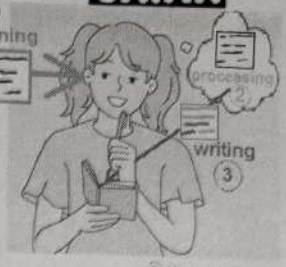
80% chance of rain in Oxford. This introduces the probabilistic nature of weather prediction

+0.1 17.6

blackboard chalkboard

Represents traditional teaching methods which might be less effective

A better learning method. This suggests that engaging more actively with material is more effective



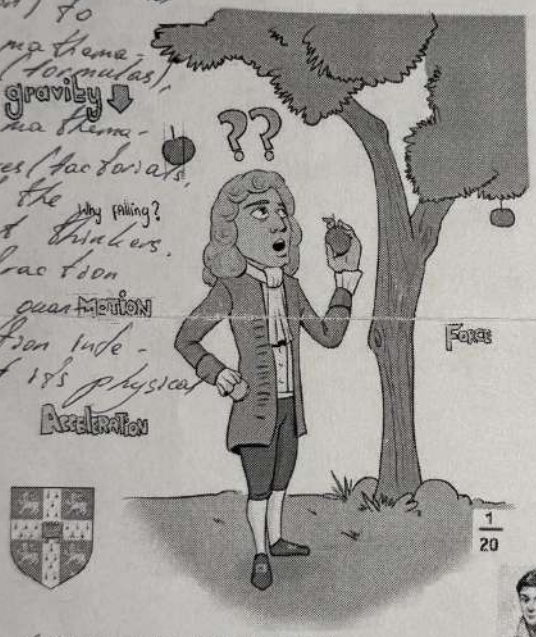
1 listening
2 first way of processing
3 Writing, incl. sth. you're not quite sure about

The contrast of school and university education.
- School = formalism, memorize formulas, symbols without deep understanding
- University = understanding, know meaning, connections, why.

School ↓ gravity ↓ MOTION ==formalism==> University $E=mc^2$ $\#\vec{D}d\vec{S}=Q$ $\iint_S \vec{J}d\vec{S}$

CONCRETE AND ABSTRACT THINKING

From concrete observations (gravity, motion) to abstract mathematical laws (formulas), then to pure mathematical structures (factorials, sequences) and the names of great thinkers. In IV, abstraction allows us to quantify information independently of its physical form.



$E=mc^2$ $\#\vec{D}d\vec{S}=Q$ $W=2\overline{uf}$ $\lambda=\frac{h}{\sqrt{2eum_e}}$ $\iint_S \vec{J}d\vec{S}$ $(\vec{E}\times\vec{B})$

ISAAC NEWTON

ALBERT EINSTEIN

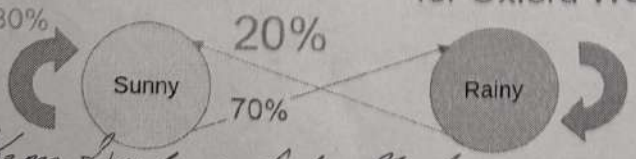
In the probability of rain each day is independent and identical from others. This implies that the occurence of rain on one day doesn't influence its occurence on another day.

Single day prob. of rain = 0.8 (80%)

Prob. of rain for n days independently = 0.8^n (80%)

Suppose the events $A_1, A_2, \ldots, A_n$ each have probability p, independently

Markoff Chain Probability Model for Oxford Weather



If it's rainy:
80% - stays rainy
20% - gets sunny

If it's sunny:
30% - stays sunny
70% - gets rainy

a mathematical model that predicts future based only on the current state

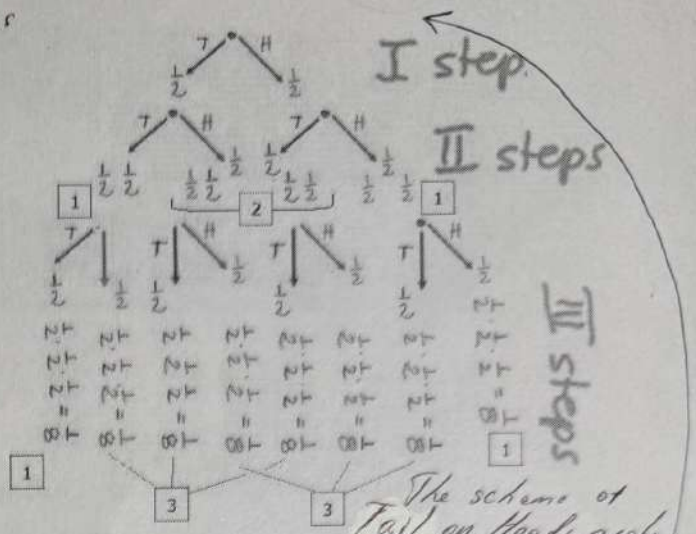
To find patterns, solve binomial expressions, answer probability questions

Pascal's triangle

1								1
1	1							2
1	2	1						4
1	3	3	1					8
1	4	6	4	1				16
1	5	10	10	5	1			32
1	6	15	20	15	6	1		64
1	7	21	35	35	21	7	1	128

