Announcements

- Final exam: Friday, December 19, 14:00, at the GYM

  `http://www.mcgill.ca/student-records/exam/`

- Final exam tutorials

- Assignment 6 deadline: Saturday, December 6

Review

- Linked-lists: nodes with data and pointer to the next
- Traversing a linked-list

```
Node p = first;
while (p != null && ...) {
  //...
  p = p.get_next();
}
```

- Difference between a linked-list and an array
  - An array has a fixed size
  - A linked-list is dynamic: its size increases each time we add a new element and we don't have to worry about running out of space

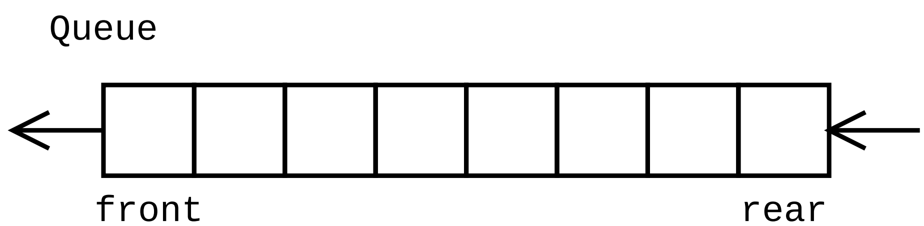
Queues and Stacks

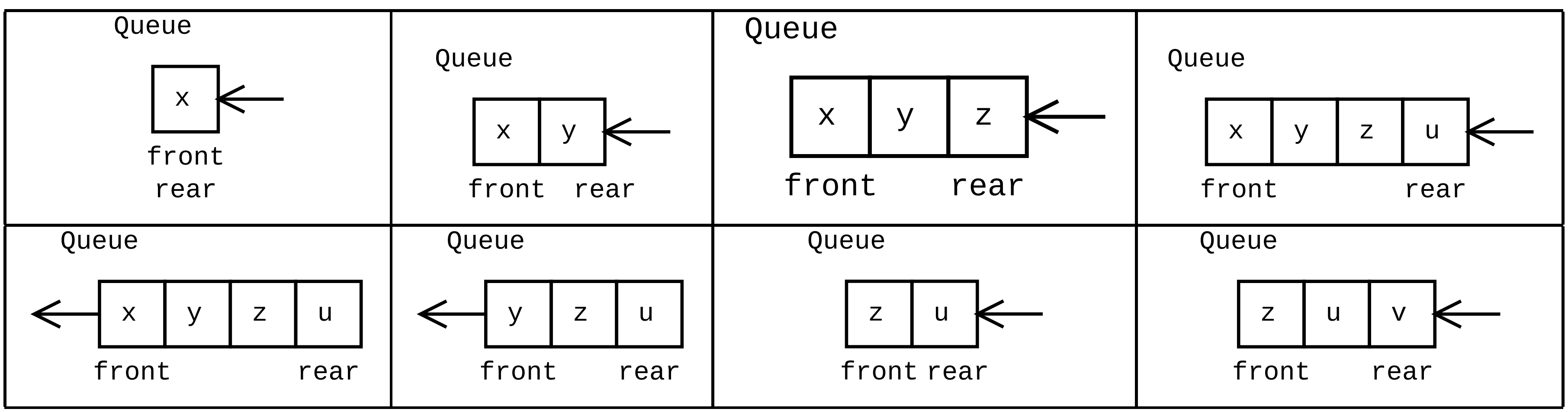
- Queues and Stacks are ADTs representing linear collections with particular operations

- A *queue* (FIFO) is a (dynamic) linear collection with (at least) the following operations:
  - *enqueue*: adds an item at the end of the sequence
  - *dequeue*: removes the first item of the sequence
  - *peek*: gets the first item of the sequence without removing it
  - *isempty*: returns true if the sequence has no items

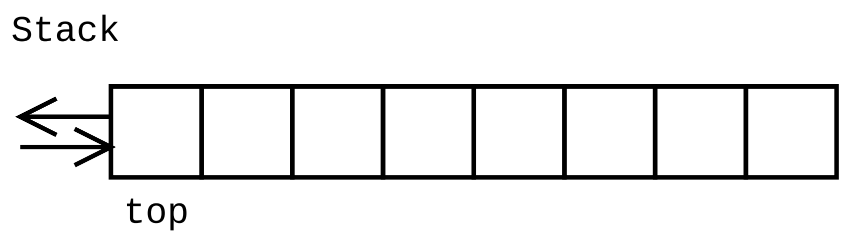
- A *stack* (LIFO, or FILO) is a (dynamic) linear collection with (at least) the following operations:
  - *push*: adds an item at the "top" of the sequence
  - *pop*: removes the "top" item of the sequence
  - *top*: returns the top item without removing it
  - *isempty*: returns true if the sequence has no items

Queues

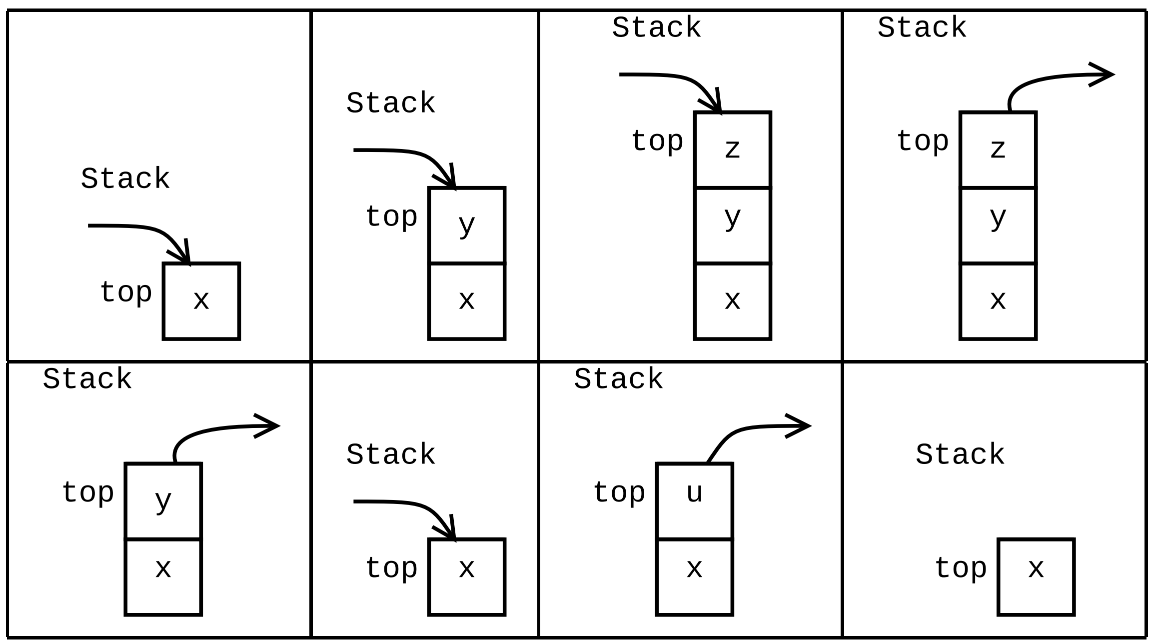

Queue
front
rear


Queue
x
front
rear
Queue
x y
front rear
Queue
x y z
front rear
Queue
x y z u
front rear
Queue
x y z u
front rear
Queue
y z u
front rear
Queue
z u
front rear
Queue
z u v
front rear

Stacks



Stack
top



Stack
top
x
Stack
top
y
x
Stack
top
z
y
x
Stack
top
z
y
x
Stack
top
y
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Stack
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x

Queues and Stacks

- Queues and Stacks are ADTs so they can be implemented in many different ways
- For example, they could be implemented using
  - Linked-lists
  - Arrays
  - Doubly-linked-lists
  - Linked-lists with front and rear pointers
  - Vectors/Growing arrays
  - "Circular" arrays
- Each implementation has advantages and disadvantages with respect to efficiency
- Queues implemented as fixed-size circular arrays are commonly called *buffers*

Implementing Queues

```
class LinkedList {
  //...
  public LinkedList() { ... }
  public void insert_at(Object o, int index) { ...
  public void remove_at(int index) { ... }
  public Object element_at(int index) { ... }
  public int length() { ... }
}
```

Implementing Queues

```
class Queue {
  private LinkedList list;
  public Queue() { list = new LinkedList(); }
  public void enqueue(Object obj)
  {
    list.insert_at(obj, list.length());
  }
  public void dequeue()
  {
    list.remove_at(0);
  }
  public Object peek()
  {
    return list.element_at(0);
  }
  public boolean isempty()
  {
    return list.length() == 0;
  }
}
```

