COMP110: Principles of Computing

2: Basic Principles for Computation

Learning outcomes

By the end of this week's sessions, you should be able to:

- **Use** binary, decimal and hexadecimal notation to represent and operate on numerical values
- **Explain** the basic architecture of a computer
- **Distinguish** the most common programming languages and paradigms in use today

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Research journal

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- **Read** some seminal papers in computing (listed on the assignment brief)

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  - With reference to appropriate academic sources

Marking rubric

See assignment brief on LearningSpace/GitHub

Timeline

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- **Peer review** in week 11 (4th December)

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- Finding and reading academic papers takes time and effort — don't leave it until the last minute!

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Binary notation

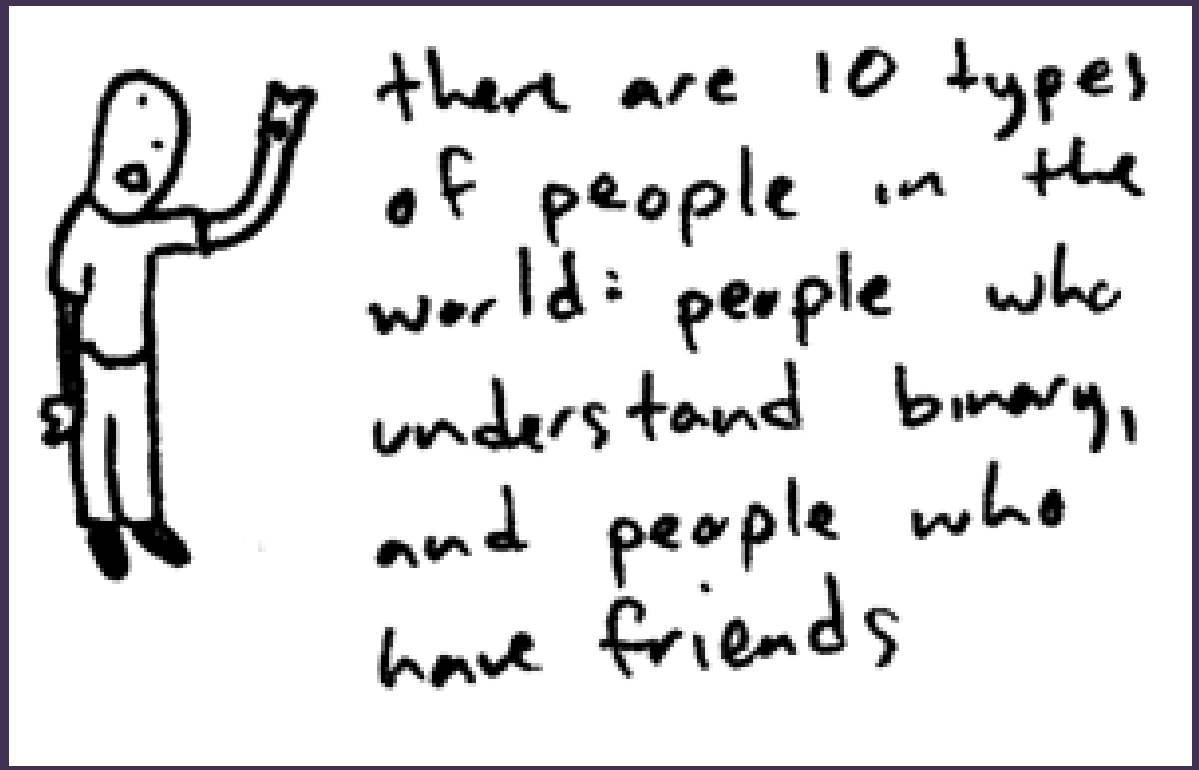

Image credit: http://www.toothpastefordinner.com

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Converting to binary

https://www.youtube.com/watch?v=OezK_zTyvAQ

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Addition with carry

In base 10:

$$\begin{array}{rcccc} & 1 & 2 & 3 & 4 \\ + & 5 & 6 & 7 & 8 \\ \hline \end{array}$$

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$$\boxed{1+1=10 \qquad 1+1+1=11}$$

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- Note that the left-most bit can be interpreted as a **sign** bit: 1 if negative, 0 if positive or zero

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- This is also the process for converting back from 2's complement, i.e. doing it twice should give the original number

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- In fact, subtraction can just be done as addition
- I.e. $a - b$ is the same as $a + (-b)$, where a and $-b$ are just n-bit numbers

Exercise Sheet i

Due next Tuesday!