Each number is the sum of the two numbers above it

1 8 28 56 70 56 28 8 1



The scheme of Tail on Heads probability using Pascal's Triangle

Newton's Binomial

$$(a+b)^0 = 1$$
$$(a+b)^1 = a+b$$
$$(a+b)^2 = a^2+2ab+b^2$$
$$(a+b)^3 = a^3+3a^2b+3ab^2+b^3$$
$$(a+b)^4 = a^4+4a^3b+6a^2b^2+4ab^3+b^4$$
$$(a+b)^5 = a^5+5a^4b+10a^3b^2+10a^2b^3+5ab^4+b^5$$
$$(a+b)^6 = a^6+6a^5b+15a^4b^2+20a^3b^3+15a^2b^4+6ab^5+b^6$$

A tree diagram illustrates step-by-step construction of Pascal's Triangle.

Each node splits into two branches, summing the values from the previous step.

Pascal's Triangle is a triangular array of numbers where each number is the sum of the two directly above it.

Each row corresponds to the coefficients in the expansion of a binomial expression $(a+b)^n$.

The binomial theorem states that $(a+b)^n$ can be expanded using the coefficients from Pascal's Triangle.

The general term in the expansion is given by $\binom{n}{k} a^{n-k} b^k$, where $\frac{n}{k}$ - is a binomial coefficient.

+0.1 +0.1 +0.1 +0.1 (+0.1) thorne

Willingness to be corrected

Sir Dr. D Mackay - a notable figure in information theory and error correction

Sir Dr. D. MacKay,
University of Cambridge
(22 April 1967 – 14 April 2016)

John Nash Alan Turing

He had dual commitment to both fields

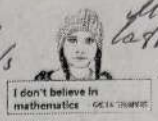
Machine Translation and coding

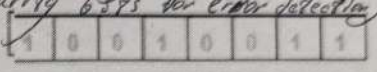
Artificial Intelligence

Parity bits for error detection

Crypto-graphy

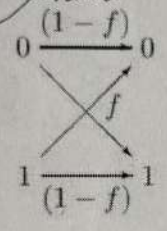
"I believe in clean energy, but I also believe in mathematics"

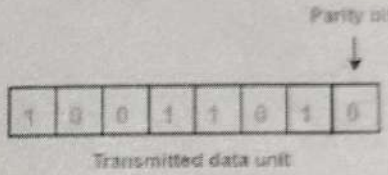




Redundant data helps ensure accuracy and reliability in the presence of errors

Is becoming common





1) Source codes the original data either 0 or 1

2) Encoding: each bit is repeated 3 times

3) Channel $f = 10\%$

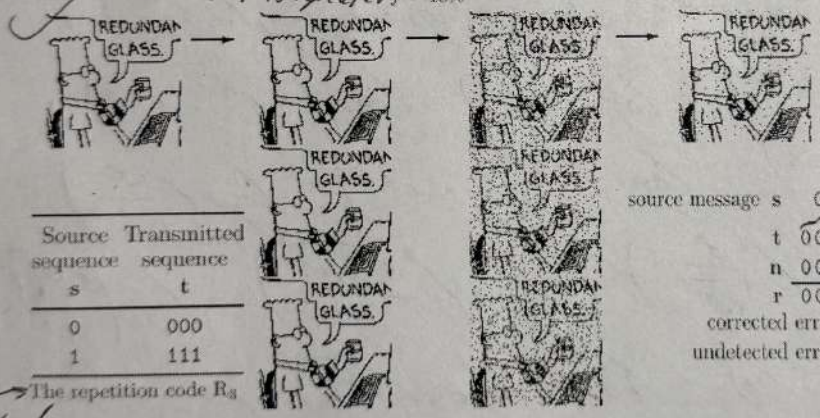
4) Reception

5) Decoding

s ENCODER t CHANNEL r DECODER ŝ

+0.1

+0.1



Source sequence s	Transmitted sequence t
0	000
1	111

The repetition code R_3

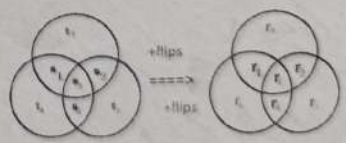
The process of error corrections

source message s	0	0	1	0	1	1	0
t	000	000	111	000	111	111	000
n	000	001	000	000	101	000	000
r	000	001	111	000	010	111	000
corrected errors		×			×		
undetected errors							

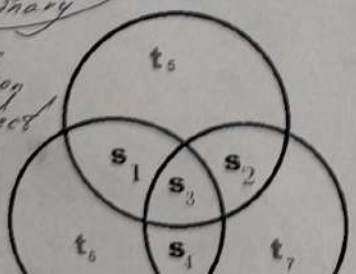
repeat each bit multiple times to create redundancy

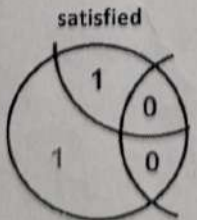
7.4. Hamming code.