Implementing Queues

```
class Queue {
  private LinkedList list;
  public Queue() { list = new LinkedList(); }
  public void enqueue(Object obj)
  {
    list.insert_at(obj, 0);
  }
  public void dequeue()
  {
    list.remove_at(list.length());
  }
  public Object peek()
  {
    return list.element_at(list.length());
  }
  public boolean isempty()
  {
    return list.length() == 0;
  }
}
```

Implementing Queues

```
class Queue {
  private LinkedList list;
  public Queue() { list = new LinkedList(); }
  public void enqueue(Object obj)
  {
    list.add_at_end(obj);
  }
  public void dequeue()
  {
    list.remove_first();
  }
  public Object peek()
  {
    return list.element_at(0);
  }
  public boolean isempty()
  {
    return list.length() == 0;
  }
}
```

Implementing Stacks

```
class Stack {
  private LinkedList list;
  public Stack() { list = new LinkedList(); }
  public void push(Object obj)
  {
    list.insert_at(obj, 0);
  }
  public void pop()
  {
    list.remove_at(0);
  }
  public Object top()
  {
    return list.element_at(0);
  }
  public boolean isempty()
  {
    return list.length() == 0;
  }
}
```

Implementing Stacks

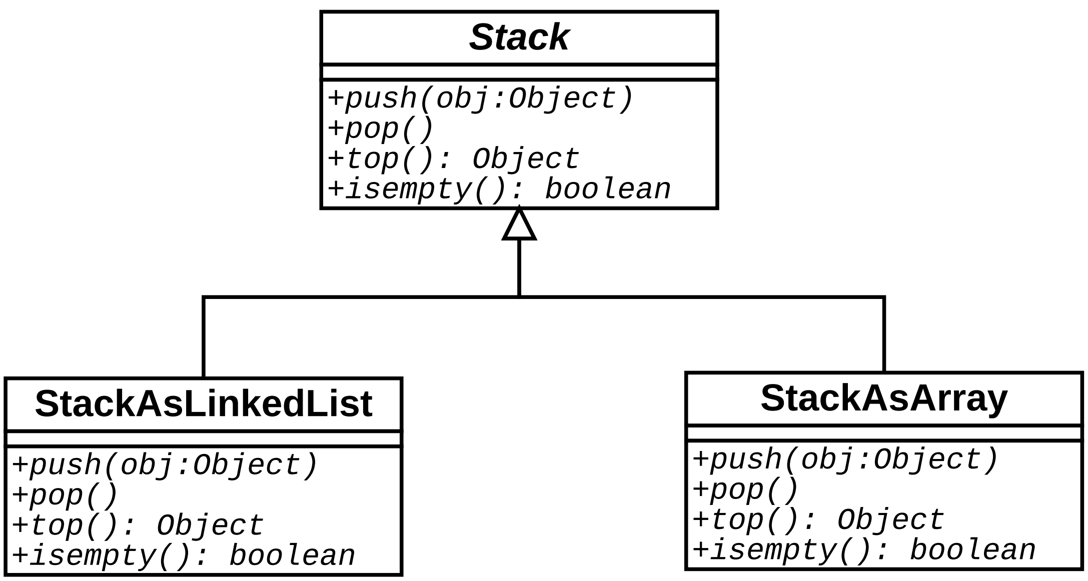
```
class Stack {
  private Object[] list;
  private int top;

  public Stack()
  {
    list = new Object[1000];
    top = 0;
  }
  public void push(Object obj)
  {
    if (top >= list.length)
      grow_array(100);
    list[top] = obj;
    top++;
  }
```

Implementing Stacks

```
  public void pop()
  {
    top--;
  }
  public Object top()
  {
    return list[top];
  }
  public boolean isempty()
  {
    return top == 0;
  }
  private void grow_array(int n)
  {
    ...
  }
} // End of Stack
```

ADTs and abstract classes

- Stacks and queues constrain the operations on a list
- An ADT should be declared as an interface or abstract class, and the concrete implementations should implement the interface or extend the abstract class



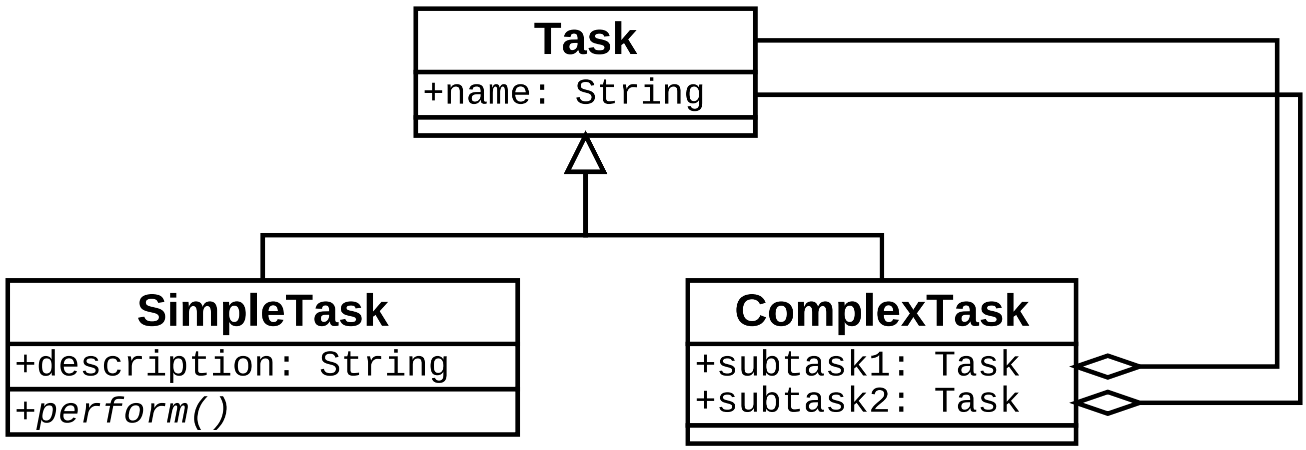
Applications (Simulation)

```
class Customer { ... }
class SuperMarket {
  Queue line;
  SuperMarket() { line = new Queue(); }
  void process(Customer c) { ... }
  void run()
  {
    while (true) {
      int coin = (int)(Math.random() * 2);
      if (coin == 1) {
        Customer first = line.peek();
        process(first);
        line.dequeue();
      }
      else {
        line.enqueue(new Customer());
      }
    }
  }
}
```

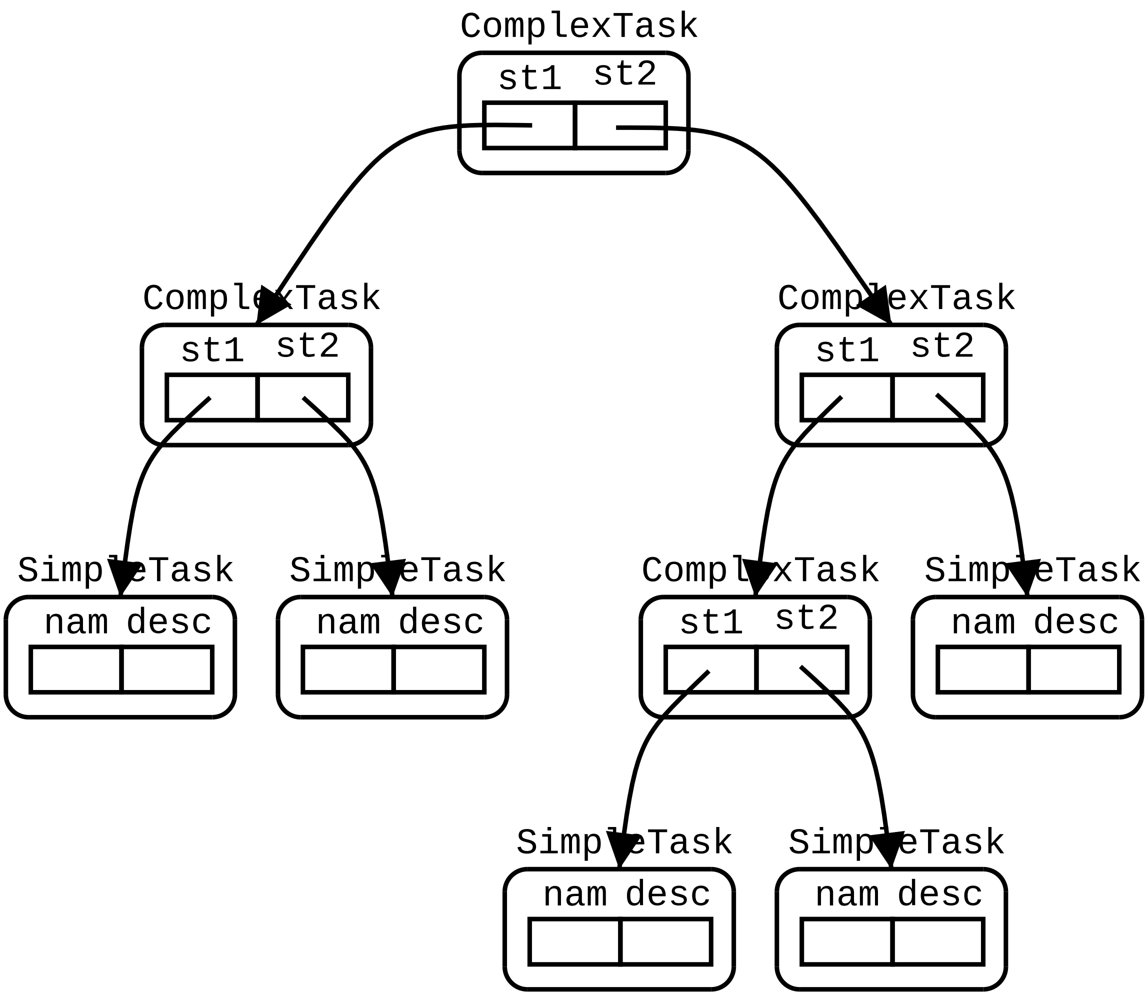
Applications (reverse)

```
static String reverse(String s)
{
  String r = "";
  Stack stack = new Stack();
  int i = 0;
  while (i < s.length()) {
    stack.push(new Character(s.charAt(i)));
    i++;
  }
  while (!stack.isempty()) {
    Character c = (Character)stack.top();
    r = r + c.charValue();
    stack.pop();
  }
  return r;
}
```

