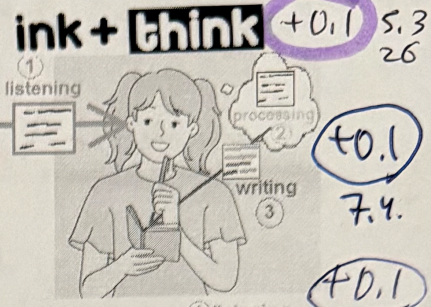
+0.1 11.2.26

+0.1 +0.1 +0.1 12.2 +0.1 16.2

80% probability of rain → probabilistic nature of weather predictions



+0.1 5.3 26

+0.1 7.4.

+0.1 4.9

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

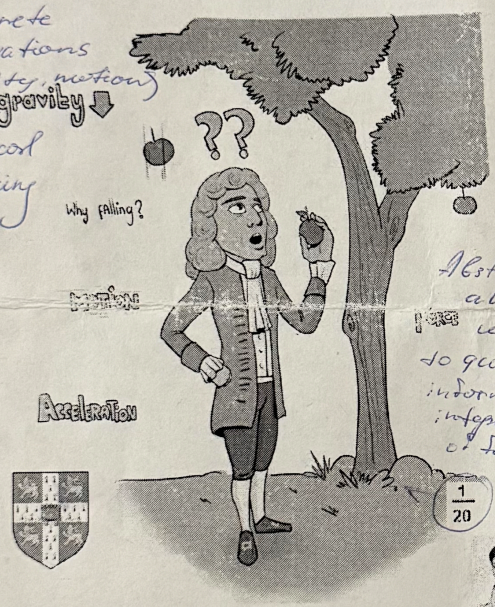
The shift from school simple intuition, formalism without deep understanding to university academic formulas, advanced traditional teaching less effective method

A 3-step more effective, engaging learning method.

School ↓ gravity ↓ MOTION knowledge ==formalism==> University $E=MC^2$ $\oint \sin\theta\, d\theta$ $\iint_S \vec{J}\, d\vec{S}$

CONCRETE AND ABSTRACT THINKING

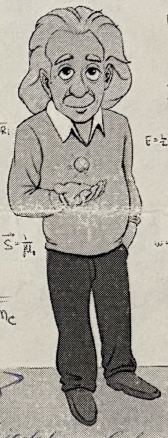
concrete observations (gravity, motion) → gravity → classical thinking



ISAAC NEWTON

(abstract mathematical laws, formulas) modeling of hidden states $W = 2\pi f$ $E = MC^2$ factorials, sequences

Abstraction allows us to generalize information independently of form



ALBERT EINSTEIN

Consult

Evariste Galois & his theory

highly abstract structurist math. „Group theory"

Motivation: 80% chance of rain

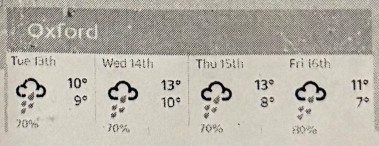
Let A_j be the event of rain at 9am on day j of this term, $1 \le j \le n$

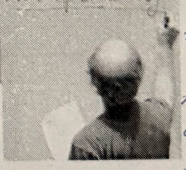
Suppose the events A_j each have probability p

Building statistical model independently

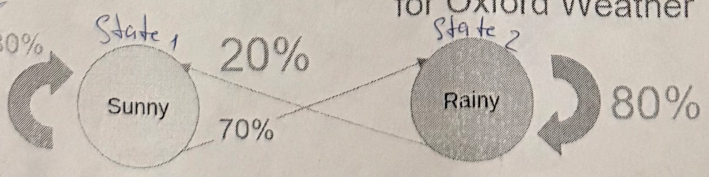
A_j - collection of events

Assumption: events are identically distributed + independent





Markoff Chain Probability Model for Oxford Weather



mathematical model that predicts future states based solely on the current one, ignoring preceded

When raining:
80% - stays raining
20% - becomes sunny
} 100%

When sunning:
30% - remains sunny
70% - gets rainy
} 100%

Pascal's triangle

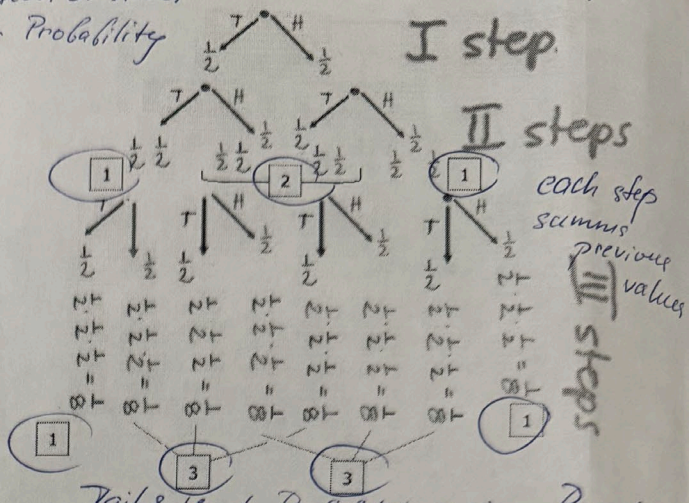
to solve Problem of Points
Division of Stakes
ground for Probability Theory.