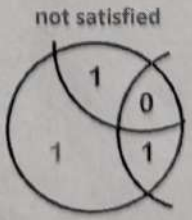
$$\frac{4}{\Sigma} \rightarrow \frac{7}{t}$$

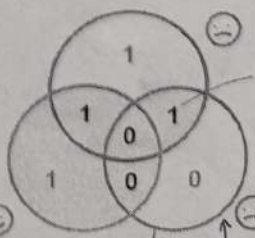


A type of binary code used for error correction that can detect and correct single-bit errors









represents different sets of parity bits. The intersections - the data bits being protected by the parity bits.

1+1+0+0=0 ☹ when the parity check results in even parity (sum of bits is even)

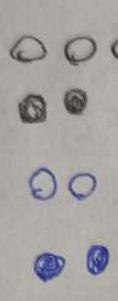
1+1+0+1=1 ☺ when the parity check results in odd parity

shows how the overlaps help in correcting the errors

Entropy

Total circles = 10

Two types of parity:
- Even parity: the parity bit is set such that the total number of 1's in the data (+ the parity bit) is even.
- Odd parity: the parity bit is set such that the total number of 1's in the data (+ the parity bit) is odd.



$\frac{4}{10} = \frac{2}{5} = 0,4$

$\frac{2}{10}\left(\frac{1}{3}\right) = 0,2$

$\frac{2}{10}\left(\frac{1}{3}\right) = 0,2$

$\left(\frac{2}{10}\right)\frac{1}{3} = 0,2$

1-st case: 1001001, add parity bit 1 to make the total case of 1's in the data until 4, which is even.

2-nd case: add parity bit 0 to make the total cost of 1's the same 4, which remains even

$$\sum_{i=1}^{N} p(i) \cdot \log_2\left(\frac{1}{p(i)}\right)$$

$$\text{Entropy} = 0,4 \cdot \log_2 \frac{1}{0,4} + 0,2 \cdot \log_2 \frac{1}{0,2} + 0,2 \cdot \log_2 \frac{1}{0,2} + 0,2 \cdot \log_2 \frac{1}{0,2} =$$

$$= 0,4 \log_2 2,5 + 0,2 \cdot \log_2 5 + 0,2 \log_2 5 + 0,2 \log_2 5 = \log_2(2,5^{0,4}) +$$

$$+ 0,6 \log_2 5 = \log_2(2,5^{0,4}) + \log_2(5^{0,6}) = \log_2(2,5^{0,4} \cdot 5^{0,6}) =$$

$$= \log_2\left(\left(\frac{5}{2}\right)^{0,4} \cdot 5^{0,6}\right) = \log_2\left(\frac{5^{0,4}}{2^{0,4}} \cdot 5^{0,6}\right) = \log_2\left(\frac{5}{2^{0,4}}\right) =$$

$$= \log_2\left(\frac{5}{2^{\frac{2}{5}}}\right) = \log_2\left(\frac{5}{\sqrt[5]{2^2}}\right) = \log_2\left(\frac{5^5\sqrt{2^3}}{2}\right) = \log_2\left(\frac{5^5\sqrt{8}}{2}\right) =$$

$$= \log_2(5^5\sqrt{8}) - \log_2(2) = \log_2 5 + \log_2(\sqrt[5]{8}) - 1 =$$

$$= \log_2 5 + \log_2(2^{\frac{3}{5}}) - 1 = \log_2 5 + \frac{3}{5} - 1 = \log_2 5 - \frac{2}{5} =$$

$$= 1,92193$$

Each code is 7 bits long: 4 bits - actual data
3 bits - parity (redundant) bits
(they take positions that are powers of 2 (1, 2, 4))

A private land-grant research univ. in Cambridge, established in 1861. Technology and Science

+ 0.1

Massachusetts Institute of Technology (MIT)

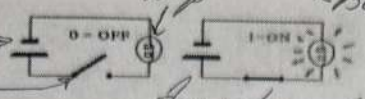
Lecture by Pr. Bob Gallagher

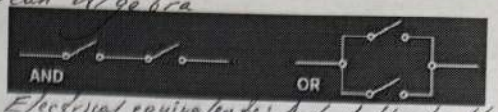
Boole (1815-1864) & **Shannon** (1916-2001)

"Father of Information Theory"

↖ Boolean Algebra

battery → switch → lamp





Two sets x and y

Electrical equivalents! And - both should be closed

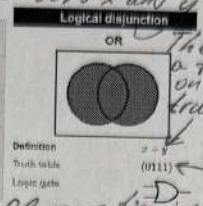
OR - at least one switch must be closed

Boolean symbols:
∧ - and
∨ - or
¬ - not

Logical addition (disjunction)