Binary Trees



Binary Trees



Binary Trees

```
abstract class Task {
  String name;
}

class SimpleTask extends Task {
  String description;
  void perform()
  {
    System.out.println(name+“:”+description);
    //...
  }
}

class ComplexTask extends Task {
  Task subtask1, subtask2;
}
```

Binary Trees

- Processing trees using recursion

```
class Worker {
  void work(Task t)
  {
    if (t instanceof SimpleTask) {
      ((SimpleTask)t).perform();
    }
    else if (t instanceof ComplexTask) {
      work(((ComplexTask)t).subtask1);
      work(((ComplexTask)t).subtask2);
    }
  }
}
```

Binary Trees

- Processing trees using stacks

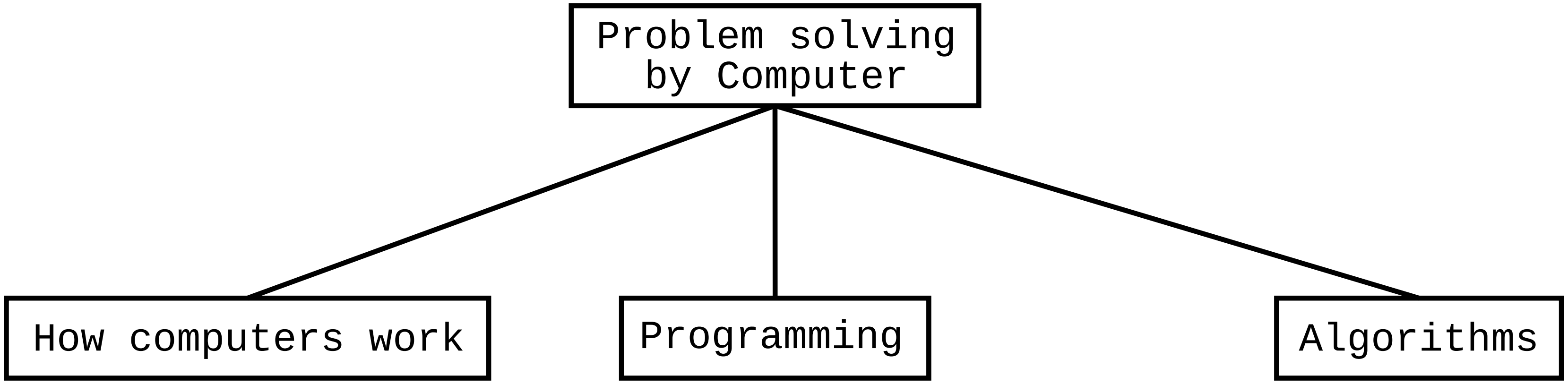
```
class Worker {
  void work(Task t)
  {
    Stack s = new Stack();
    s.push(t);
    while (!s.isempty()) {
      Task temp = s.top();
      s.pop();
      if (temp instanceof SimpleTask) {
        ((SimpleTask)t).perform();
      }
      else {
        s.push(((ComplexTask)temp).subtask2);
        s.push(((ComplexTask)temp).subtask1);
      }
    }
  }
}
```

Data structures zoo

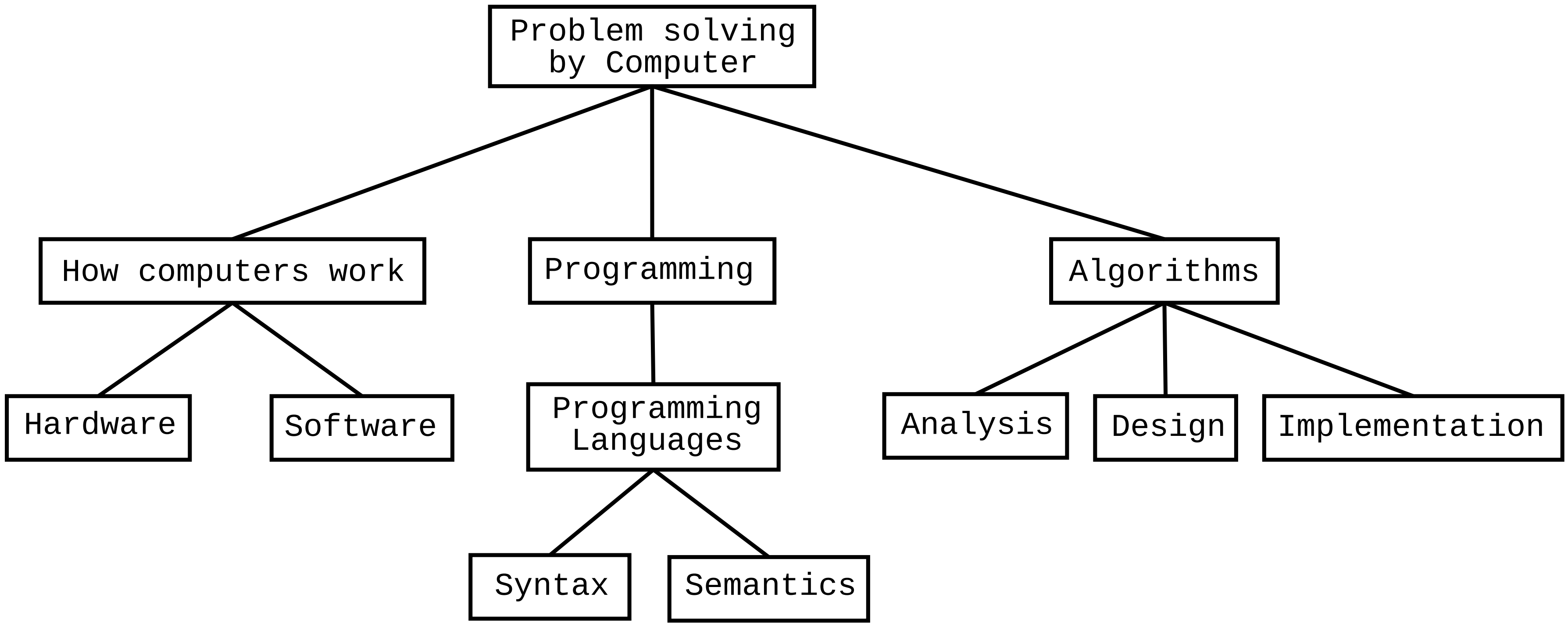
- Other data-structures: sets, bags, priority queues, heaps, binary trees, n-ary trees, red-black trees, AVL trees, graphs, hyper-graphs, hi-graphs, dictionaries/mappings, etc.

- The selection of data-structure has a major impact on the efficiency of an algorithm.