Each number - the sum of 2 numbers above

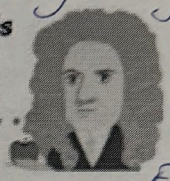
				1				1
			1	1				2
		1	2	1				4
	1	3	3	1				8
1	4	6	4	1				16
1	5	10	10	5	1			32
1	6	15	20	15	6	1		64
1	7	21	35	35	21	7	1	128
1	8	28	56	70	56	28	8	1

Corresponds to the coefficient in the expansion of binomial expression

Bernoulli Trial with 2 outcomes: H/T



Tail & Heats Probability using Pascal's Triangle



Newton's Binomial Theorem or Binomial Expansion

Formalized Pascal's Triangle.

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

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

$$(a+b)^8 = a^8+8a^7b+28a^6b^2+56a^5b^3+70a^4b^4+56a^3b^5+28a^2b^6+8ab^7+b^8$$

General form:

$\binom{n}{k} a^{n-k} b^k$, where $\frac{n}{k}$ - binomial coefficient

Proves that: $(a+b)^n = \sum_{k=0}^{n} \binom{n}{k} a^{n-k} b^k$

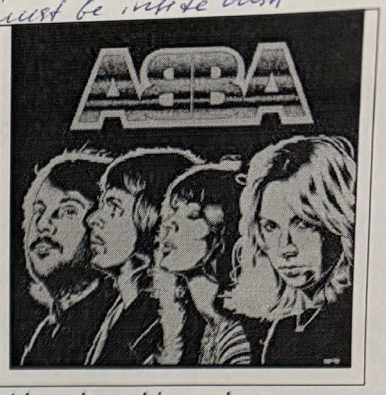
Lab 0

container for code; every piece of C# code must be inside class

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!");
   }
  }
```

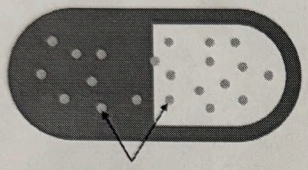
entry point for console appl.



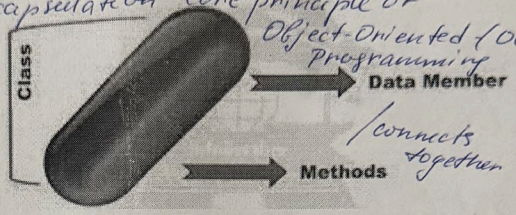
So there's the keyword class. Unlike C++, in C# all code must be placed in a class.

Encapsulated in a class.

Encapsulation - core principle of Object-Oriented (OOP) Programming



Medicines Inside Capsule



/connects together

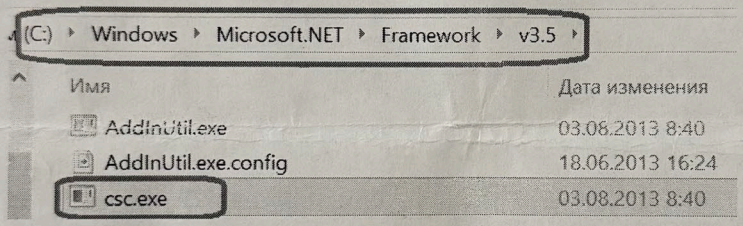
A ≠ a

C# is case sensitive

Value & value - 2 different variables.

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

C Sharp Compiler



Compiler translates source code into executable one

ABBA.cs ⇒ csc.exe = ABBA.exe

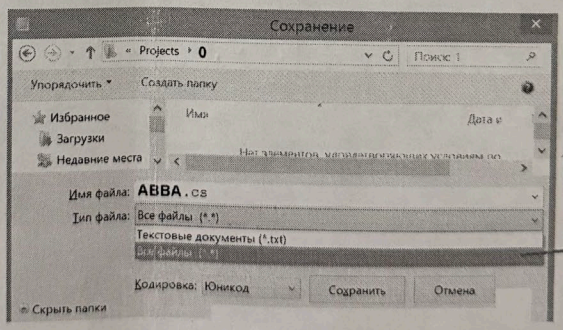
C# Compiler

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

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



C# tools are built in with Windows, so can be written with the use of NotePad

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

Otherwise, notepad with *.txt extension

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>
```

Active prompt to run compiler tool

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

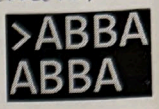
Step 5.