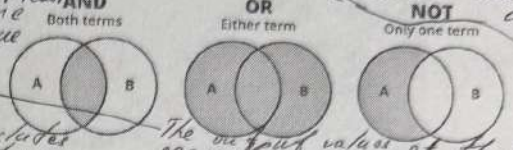
A	B	F=A∨B
0	0	0
0	1	1
1	0	1
1	1	1

A	B	$A \vee B$
True	True	True
True	False	True
False	True	True
False	False	False



The result if at least one is true

BOOLEAN LOGIC



A∨B is true if either A or B or both are true

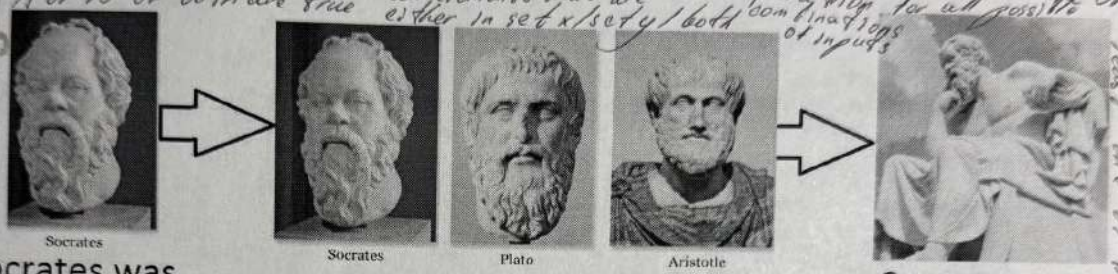
OR operation includes all elements that are either in set x/set y/both

The output values of the OR operation for all possible combinations of inputs

Venn diagram (visual representation)

Gate outputs true (1) when at least one of the inputs is true.

Good logic

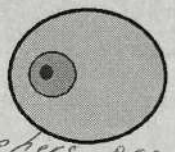


Socrates was a philosopher

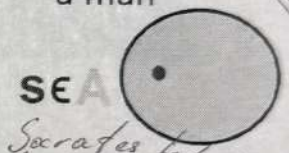
philosophers are men

Socrates was a man

Socrates belongs to the set of philosophers (Φ)

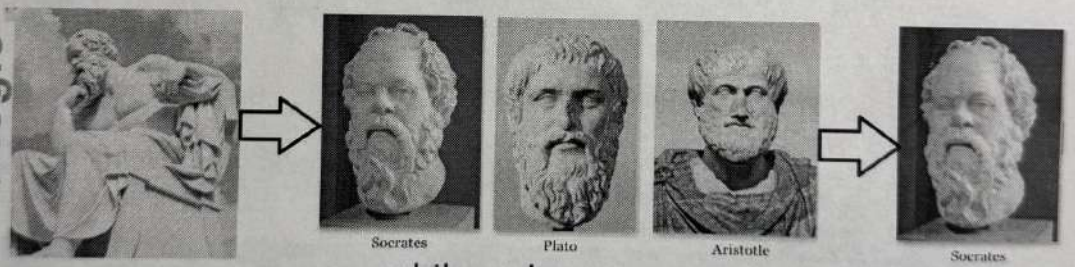


Philosophers are a subset of men (A)



Socrates belongs to the set of men

Bad logic

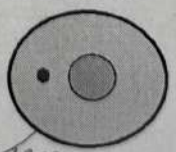


Socrates was a man

philosophers are men

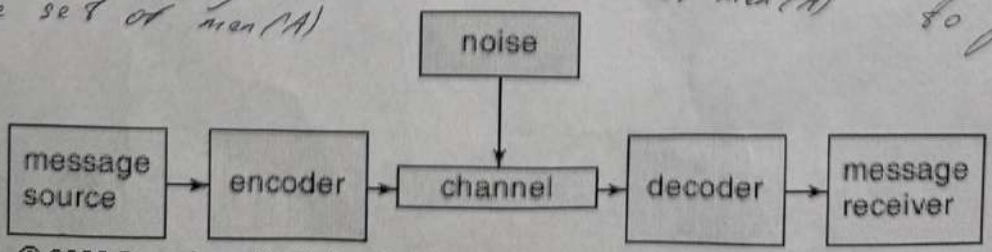
Socrates was a philosopher

Socrates belongs to the set of men (A)



Philosophers are a subset of men (A)

Socrates belongs to philosophers



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Good logic: knowing Socrates is a philosopher and philosophers are men, it's correct that Socrates is a man.

Bad logic: From the fact that Socrates is a men and philosophers are men, it's wrong that Socrates is a philosophers.

George Boole showed that logical reasoning could be expressed mathematically using true and false values. His work became the foundation of modern computing.

Resume of Lecture by Pr. Bob Gallagher from MIT

Massachusetts Institute of Technology (MIT)

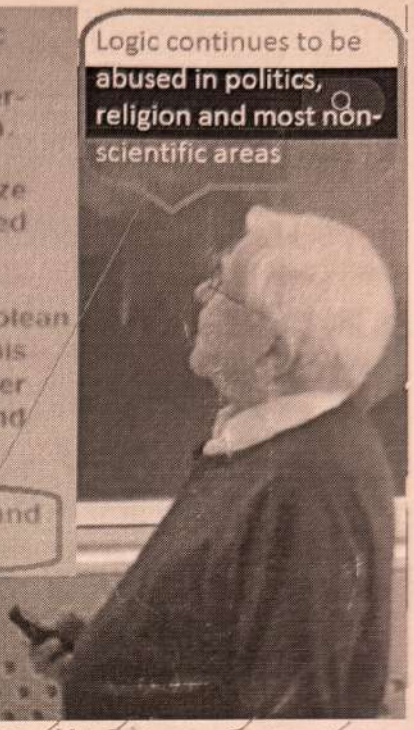
George Boole (1815-1864) developed Boolean logic

The principles of logical thinking have been understood (and occasionally used) since the Hellenic era.