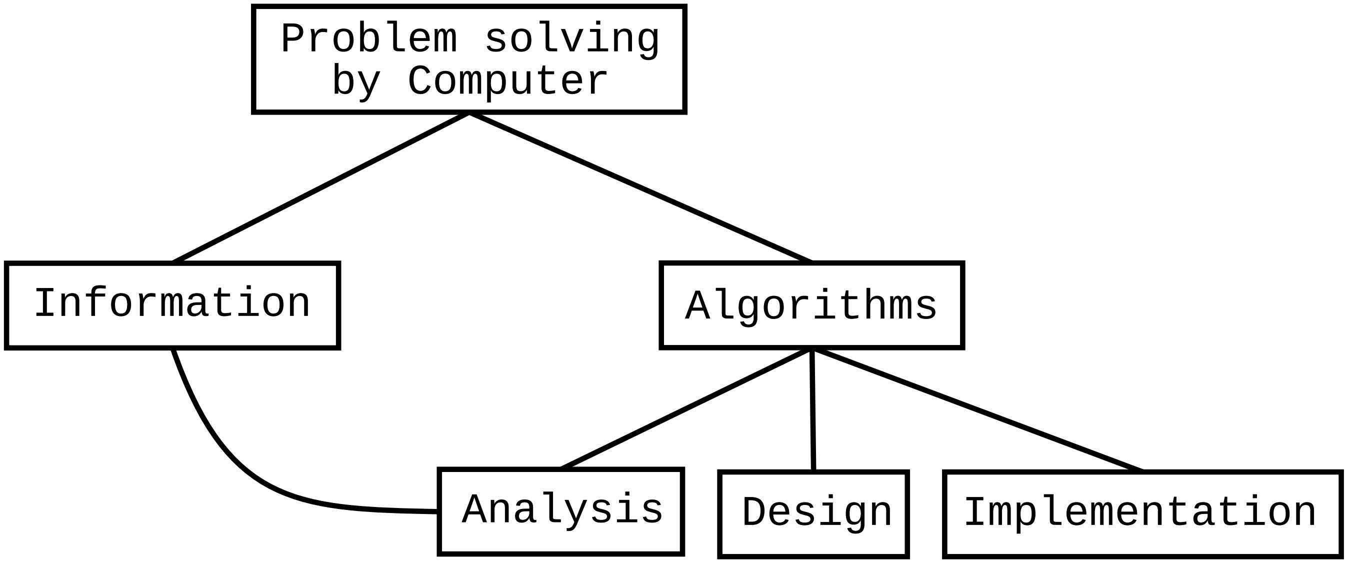
The big picture



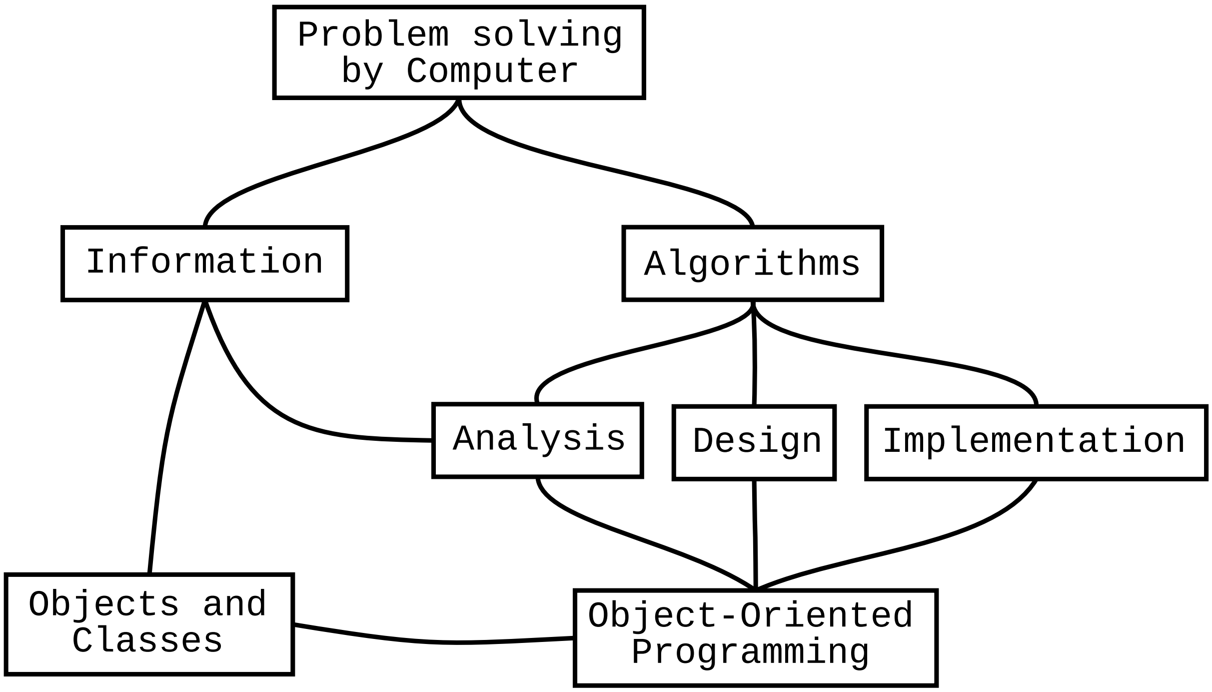
The big picture



The big picture



The big picture



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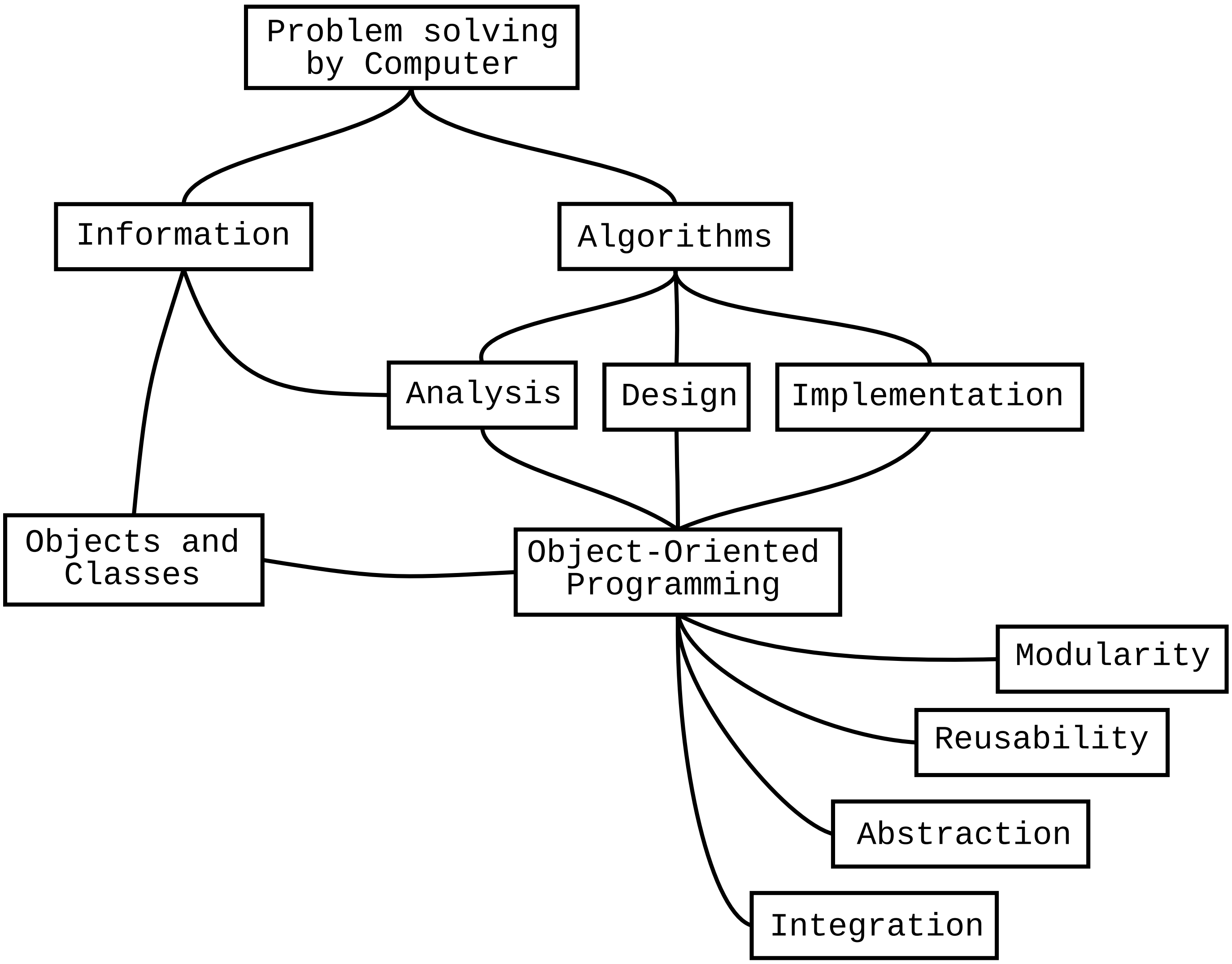