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** - points compiler - passes as argument source code

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**.



Dinamic Link Library

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));
   }
}
```

math function

prevents infinite recurrion

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

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

>ABBA
ABBA – 24
```

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) );
 }
}
```

(V) waites for users input converts string into integer (C)

$V! \cdot C!$ formula to calculate

```
>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
```

Visual illustration of permutations in real life

1 2 3 4

Showed that logical reasoning can be expressed mathematically using true/false; basis for modern computing.

Resume of Lecture by Pr. Bob Gallagher from MIT

Massachusetts Institute of Technology (MIT)

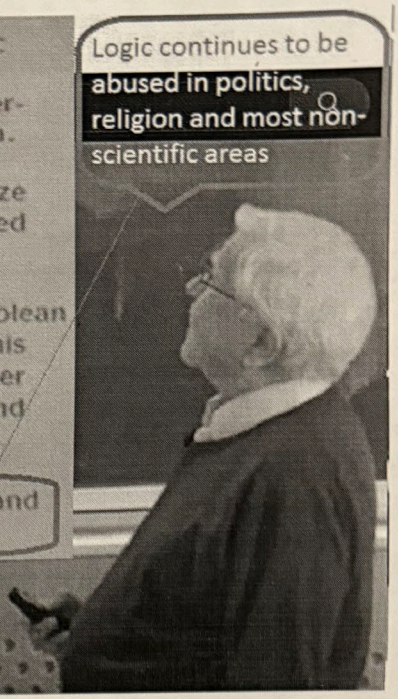
George Boole (1815-1864) developed Boolean logic

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

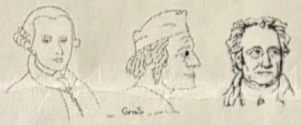
Boole's contribution was to show how to systemize these principles and express them in equations (called Boolean logic or Boolean algebra).

Claude Shannon (1916-2001) showed how to use Boolean algebra as the basis for switching technology. This conribution 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 reliable when conclusions are drawn from evidence, otherwise it leads to structural fallacy. These fields do not rely on strict logical proofs.

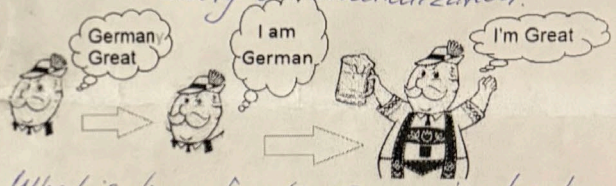


A little nationalistic, but this is an example of right logic

Kant, Gauss, Goethe are great ⇒ Kant, Gauss, Goethe - Germans ⇒ Germany Great

Valid reasoning:

Faulty of Generalization.

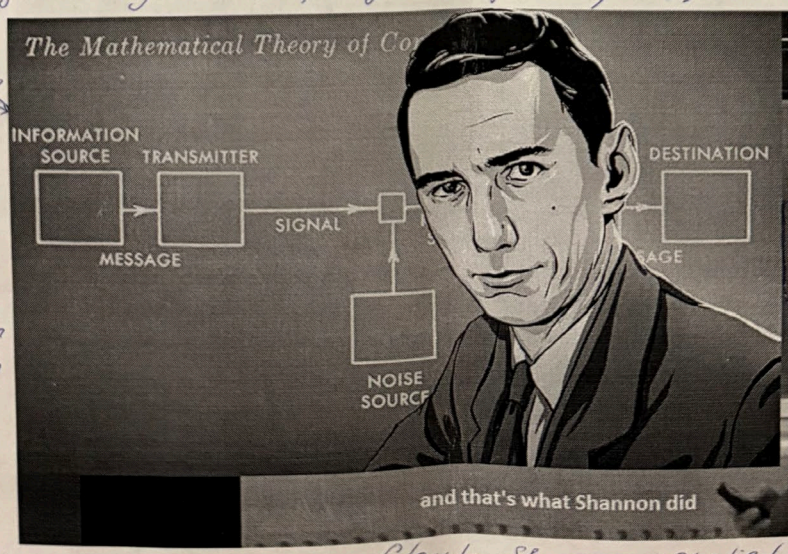


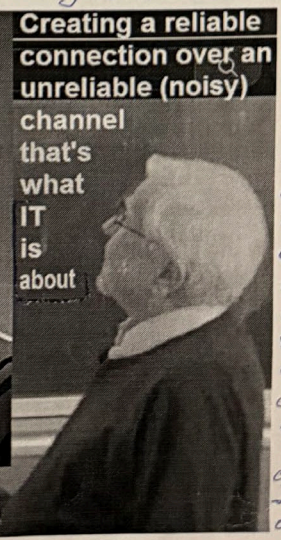
What is true for the group isn't automatically true for each individual within group.

Bad logic (abuse of logic)