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Programming languages and paradigms

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- A **program** is a sequence of instructions for a computer to perform a specific task
- A **programming language** is a formal language for communicating these sequences of instructions

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- There are hundreds of programming languages, each better suited to some tasks than others
- Sometimes your choice is dictated by your choice of platform, framework, game engine etc.
- To become a better programmer (and maximise your employability) you should learn several languages (but one at a time!)

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- High level languages trade efficiency for ease of programming
- Lower level languages were once the choice of game programmers, but advances in hardware mean that higher level languages are often a better choice

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- **Declarative**: does not define the control flow of a program, but rather defines logical relations

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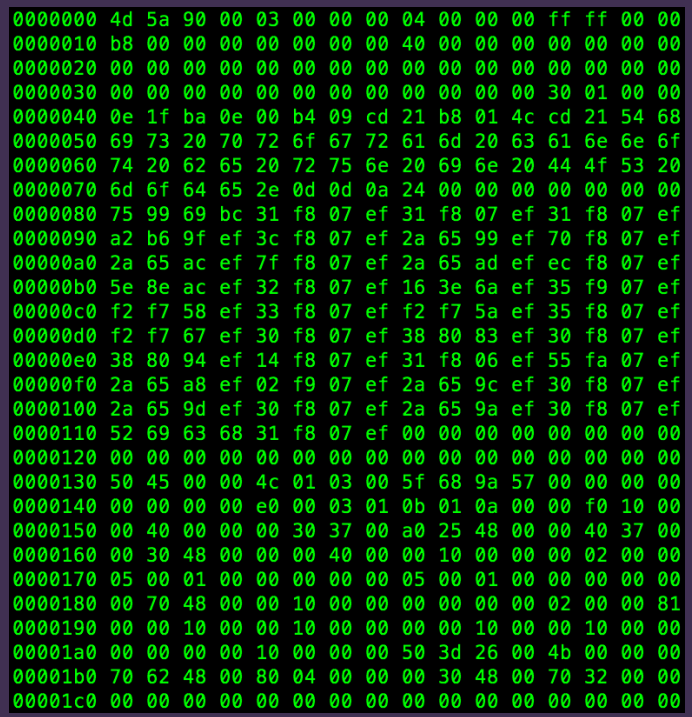
- Purely **functional** languages are mainly used in academia, but favoured by some programmers
- Purely **declarative** languages have uses in academia and some special-purpose languages