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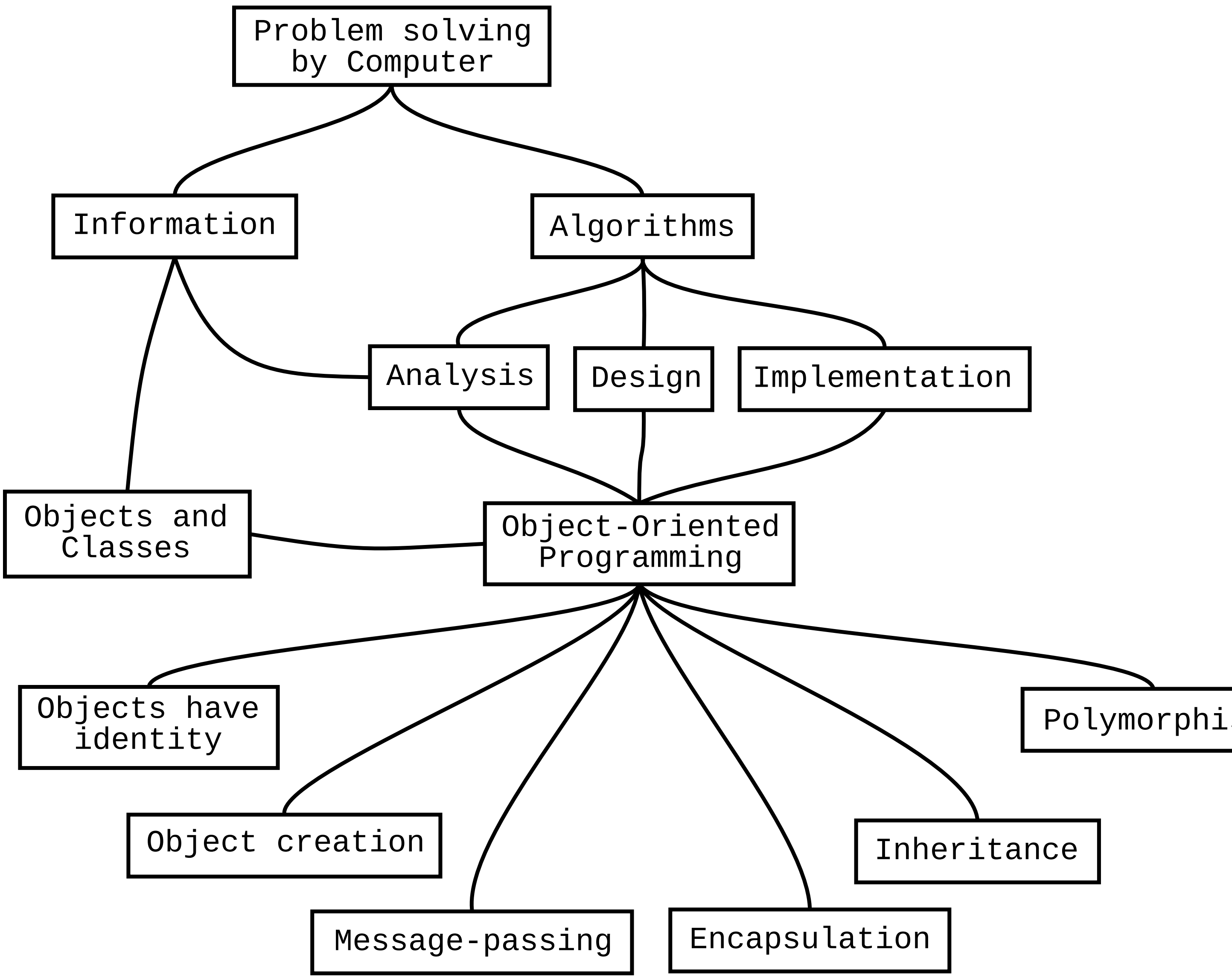

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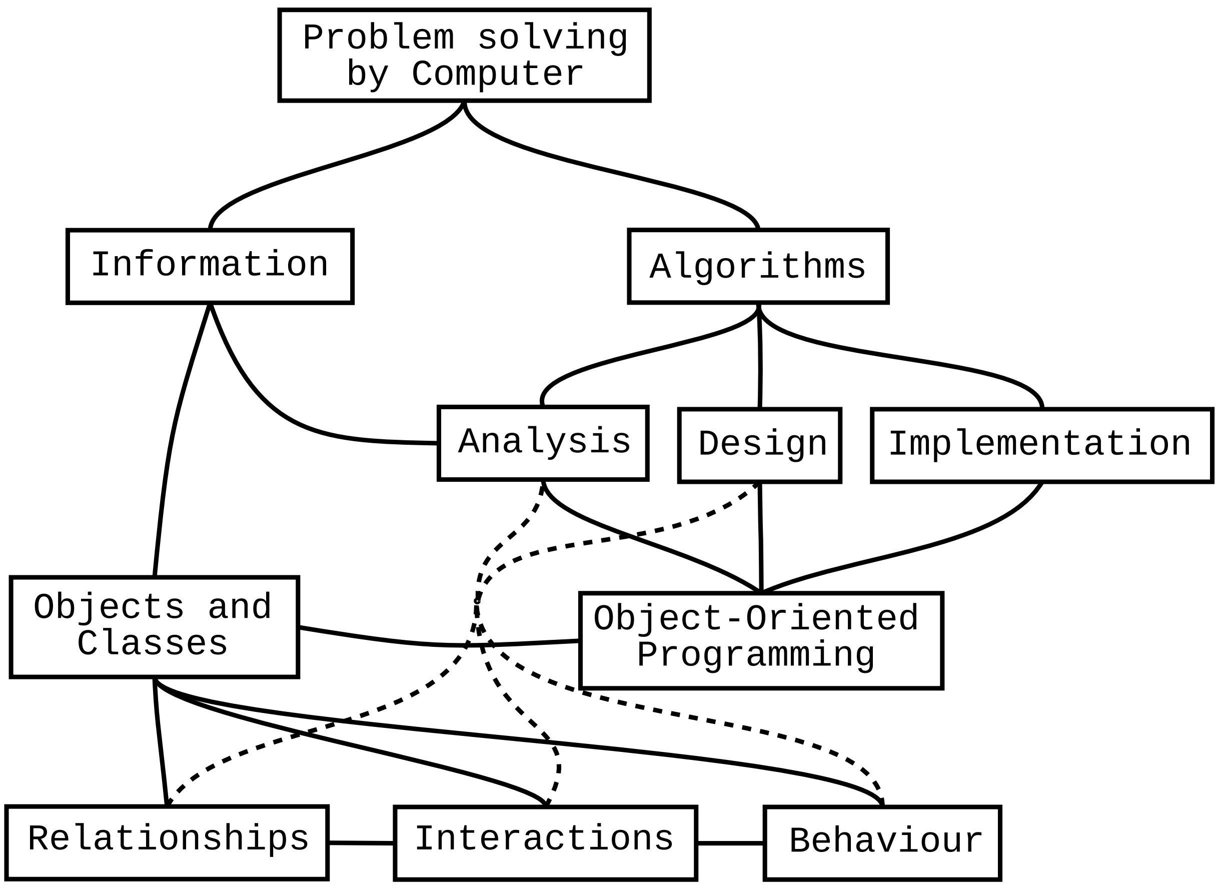