are recognised as great minds, are German, Germany has greatness by collective achievements

Communication Diagram.





Shannon showed that communication is possible even through noise with smart encoding: error detection and correction instead of stronger signal.

Information goes through the channel in the form of signal. Noise can corrupt the message and cause errors.

Claude Shannon applied Boolean logic to communication systems, founded field of Information Theory, paved way to digital age.

Math. study how Data is generated, compressed, transmitted, secured.

Shannon Entropy formula

Massachusetts Institute of Technology (MIT)

Lecture by Pr. Bob Gallagher

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

father of Information Theory

invented Boolean Algebra

Battery — Lamp — switch — 0 = OFF — 1 = ON

AND — OR

Sets x and y

Electrical equivalents: And - both should be closed. Or - at least 1

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

Logical disjunction

OR

Definition: $x + y$

Truth table: (0111)

Logic gate

BOOLEAN LOGIC

AND Both terms — **OR** Either term — **NOT** Only one term

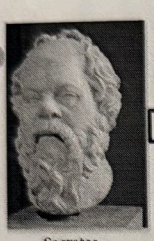
A ∨ B - true if either A/B/both - true.

output values of OR operation

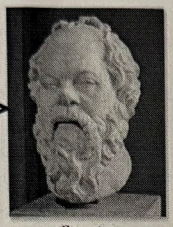
Three Venn Diagrams (visual representation)

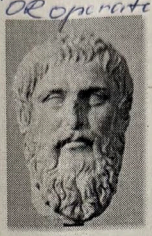
Aristotelian Syllogism

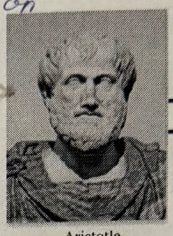
Good logic


Socrates

Socrates was a philosopher


Socrates


Plato


Aristotle

philosophers are men

Socrates was a man

$S \in \Phi$ — belong — Socrates — philosophers set

$\Phi \in A$ — philosophers - subset — men set

$S \in A$

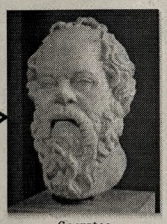
Follows that Socrates belong to the set of men.

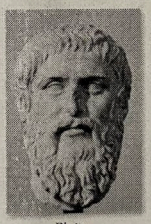
Logical Fallacy

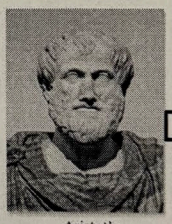
Bad logic


Socrates

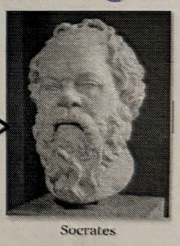
Socrates was a man


Socrates


Plato


Aristotle

philosophers are men


Socrates

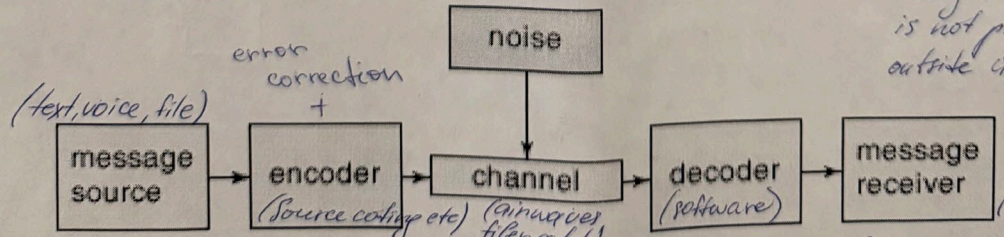