Machine code

```
0000000 4d 5a 90 00 03 00 00 00 04 00 00 00 ff ff 00 00
0000010 b8 00 00 00 00 00 00 00 40 00 00 00 00 00 00 00
0000020 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0000030 00 00 00 00 00 00 00 00 00 00 00 00 30 01 00 00
0000040 0e 1f ba 0e 00 b4 09 cd 21 b8 01 4c cd 21 54 68
0000050 69 73 20 70 72 6f 67 72 61 6d 20 63 61 6e 6e 6f
0000060 74 20 62 65 20 72 75 6e 20 69 6e 20 44 4f 53 20
0000070 6d 6f 64 65 2e 0d 0d 0a 24 00 00 00 00 00 00 00
0000080 75 99 69 bc 31 f8 07 ef 31 f8 07 ef 31 f8 07 ef
0000090 a2 b6 9f ef 3c f8 07 ef 2a 65 99 ef 70 f8 07 ef
00000a0 2a 65 ac ef 7f f8 07 ef 2a 65 ad ef ec f8 07 ef
00000b0 5e 8e ac ef 32 f8 07 ef 16 3e 6a ef 35 f9 07 ef
00000c0 f2 f7 58 ef 33 f8 07 ef f2 f7 5a ef 35 f8 07 ef
00000d0 f2 f7 67 ef 30 f8 07 ef 38 80 83 ef 30 f8 07 ef
00000e0 38 80 94 ef 14 f8 07 ef 31 f8 06 ef 55 fa 07 ef
00000f0 2a 65 a8 ef 02 f9 07 ef 2a 65 9c ef 30 f8 07 ef
0000100 2a 65 9d ef 30 f8 07 ef 2a 65 9a ef 30 f8 07 ef
0000110 52 69 63 68 31 f8 07 ef 00 00 00 00 00 00 00 00
0000120 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0000130 50 45 00 00 4c 01 03 00 5f 68 9a 57 00 00 00 00
0000140 00 00 00 00 e0 00 03 01 0b 01 0a 00 00 f0 10 00
0000150 00 40 00 00 00 30 37 00 a0 25 48 00 00 40 37 00
0000160 00 30 48 00 00 00 40 00 00 10 00 00 00 02 00 00
0000170 05 00 01 00 00 00 00 00 05 00 01 00 00 00 00 00
0000180 00 70 48 00 00 10 00 00 00 00 00 00 02 00 00 81
0000190 00 00 10 00 00 10 00 00 00 00 10 00 00 10 00 00
00001a0 00 00 00 00 00 10 00 00 00 50 3d 26 00 4b 00 00
00001b0 70 62 48 00 80 04 00 00 00 30 48 00 70 32 00 00
00001c0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

Machine code



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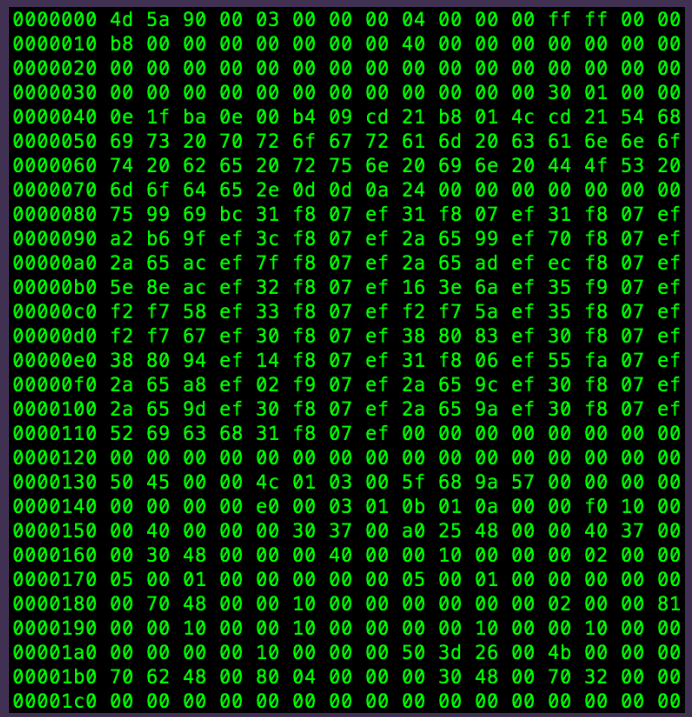

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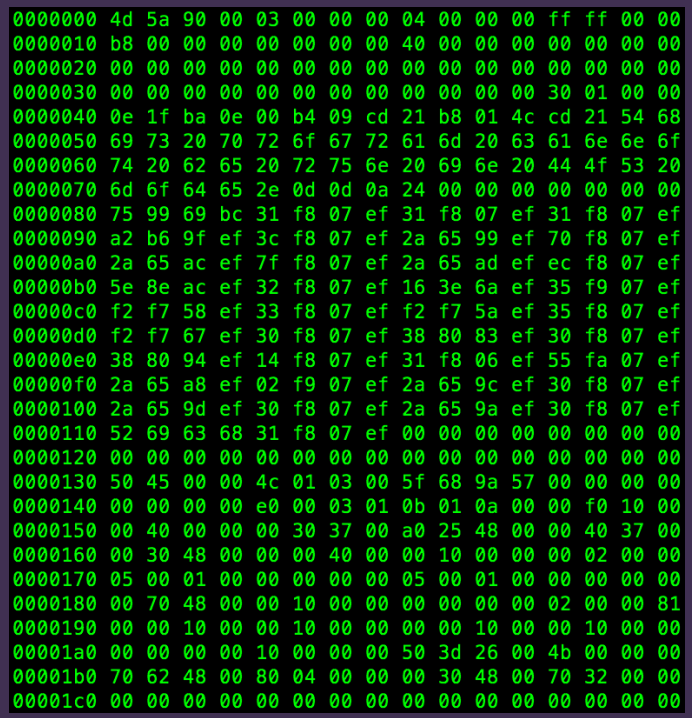

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- More on this later in the module
- Nobody has actually written programs in machine code since the 1960s...

Assembly language

```
section     .text
global      _start

_start:

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- Also not portable between CPU architectures

C++

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#include "stdafx.h"
#include "GameObject.h"
#include "CoinGame.h"