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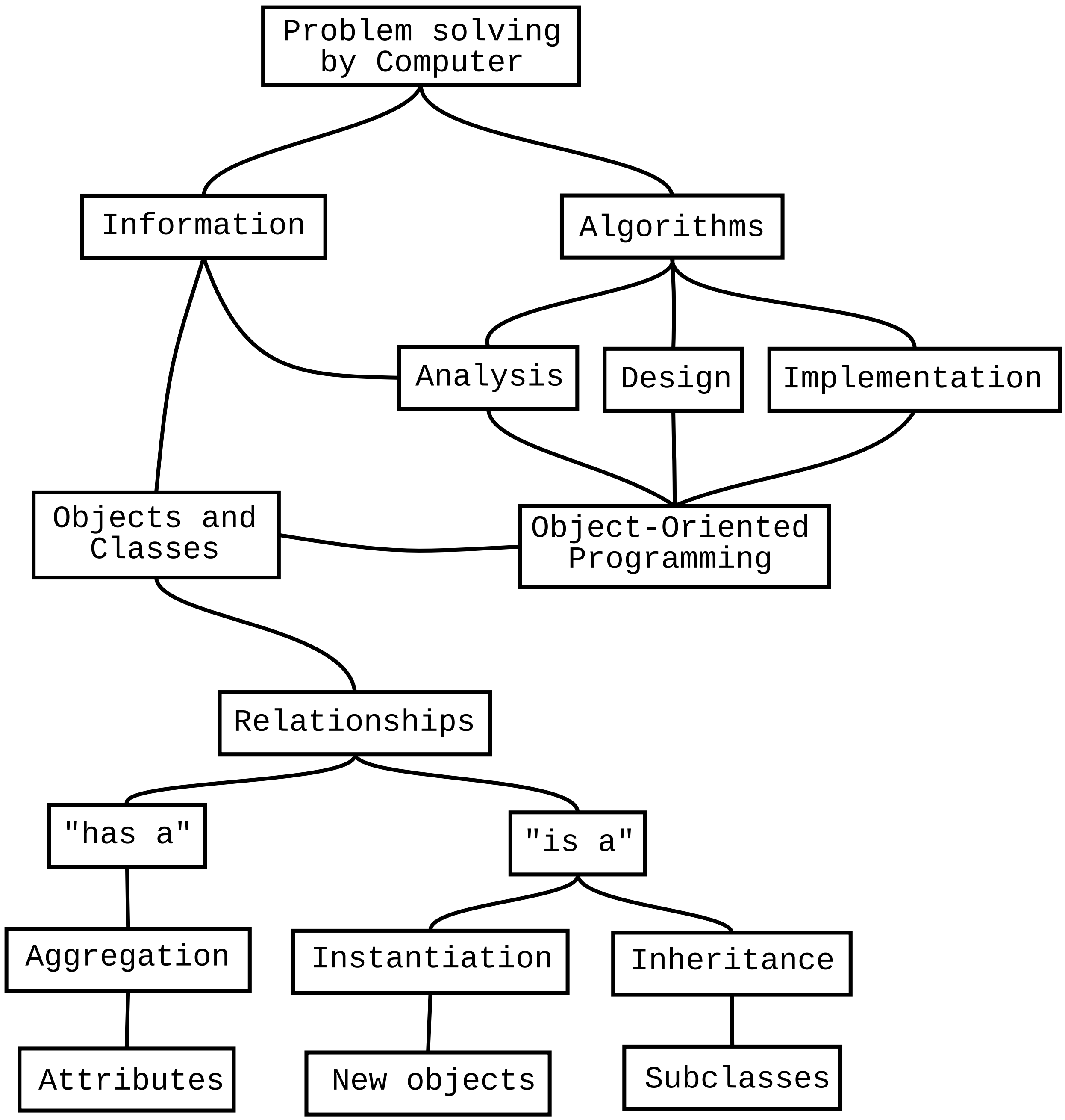

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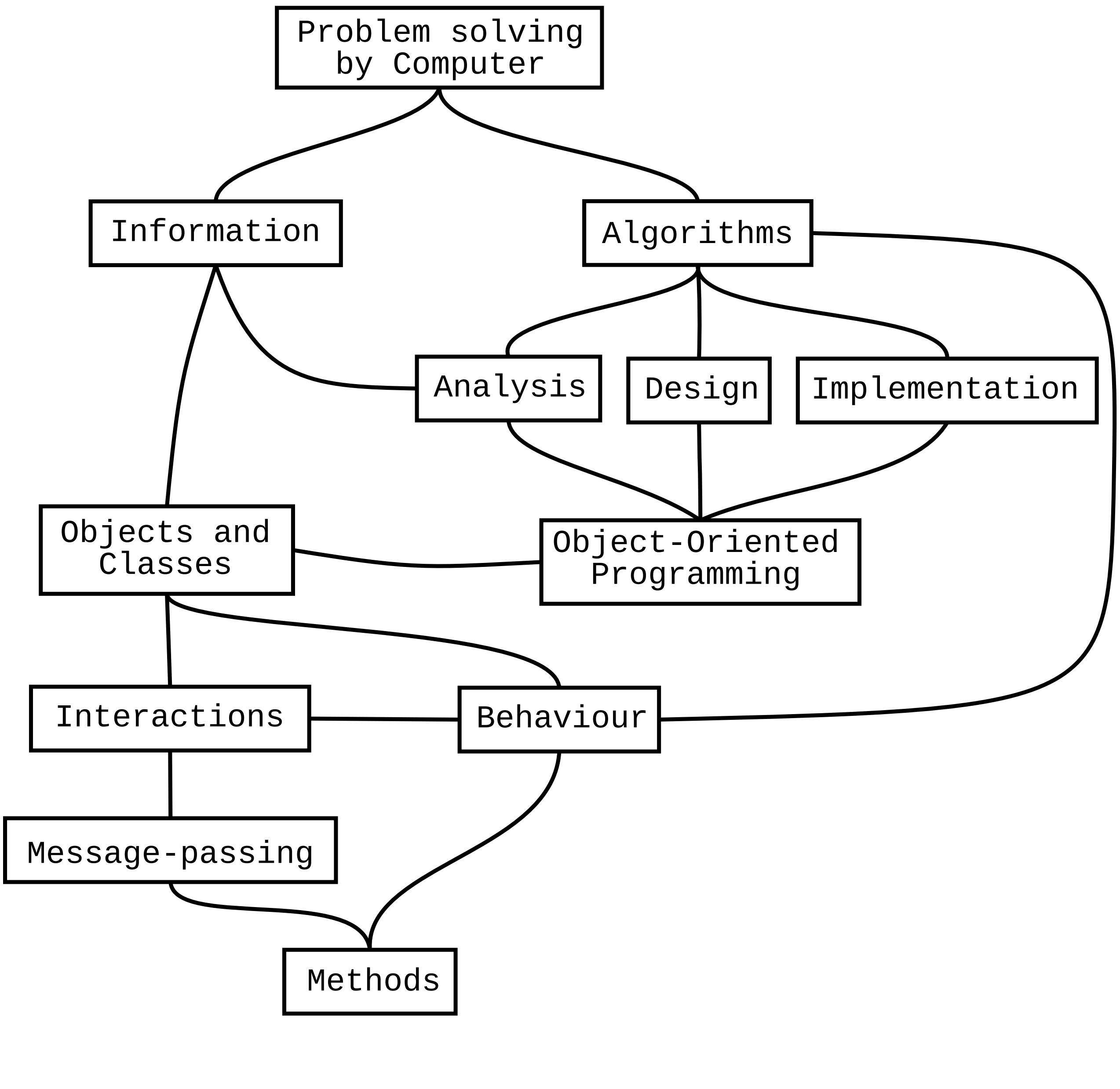