Socrates was a philosopher

$S \in A$ — belong — Socrates — set of men

$\Phi \in A$ — philosophers - subset of men

$S \in \Phi$

Socrates belong to philosophers is not proved, dot is outside circle.

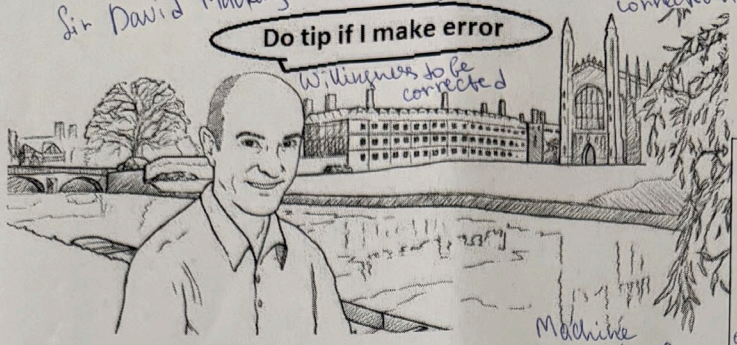


Shannon-Weaver Communication Model (tracks how data moves from beginning to end in the system)

+0.1

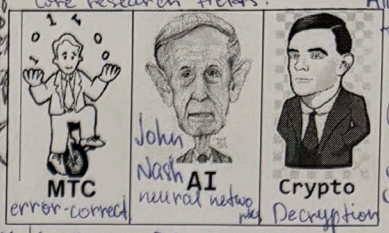
Received signal = Transmitted signal + noise

Sir David MacKay - notable figure in IT & Error correction



+0.1 7.4

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



Dual commitment

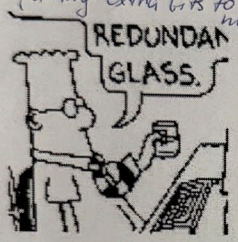
Machine Translation & Coding

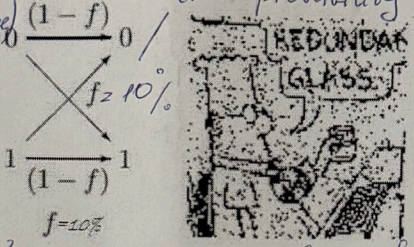
Binary Symmetric Channel

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

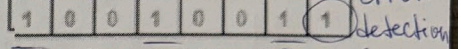
Redundant data helps to ensure accuracy in the presence of errors

(adding extra bits to message)



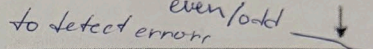


Math. Theory of Communication
Claude Shannon



for error detection

should be even/odd to detect errors



2 types parity even odd

$6^2 = npf = \sqrt{900}$ - Gaussian distribution of error occurrence

Solution → Physical → system

1) Source code: original data (1/0)

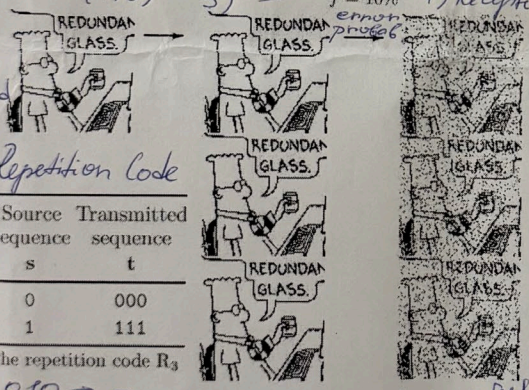
2) encoding each bit repeated (3 times)

3)

4) Reception

5) Decoding, correcting errors

0 → 000 → 001 → 0



Process of error correction

Repetition Code

Source sequence s	Transmitted sequence t
0	000
1	111

The repetition code R_3

Repeat each code multiple times (3) to create redundancy.

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						*	

- 2 errors

Total number of useful bits: 0,027 + 0,001 = 0,028

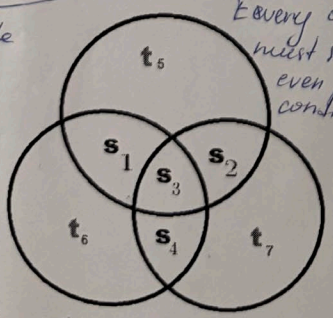
0 1 0 → 0 - error is corrected

4 / 7 → 0,972

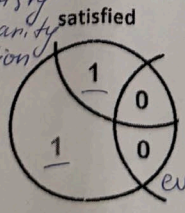
raw message(s) → redundant bits to protect (t)

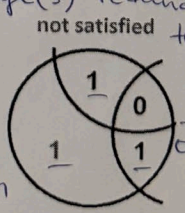
7.4. Hamming code.

Binary code for error correction that can detect & correct single-bit errors.



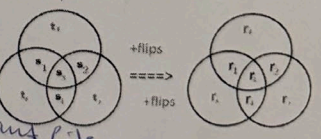