GameObject::GameObject(CoinGame* game, Texture* sprite)
	: game(game), sprite(sprite), isDead(false)
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	x = rand() % CoinGame::WINDOW_WIDTH;
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GameObject::~GameObject()
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void GameObject::render(SDL_Renderer* renderer)
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	sprite->render(renderer, x, y, CoinGame::SPRITE_SIZE, CoinGame::SPRITE_SIZE);
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bool GameObject::checkCollision(int otherX, int otherY)
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- Also used by developers of operating systems and embedded systems, but falling out of favour with other software developers

High level languages

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There are many others, but these are the most commonly used in game development

Scripting languages

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Many games use scripting languages in addition to their main development language

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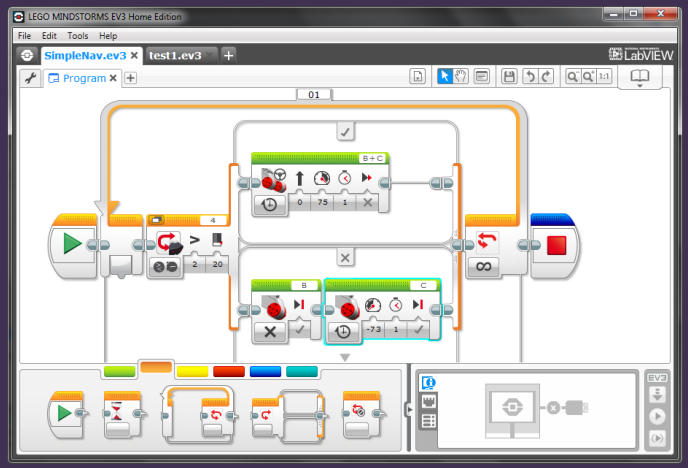
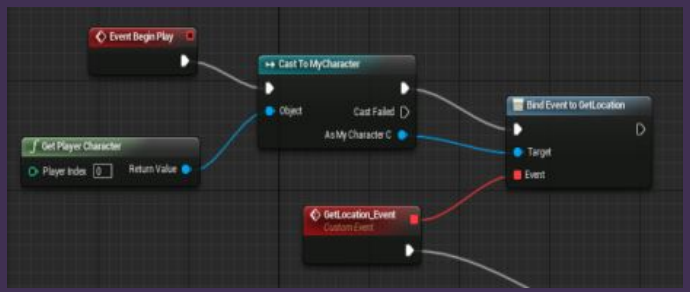
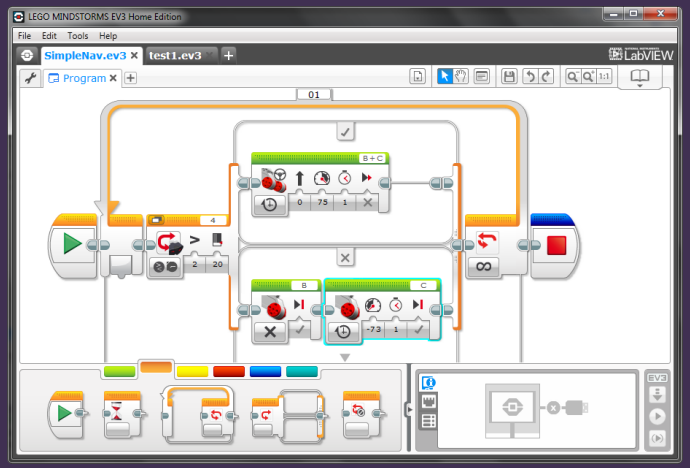
- UnrealScript, Blueprint (Unreal Engine)
- GML (GameMaker)