Boole's contribution was to show how to systemize these principles and express them in equations (called Boolean logic or Boolean algebra).

Claude Shannon (1916-2001) showed how to use Boolean algebra as the basis for switching technology. This contribution systemized logical thinking for computer and communication systems, both for the design and programming of the systems and their applications.

Logic continues to be abused in politics, religion, and most non-scientific areas.



Logic is only reliable when conclusions follow from evidence. Poor reasoning often leads to false conclusions

A little nationalistic, but this is an example of right logic

Kant, Gauss, Goethe are great

Kant, Gauss, Goethe - Germans

Germany Great

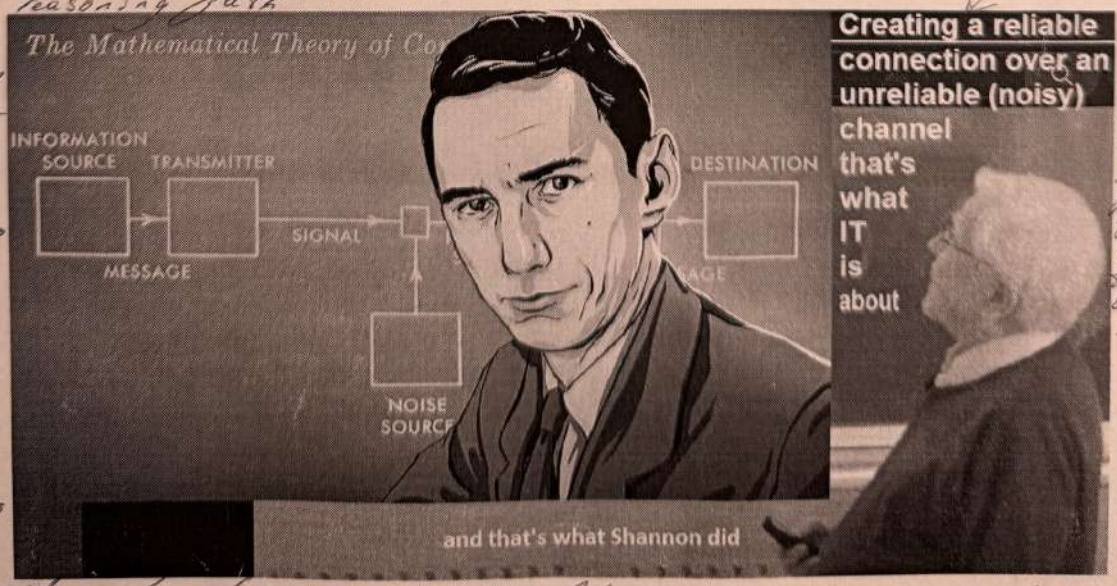
The logical structure is valid and follows a clear, correct reasoning path

Faulty generalization. A conclusion cannot be applied to the entire group based on a few examples.

Bad logic (abuse of logic)

An individual incorrectly generalizes personal attributes based on group identity

A diagram of a communication system



Shannon showed that accurate communication is possible even when noise is present through error detection and correction.

Information travels through a channel from sender to receiver. Noise can interfere with the message and cause errors.

Claude Shannon applied Boolean logic to communication systems and founded the field of Information Theory.

Labo

Every C# program must be inside a class

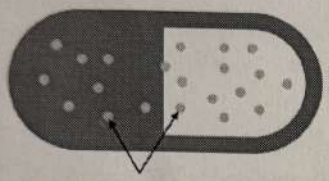
as template that grags data and methods togather

This is the program we need to write today

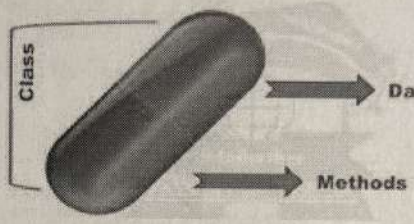
```
class ABBA
  {
  static void Main(string[] args)
                    // Here's a method called Main.
  {
      System.Console.WriteLine("ABBA!");
   }
  }
```

So there's the keyword class. Unlike C++, in C# all code must be placed in a class.

Encapsulated in a class.