Every circle must satisfy even parity condition

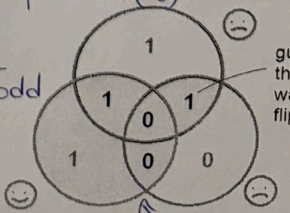




1+1+0+0=0

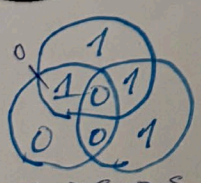
1+1+0+1=1

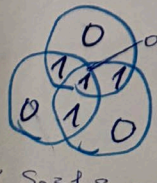


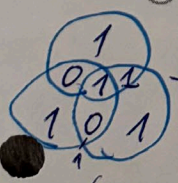


how the overlap helps in pointing errors.

Intersections - data bits being protected by the parity bits.







+0.1

— Flips

$f = 0111 \Rightarrow s_1=0\ s_2=1\ s_3=1\ s_4=1 \Rightarrow t_5=0\ t_6=0\ t_7=1$

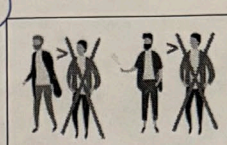
Entropy H(A) - quantifies average amount of inf. Self Information - how surprising the info may be
- Every outcome equally likely – High Entropy
- 1 outcome much more likely than others – Low (Predictability)

Optimal Choice Strategy: (Stopping Problem)

Say **NO** to the **first**

automatically no, it primary establishes baseline

Say **YES** to the **second** if it is better than the first (compare to baseline)

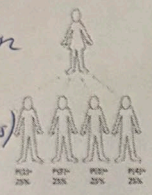


Say **NO** to the **third** only if it is worse than all the others

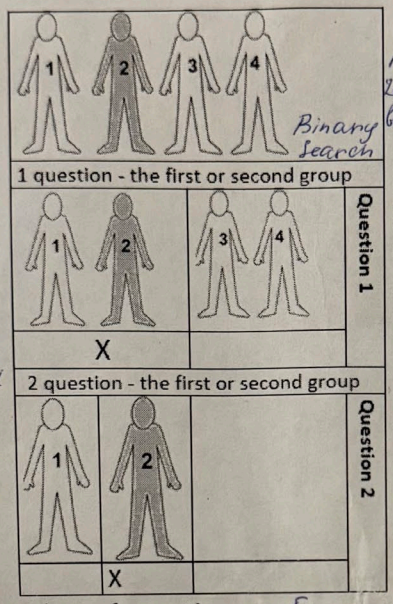
(if rejected 2nd, take 3rd, unless it's worst)

Uniform Distribution Entropy (equal chances)

$\log_2(4) = 2$



Comparing candidates in pairs to determine best option



Average number of questions =

Mark Zuckerberg

1*0.5+	2*0.25+	3*0,125+	3*0,125
	Sergey Brin	Stefan Quandt	P. Saud

Non-Uniform Distribution (Huffman Coding Principle) Shannon

Question 1. Is this Zuckerberg? 1st to most likely	50%	1*0.5 + if yes - stop
Question 2. Is this Sergey Brin? 2nd	25%	2*0.25 + if yes - stop
Question 3. Is this Stefan from BMW? 3rd likelihood	12,5%	3*0,125 + if yes
So Prince Saud	12,5%	3*0,125 4

How to determine av. number of questions: 3 questions + identify specific person

Average number of questions = 1,75

Average number of questions = Every person requires only 2 questions

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

Shannon entropy

instead of 2 (shorter search paths for higher probability)

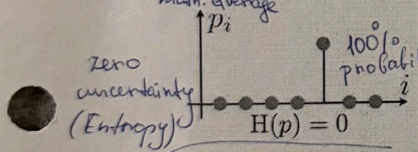