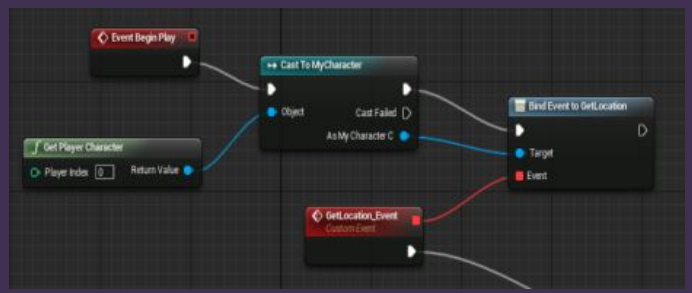
Visual programming languages





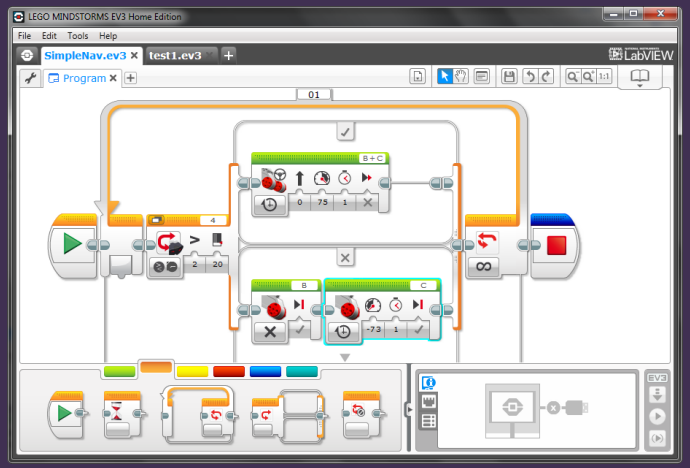
Visual programming languages

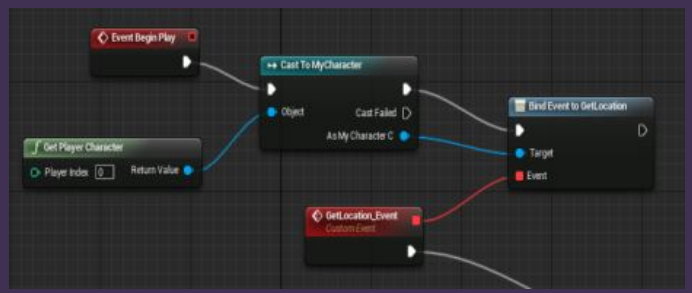




Based on connecting graphical blocks rather than writing code as text

Visual programming languages





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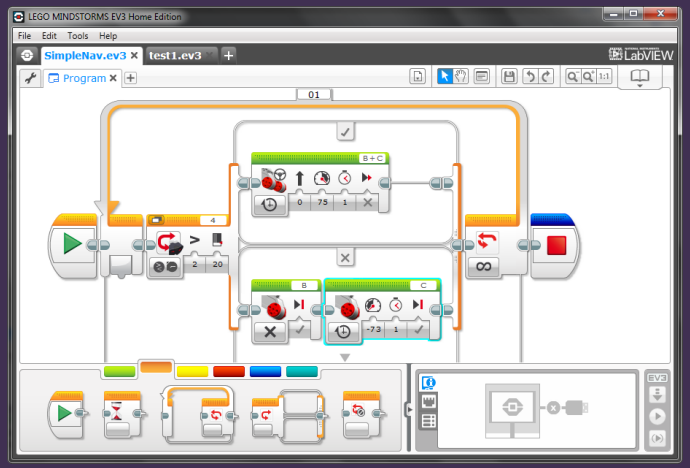

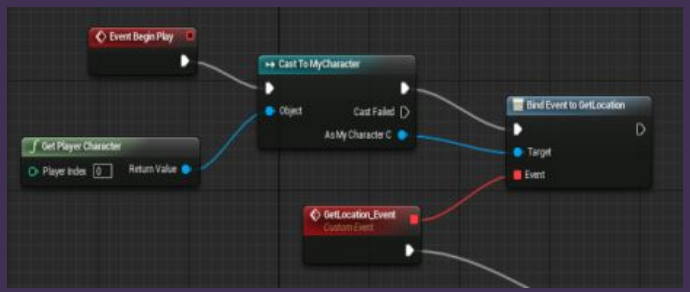

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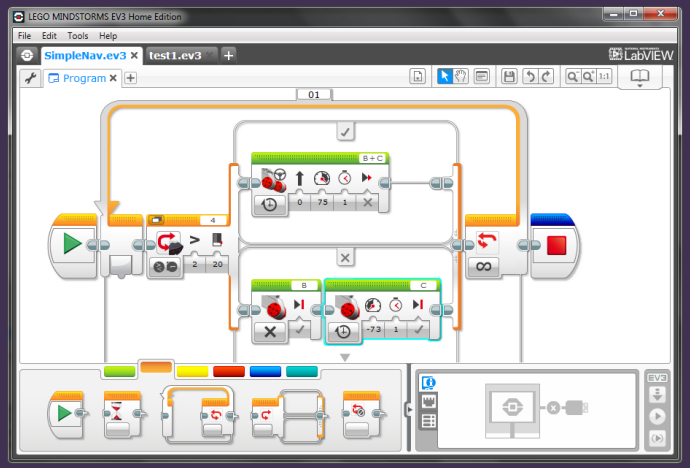