Medicines Inside Capsule



A ≠ a

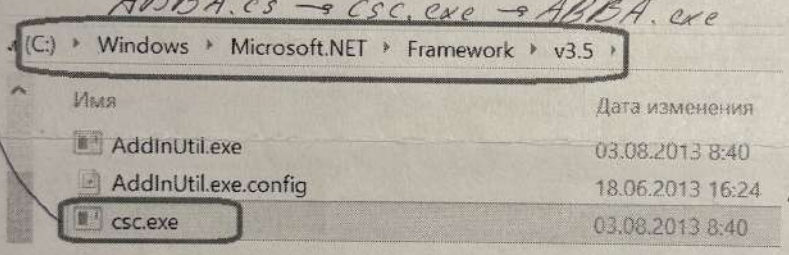
C# is case sensitive

int Number;
int number;
these are 2 different variables

C:\WINDOWS\Microsoft.NET\Framework\v3.5\ csc.exe

ABBA.cs → csc.exe → ABBA.exe

Compiler-translates source code (.cs) into executable code (.exe)



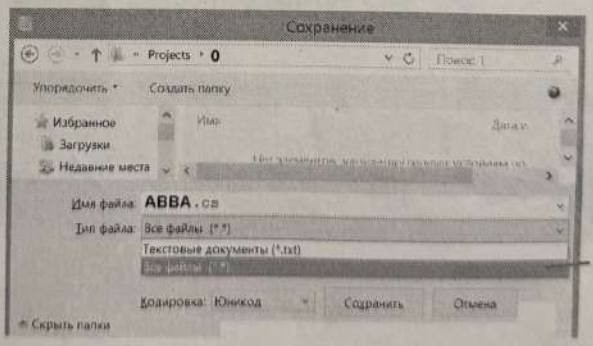
ABBA.cs => csc.exe = ABBA.exe

C# Compiler

Step 1. And on my HDD, I also make a folder with the same name D:\ IT

Step 2. In the folder **E:** IT\ we make the folder of the **Projects** - **E:\ IT\Projects**

And in the **Project** folder make folder **0** - **E:\ IT\Projects\0** where our today's practical work will be stored



You need to switch from *.txt (Text documents) to *.* (all files)

Otherwise, notepad with *.txt extension

Step 3. As I mentioned above, C# is a built-in language of Windows. Notepad is enough to write a program

Step 4.Entering command mode

Start=>Run=>cmd

cd E: - After that go to the folder IT/Projects/0/

cd IT -Then go to the folder Projects

cd projects - Then go to the folder 0

cd 0 –

```
E:\>cd IT
E:\IT>cd Projects
E:\IT\Projects>cd 0
E:\IT\Projects\0>
```

1. write code → 2. save (.cs) → 3. compile → 4. errors fix → → 5. run → 6. test & output

$n! = n \cdot (n-1) \cdot \ldots \cdot 1$

$1! = 1$ $4! = 24$

$3! = 6$ $5! = 120$

Step 5.

Now we need to compile the file using the compiler csc.exe which is in the folder

C:\Windows\Microsoft.NET\Framework\v3.5

C:\WINDOWS\Microsoft.NET\Framework\v3.5\csc.exe ABBA.cs

the result is a file ABBA.exe that can already be run (which is located in the same folder). If you have taken the 1st step, then this means that the education-process has begun. This is victory. csc /target:library ABBA.cs - will make ABBA.dll.

```
>ABBA
ABBA
```

Step 6. Modify the file as follows

```
using System;

class ABBA
{
  static int Factorial(int n)
  {
    if (n == 1) return 1;
    return n * Factorial(n - 1);
  }

  static void Main(string[] args)
  // Here's a method called main.
  {
    System.Console.WriteLine("ABBA -"+
                             Factorial(4));
  }
}
```

prevents infinite recursion

```
>C:\WINDOWS\Microsoft.NET\Framework\v3.5\csc.exe ABBA.cs

>ABBA
ABBA – 24
```

V - number of vowels

C - number of consonants

$V! \cdot C!$ - number of possible arrangements

Step 7. Modify the file as follows

```
using System;

class ABBA
{
  static int Factorial(int n)
  {
   if (n == 1) return 1;
    return n * Factorial(n - 1);
  }

public static void Main()
  {
   System.Console.WriteLine("ABBA");
   System.Console.Write("Enter number of Vovels:");
   string s = Console.ReadLine();
   int vovels=int.Parse(s);
   System.Console.Write("Enter number of Consonants:");
   s=System.Console.ReadLine();
   int consonants=int.Parse(s);
   Console.WriteLine(Factorial(vovels)*Factorial(consonants) );
   }
}
```

```
>ABBA
ABBA
Enter number of Vovels:2
Enter number of Consonants:2
4
```

```
>ABBA
ABBA
Enter number of Vovels:3
Enter number of Consonants:3
36
```

1 2 3 4

* Entropy (H(x)) - quantifies the average amount of information
Self-information (I(x)) - measures how surprising the information/event may be

- If every outcome is equally likely => Entropy is high / lots of unpredictability
- If 1 outcome is much more likely than others => Entropy is low (more predictability)