number of bits required to encode

Shannon Entropy

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

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

Probability of occurrence of event i

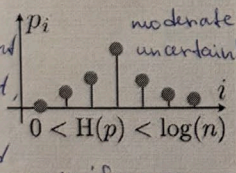


Quantifying information

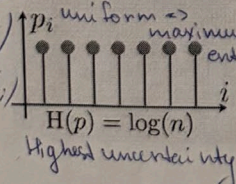
Self-Information Formula:

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

gives info content of a single event (the number of bits required to encode event)

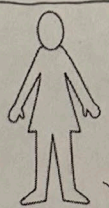


number of bits required to encode choice



Low p_i – High $I(x_i)$ v.v.

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



50 billion	25 billion	12.5 billion	12,5 billion
			
Mark Zukerberg	Sergey Brin	Stefan Quandt	Prince Al Saud
P(1)= 50%	P(2)= 25%	P(3)= 12,5%	P(4)= 12,5%
I=1	I=2	I=3	I=3

H(X) = (0,5 · 1) + (0,25 · 2) + (0,125 · 3) · 2 = 1,75

00000 = 5/10 = 0,5

000 = 3/10 = 0,3

00 = 2/10 = 0,2

1 · 0,5 = 0,5

2 · 0,3 = 0,6 < 1,7

3 · 0,2 = 0,6

1 · 0,5 0,5

2 · 0,3 0,6

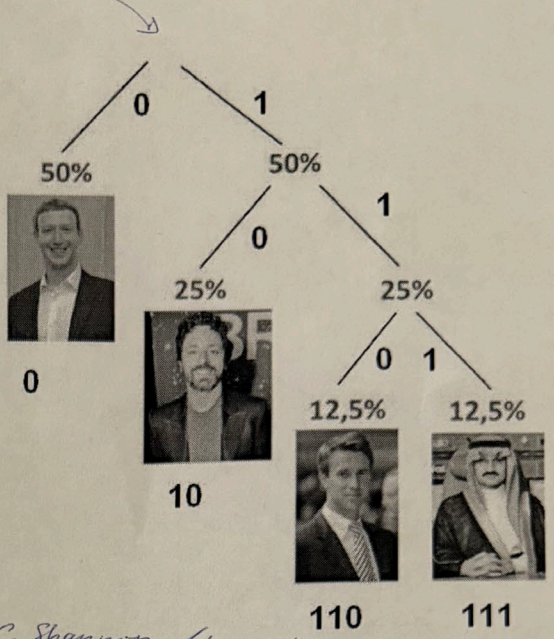
2 · 0,2 0,4

1,5

Это 2-5 кол

Huffman Coding Tree:

Each character is assigned a binary code based on its frequency. Higher frequencies - closer to the root (shorter codes). Directional Convention: we assign 0s to left branch, 1s to right one.



Language Approximation studied by C. Shannon. (how statistical patterns create meaningful text)

1) First-Order Approximation

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

Мама мыла ра

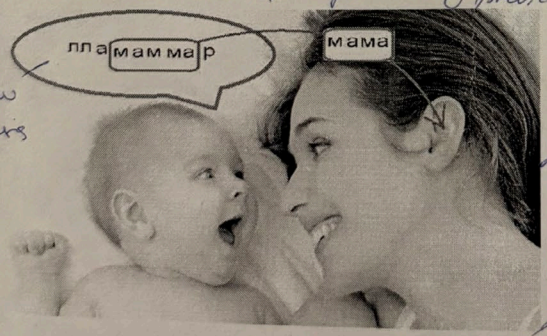
М - 3	30%	1-3	М
а - 4	40%	4-7	а
ы - 1	10%	8	-ы
л - 1	10%	9	-л
р - 1	10%	10	-р

(times of appearances)

10 - total numbers generated using percentages only.

лламаммар

looks only on individual letters frequencies, independently from previous.



raw letters

more structure

2) Second-Order Approximation

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
total 9			

(percentage of appearances)

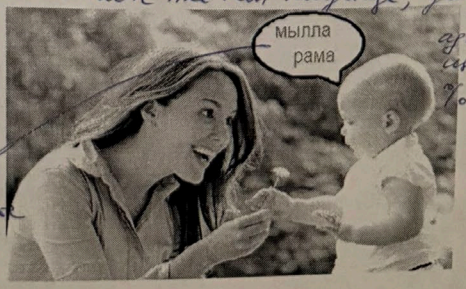
Considers pairs of letters, based on patterns

