
```

Playground.hh [template version, v3][2/2]

```
#include<iostream>
#include "Playground.hh"
#include "Cell.hh"

#define PLAYGROUND_SIZE 80
#define GENERATIONS     100
#define RULE            30


int main (int argc, const char * argv[]) {

  Playground<Cell>* myPlayground = new Playground<Cell>(PLAYGROUND_SIZE, RULE);

  for(int idx=0; idx<GENERATIONS; idx++) {
    myPlayground->nextGeneration();
    myPlayground->printArena();
  }

  return 0;
}
```

...and here I instantiate the template with 'Cell' instead of T...

V.4

```
#ifndef _ABSCELL_H_
#define _ABSCELL_H_

#include <iostream>

class AbsCell {

public:
  virtual ~AbsCell() {};

  virtual int evolve(AbsCell* neighbors[])=0;
  virtual int getState()=0;
  virtual int setState(int)=0;
  virtual void print()=0;
};

#endif
```

Responsibility: who should do what?
Shouldn't the AbsCell decide how to display itself?

Somebody should, and everybody should be able to delegate to someone else, as long as somebody knows how to to do it (The perfect hyerarchical principle).

AbsCell.hh [v4]

```
#ifndef _CELL_H_
#define _CELL_H_

#include <iostream>
#include "AbsCell.hh"

using namespace std;

class Cell: public AbsCell {
private:
  int state;
  int RuleSet[8];

public:
  Cell() { state = 0; }

  Cell(int aState): state(aState) {}

  Cell(int aState, int* aRuleSet) {
    state = aState;
    for(int i=0; i<8; i++) {
      RuleSet[i] = aRuleSet[i];
    }
  }

  virtual ~Cell() {}

  virtual int evolve(AbsCell* neighbors[]);

  virtual int getState() {
    return state;
  }

  virtual int setState(int aState) {
    state = aState;
  }

  virtual void print();
};

#endif
```

```
#ifndef _CELL3_H_
#define _CELL3_H_

#include <iostream>
#include "AbsCell.hh"

using namespace std;

class Cell3: public AbsCell {
private:
  int state;
  int RuleSet[8];

public:
  Cell3() { state = 0; }

  Cell3(int aState): state(aState) {}

  Cell3(int aState, int* aRuleSet) {
    state = aState;
    for(int i=0; i<8; i++) {
      RuleSet[i] = aRuleSet[i];
    }
  }

  virtual ~Cell3() {}

  virtual int evolve(AbsCell* neighbors[]);

  virtual int getState() {
    return state;
  }

  virtual int setState(int aState) {
    state = aState;
  }

  virtual void print();
};

#endif
```

`Cell.hh / Cell3.hh[v4]`

```cpp
#include "Cell.hh"

int Cell::evolve(AbsCell* neighbors[]) {
  int stateInfo = 4*(neighbors[0])->getState() + 2 * state + (neighbors[1])->getState();
  return RuleSet[stateInfo];
}

void Cell::print() {
  if(state) {
    cout << "o";
  } else {
    cout << " ";
  }
}
```

```cpp
#include "Cell3.hh"

int Cell3::evolve(AbsCell* neighbors[]) {
  int stateInfo = 4*(neighbors[0])->getState() + 2 * state + (neighbors[1])->getState();
  return RuleSet[stateInfo];
}

void Cell3::print() {
  if(state) {
    cout << ".";
  } else {
    cout << " ";
  }
}
```

Cell.cc / Cell3.cc [v4]

```
[... same code as before, this is the only method that was
affected by the interface change due to delegation...]

template <class T> void Playground<T>::printArena() {
   for(int idx=0; idx<size; idx++) {
      (currentArena[idx])->print();
   }
   cout << endl;
}
```

Playground.hh [v4]

```cpp
#include<iostream>
#include "Playground.hh"
#include "Cell.hh"
#include "Cell3.hh"

#define PLAYGROUND_SIZE 80
#define GENERATIONS     100
#define RULE            30


int main (int argc, const char * argv[]) {

  Playground<Cell>* myPlayground = new Playground<Cell>(PLAYGROUND_SIZE, RULE);

  for(int idx=0; idx<GENERATIONS; idx++) {
    myPlayground->nextGeneration();
    myPlayground->printArena();
  }

  cout << endl << "And now for something completely different... " << endl;

  Playground<Cell3>* myPlayground2 = new Playground<Cell3>(PLAYGROUND_SIZE, RULE);
  for(int idx=0; idx<GENERATIONS; idx++) {
    myPlayground2->nextGeneration();
    myPlayground2->printArena();
  }

  return 0;
}
```

ca1d.cc [v4]

In the end (this time really for real)

- You don’t know C++, you didn’t learn it today
  - unless you knew it already
- It will take time to learn it
  - a lot of time
    - deal with it ;)
- There’s a lot more out there, and you will learn it over time.
- Like it or not, it’s a tool
- Object oriented programming is NOT C++
  - and vice versa!
- The more you know the less you’ll be surprised...
  - and you don’t want to be surprised. Right? ;)