Say NO to the **first**

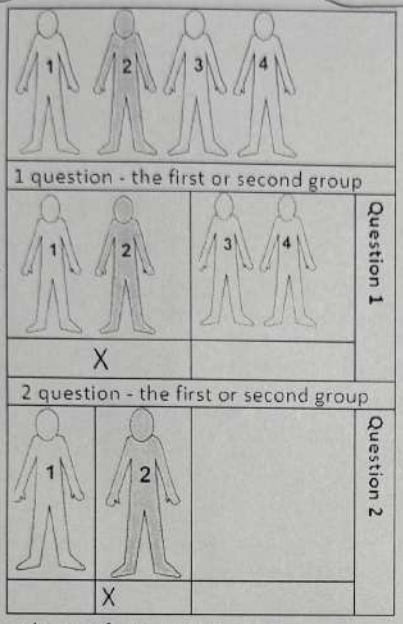
Say YES to the **second** if it is better than the first

Say NO to the **third** only if it is worse than all the others

explains how to determine the average number of questions needed to identify a specific person from a set of candidates based on their probability

Average number of questions =

1*0.5+	2*0.25+	3*0,125+	3*0,125
			



The decision-making process involves comparing these candidates in pairs to determine the best option

Question 1. Is this Zuckerberg?	 50%	1*0.5
Question 2. Is this Sergey Brin?	 25%	2*0.25
Question 3. Is this Stefan from BMW?	 12,5%	3*0,125
So Prince Saud	 12,5%	3*0,125
Average number of questions =		1,75

Average number of questions =

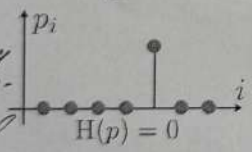
2*0.25+ 2*0.25+ 2*0,25+ 2*0,25 =2

This formula calculates the entropy which is the measure of uncertainty or information content

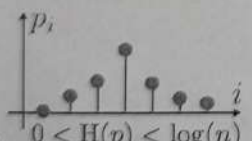
$$H(X) = \sum_{i=1}^{n} p(x_i) \log_b \frac{1}{p(x_i)}$$

$$\sum_{i=1}^{n} p(i) \log_2 \frac{1}{p(i)}$$

Probability of occurance of event i



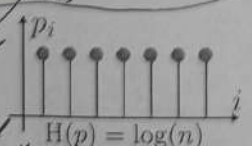
Quantifying information



$$I(x_i) = \log_2\left(\frac{1}{p_i}\right)$$

number of bits required to encode choice

This formula gives the information content $I(x_i)$ of a single event x_i, which is the number of bits required to encode that event



$$\sum_{i=1}^{n} p(x_i)\, I(x_i)$$

The formula takes into account the probability of each candidate being the correct one and the number of questions required to identify them

Mark Zukerberg P(1)= 50% (1 bit)
Sergey Brin P(2)= 25% (2 bits)
Stefan Quandt P(3)= 12,5% (3 bits)
Prince Al... Saud P(4)= 12,5% (3 bits)

$$I(\text{Mark Z}) = \log_2\left(\frac{1}{0{,}5}\right) = 1 \text{ bit}$$

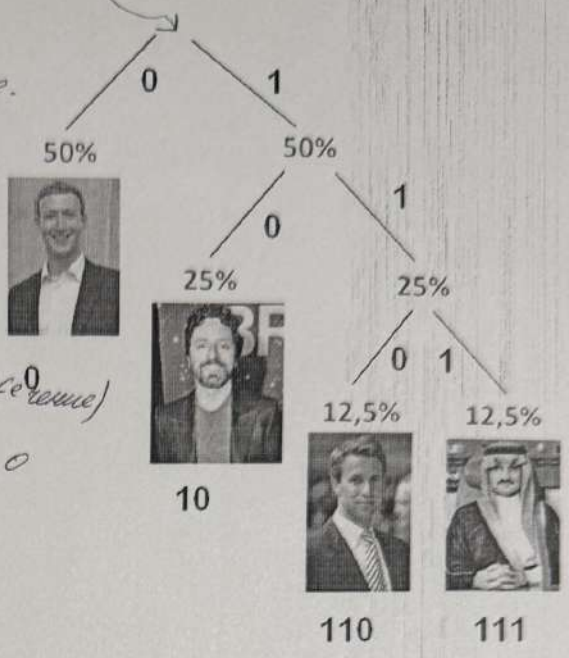
32 → f(x) → 5
64 → f(x) → 6
128 → f(x) → 7

$\log_b(n) = x \iff b^x = n$

base, exponent, argument

Huffman Tree

The tree shows the process of creating a Huffman coding tree. Each character is asstgned a binary code based on its frequency. Characters with higher frequencies are closer to the root, resulting in shorter codes. The binary codes are created by traversing the tree left. Branches are 0 and right branches are 1.



First-order approximation (symbols independent but with frequencies of Belarusian txt).