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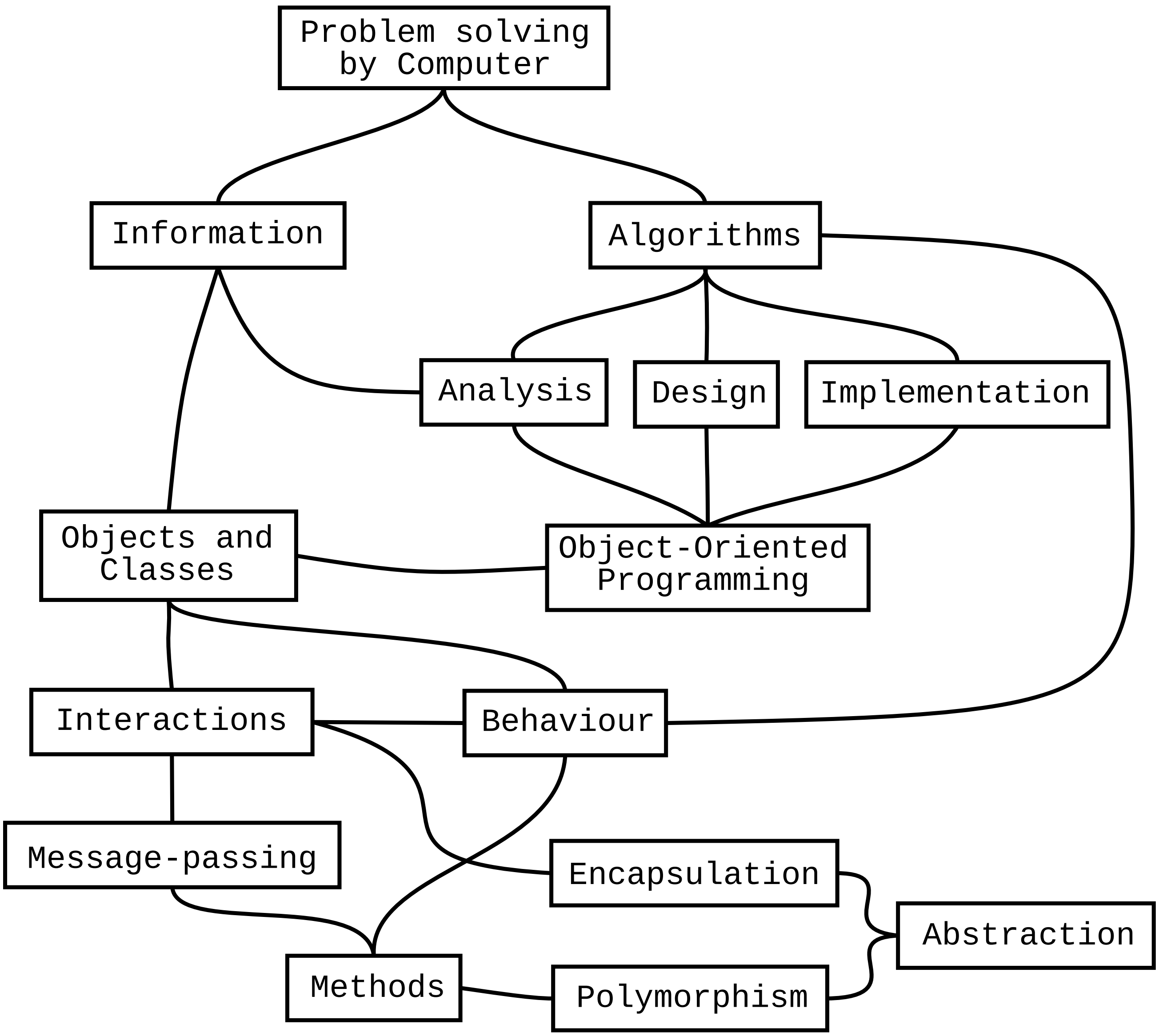

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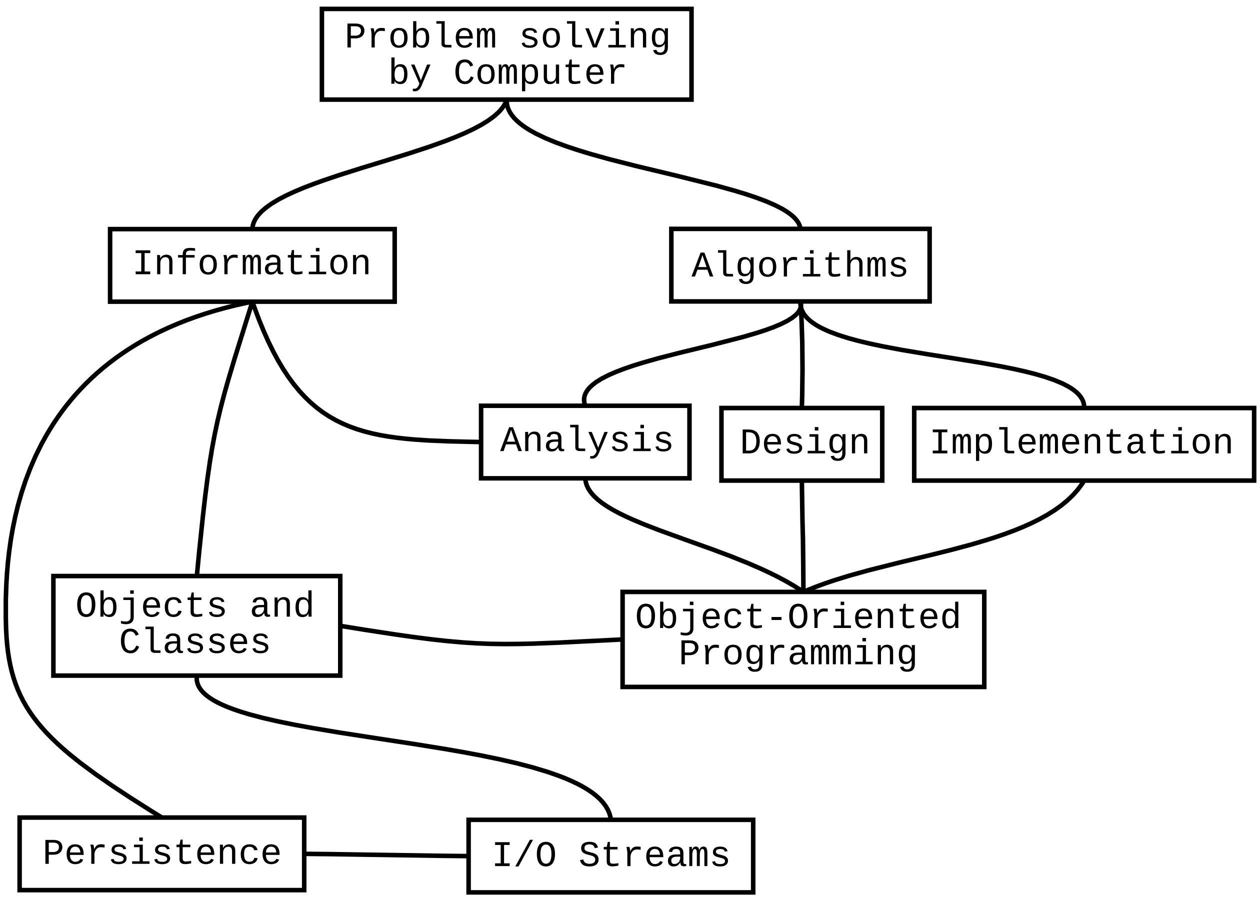

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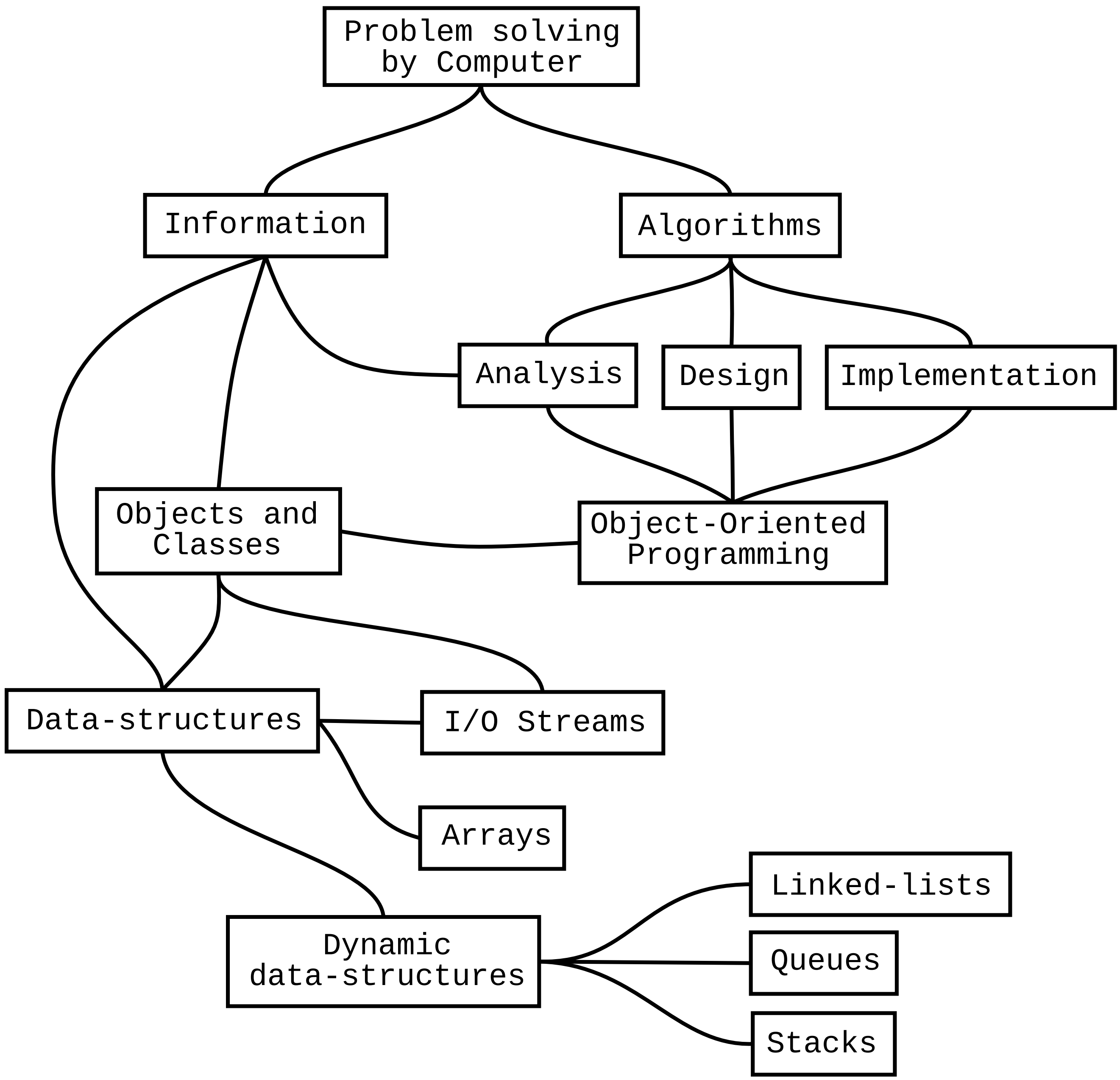