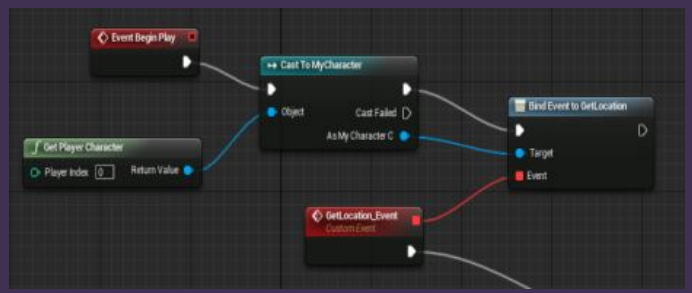

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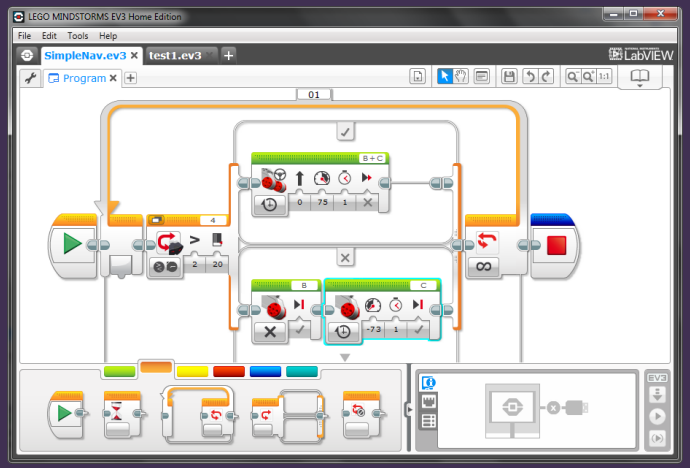

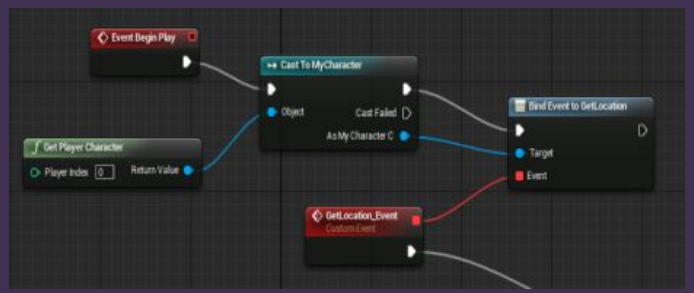

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Note: despite the name, Microsoft Visual Studio is **not** a visual programming environment!

Special purpose languages

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- LEX, YACC (script interpreters)

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- LaTeX, Markdown (documentation)
- XML, JSON (data storage)

Which programming language is most popular?

http://githut.info

“Family tree” of programming languages

https://www.levenez.com/lang/lang.pdf

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Turing machines

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- Introduced in 1936 by Alan Turing

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- Theoretical model of a "computer"
  - I.e. a machine that carries out computations (calculations)

Turing machine

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Turing machine

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- Each space on the tape holds a **symbol** from a finite **alphabet**
- Has a **tape head** pointing at one space on the tape
- Has a transition table which, given:
  - The current state
  - The symbol under the tape head

  specifies:
  - A new state
  - A new symbol to write to the tape, overwriting the current symbol
  - Where to move the tape head: one space to the left, or one space to the right

Activity

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- In groups of 3-4

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- Line up 5-10 chocolates of different colours — this is your **tape**

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- What computation does this machine perform?

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- Repeatedly apply the rules on the next slide
- What computation does this machine perform?
  - Hint: Milk $= 0$, White $= 1$, and remember yesterday's lecture...

Current lolly	Current chocolate	New lolly	New chocolate	Move direction
Drumstick	Blank	Fruit	Blank	$\leftarrow$
Drumstick	Milk	Drumstick	White	$\rightarrow$
Drumstick	White	Drumstick	Milk	$\rightarrow$
Fruit	Blank	Swizzels	White	$\rightarrow$
Fruit	Milk	Swizzels	White	$\leftarrow$
Fruit	White	Fruit	Milk	$\leftarrow$
Swizzels	Blank	Stop	Blank	$\rightarrow$
Swizzels	Milk	Swizzels	Milk	$\leftarrow$
Swizzels	White	Swizzels	White	$\leftarrow$

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- I.e. a Turing machine is the most "powerful" computer possible, in terms of what is possible or impossible to compute
- A machine, language or system is **Turing complete** if it can simulate a Turing machine

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Worksheet A review