Мама мыла ра

М - 3 — 30%		1-3 М
а - 4 — 40%		4-7 а
ы -1 — 10%		8 -ы
л - 1 — 10%		9 -л
р - 1 — 10%		10 -р
10		

лламаммар

Second-order approximation (digram (2-symbols) structure as in Belarusian)

Мама мыла ра

Ма - 2	22%	1-2	ма
ам - 2	22%	3-4	ам
мы - 1	11%	5	мы
ыл - 1	11%	6	ыл
ла - 1	11%	7	ла
ар - 1	11%	8	ар
ра - 1	11%	9	ра

breaks down the sentence into individual symbols using F-order approximation

numbers represent positions in the text

0.4673191673 5

ам ыл ла ам ма ра ма ыл ла ам мы

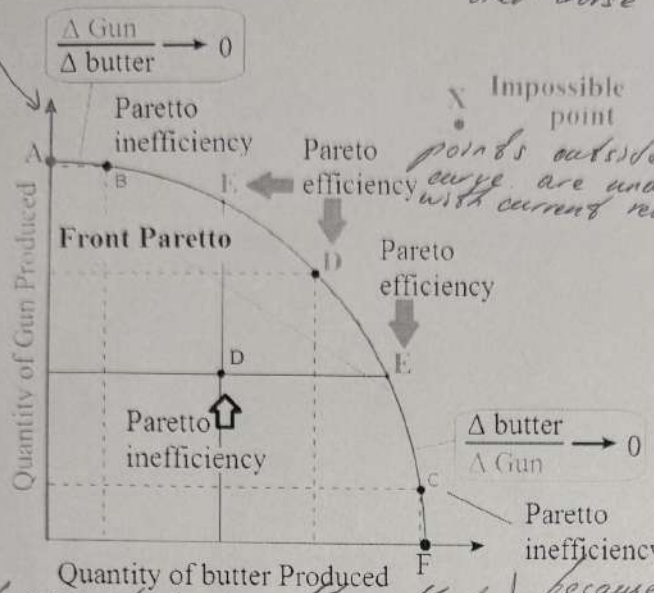
мылла рама

using S-order approximation

Assumes that each symbol is independent from others meaning the probability of each symbol appearing doesn't depend on previous symbols

Considers pairs of symbols where the probability of a symbol appearing depends on the previous symbol

The trade-off between two goods (guns and butter)
- Points on the curve represent efficient allocations of resources



Pareto efficiency or Pareto optimality is a state where resources are allocated in the most efficient manner, such that any change to make one individual better off would make another worse off.

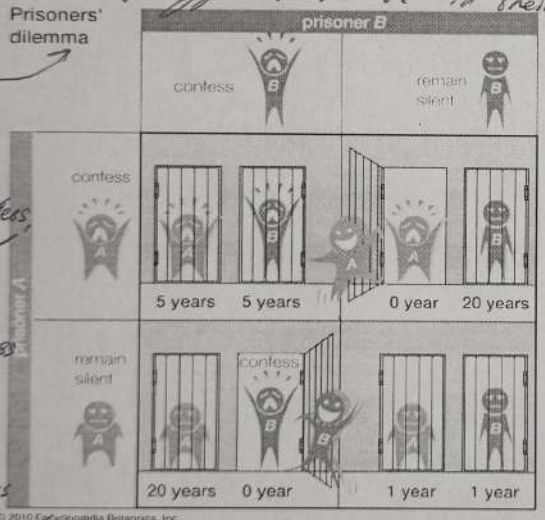
by Vilfredo Pareto (1848-1923)

The orange sector E-D-E is the most Pareto efficient - since an increase in one indicator leads to a decrease in another.

because there are unutilized resources and moving to the point on the curve would make at least one person better without making anyone else off.

A standard example in game theory that shows why two rational individuals might not cooperate, even it it appears to be in their best interest

Prisoners' dilemma



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- If both confess, they both get 5 years
- If one confess and the other doesn't, the confessor gets 0 years and the silent one gets 20 years
- If both remain silent, they both get 1 year

Game Theory

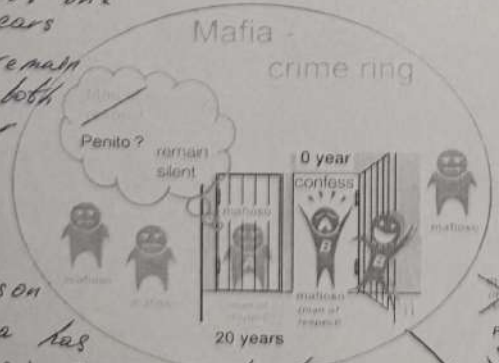
Nash Equilibrium

** => Nash equilibrium

- If both recognize, the payoff is 5 each

$H_2(x)$ / $H_1(x)$	Player 2	Recognition	Non-recognition
Player 1		1	2
Recognition	1	-5 / -5	-20 / 0
Non-recognition	2	0 / -20	-1 / -1

- If one recognizes and the other doesn't, the one who recognizes gets -20 and the other gets 0
- If neither recognizes, the payoff is -1 each



Each person from mafia has two choices: remain silent or confess
1) If both remain silent, they betray the considered man of respect, they both receive a lesser punishment due to the lack of evidence.
2) If one confess and the other remains silent, the one who confesses is rewarded with freedom (Penitto on the picture). And the one who remains silent - receives the full punishment of 20 years.

Nash equilibrium - a concept of a game theory where no player can benefit by changing their strategy while the other players keep theirs unchanged.

Pareto Optimality