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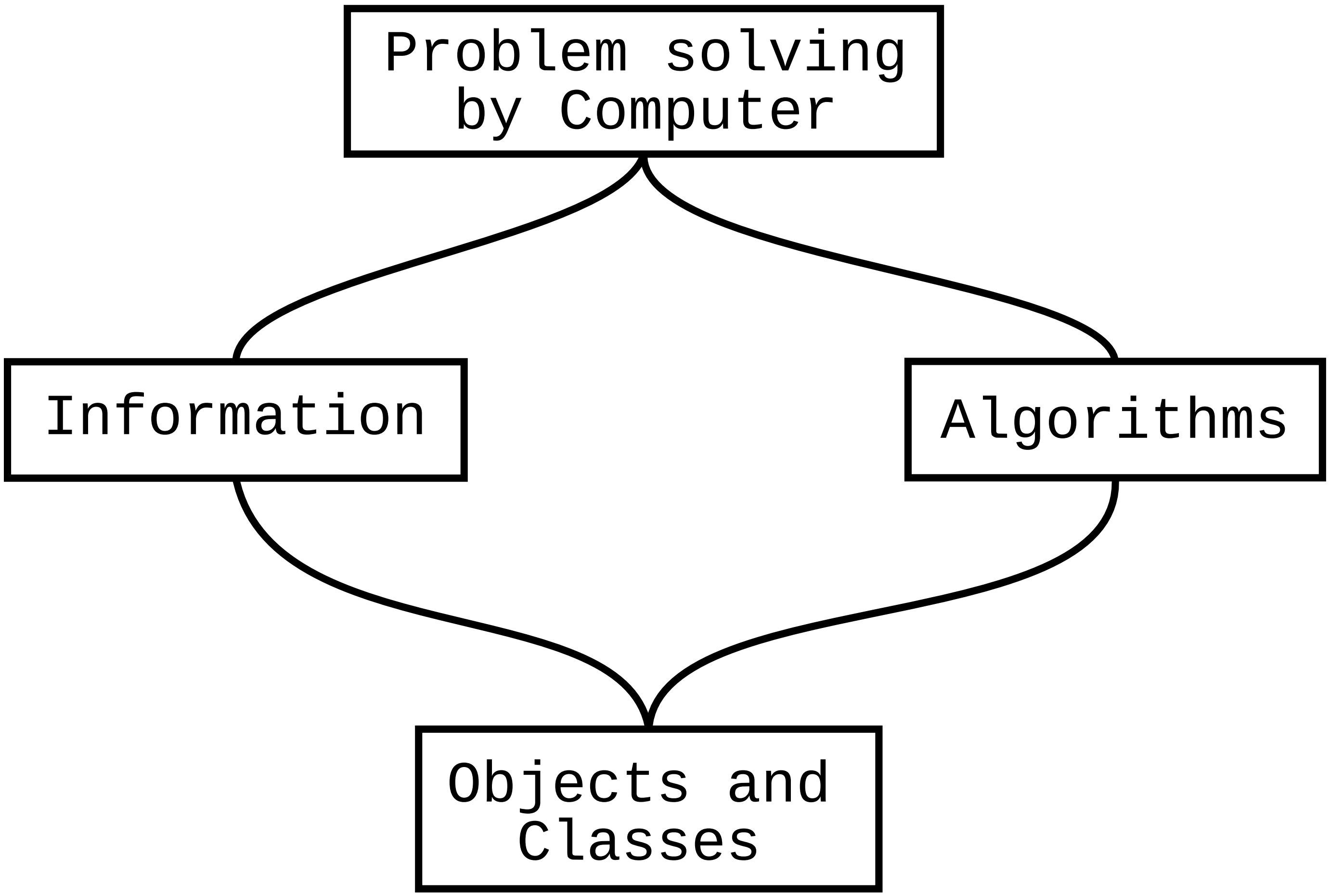

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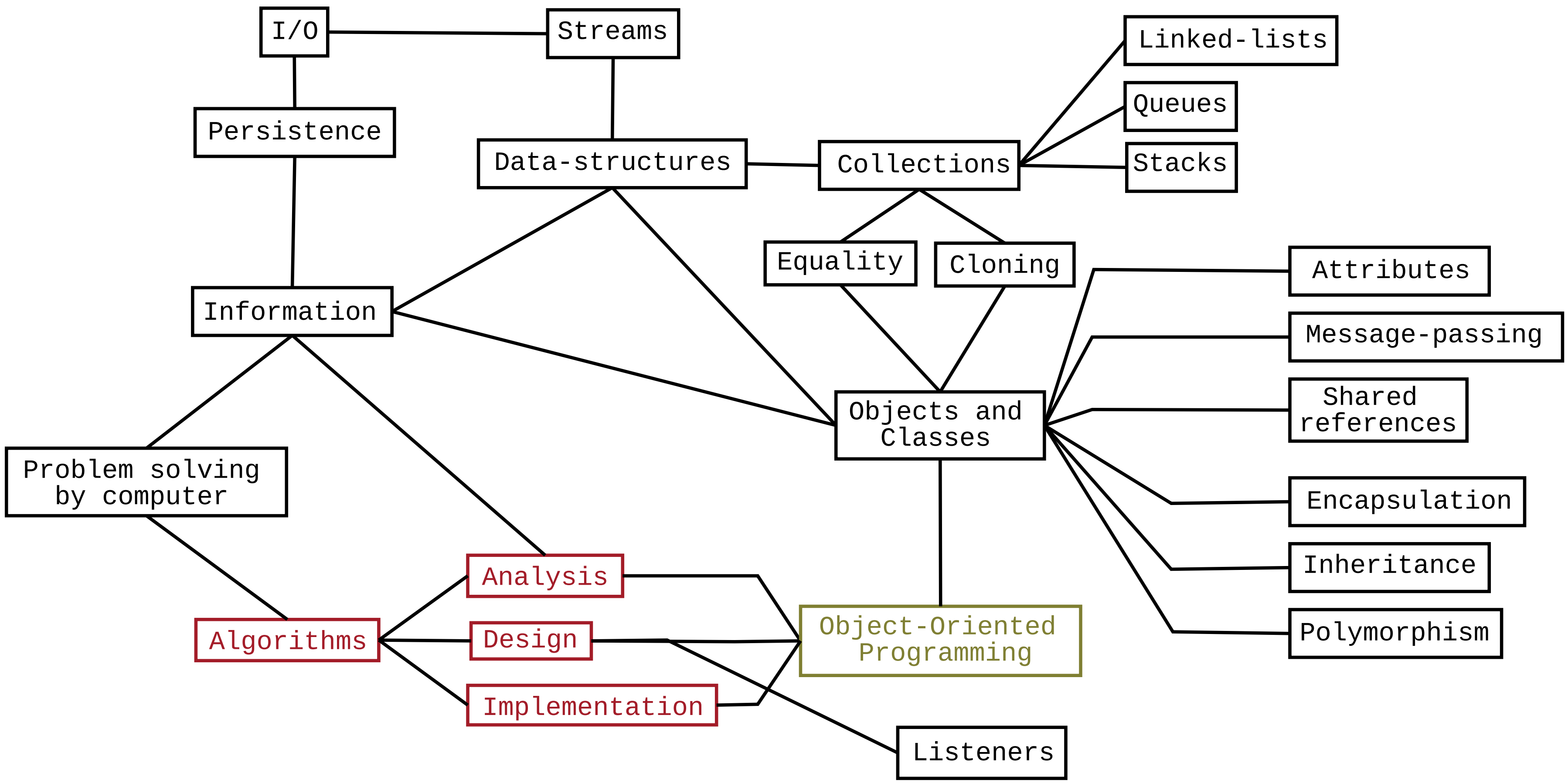

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