0.467319167350 (dependent on previous)

ам ыл ла ам ма ра ма ыл ла ам мы

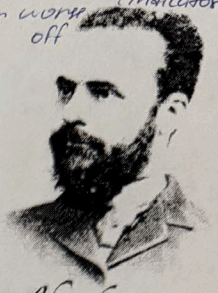
мылла рама

looks more like real language; generated again using %

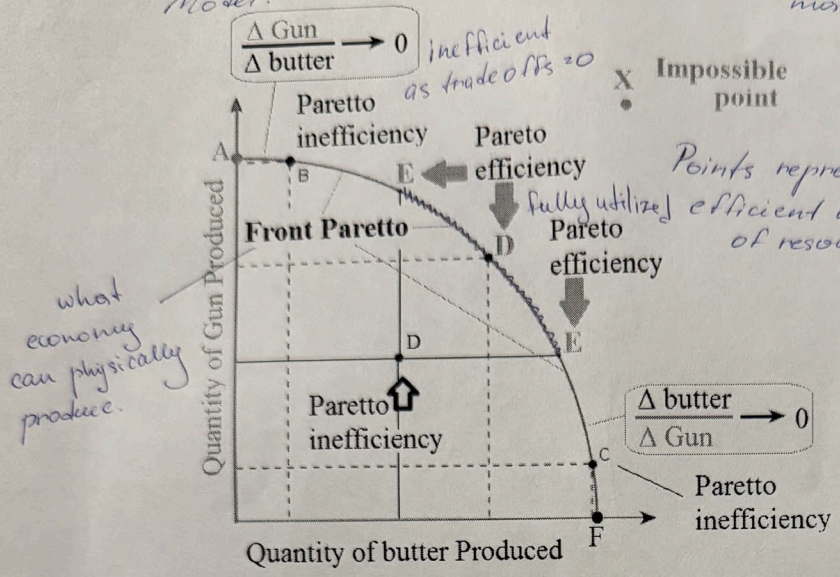


Pareto efficiency (Optimality) - state where resources are allocated in the most efficient manner. Any change to make 1 individual better off, make another worse off (indicator)

Guns VS Butter model.



by Vilfredo Pareto (italian engineer economist) 1848-1923

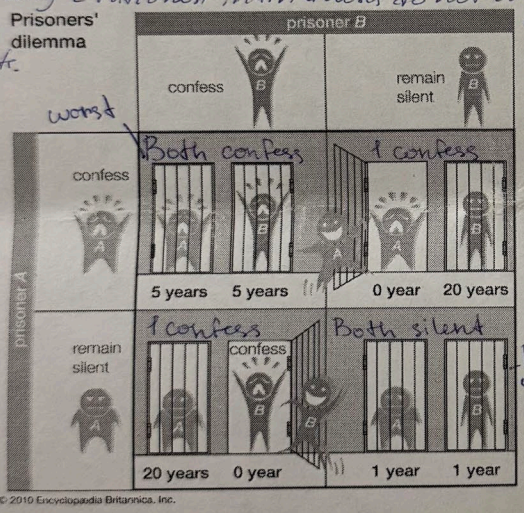


Points represent fully utilized efficient allocation of resources.

what economy can physically produce.

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

Standard example of Game Theory, shows why 2 rational individuals do not cooperate, even if its in their interests.



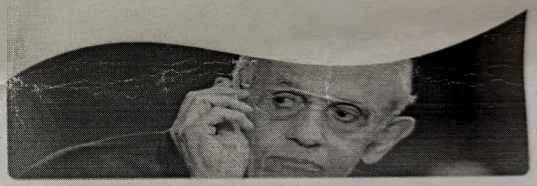
worst

Best outcome

Concept of game theory, where no player can benefit by changing their strategy, while other players keep theirs unchanged.

Game Theory

Nash Equilibrium



John Nash

** => Nash equilibrium

Neither player will change their mind from this position

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

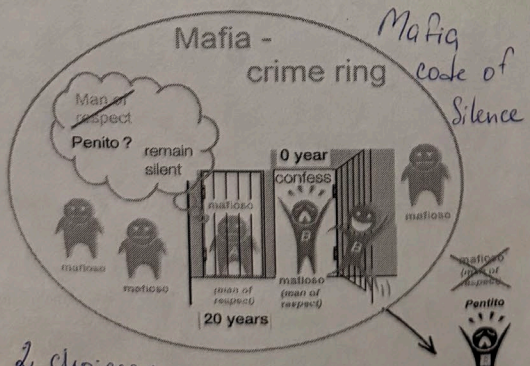
Both recognize : -5

One : -20 / 0

Neither : -1

-1-1 Pareto Optimality

most efficient outcome; however all tempted to cheat & try 0.



Mafia code of Silence

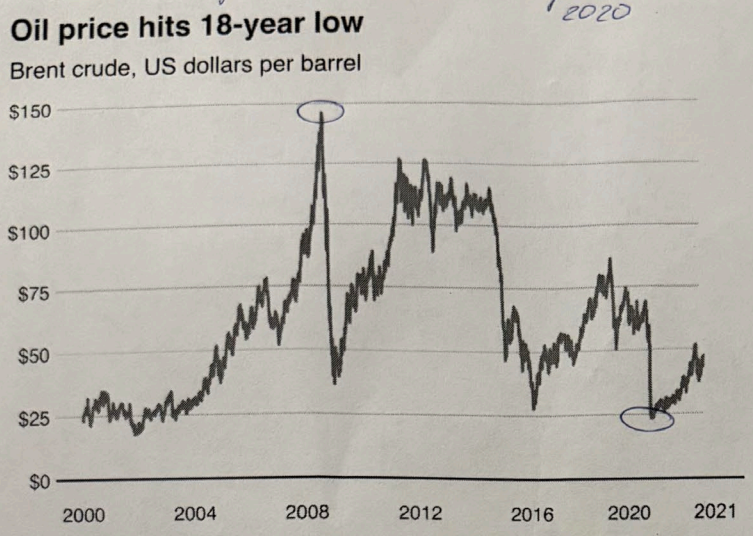
2 choices:

1) remain silent → keep man of respect

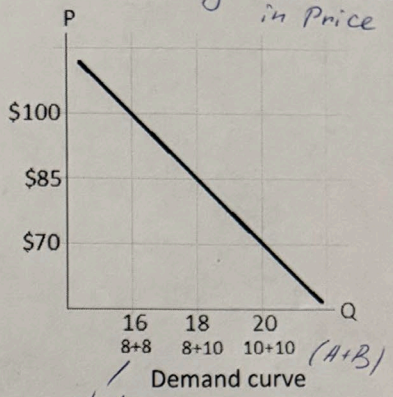
2) confess → Penitito → death

Remaining silent results to be the only logical option leading to cooperative Pareto Optimal Box

Historical price of Brent crude oil from 2000 to 2021 with peak in 2008 & collapse in 2020



Law of Demand:
Increase in Quantity forces decreas in Price



state-space
bit allocations
balanced, asymmetric, max. volume

Game Theory Matrix: a payoff matrix to analyze strategies & potential outcomes.
(Nash Equilibrium)

Barrel	Restrict Supply 1.	Flood the Market 2.
	$8 \cdot 10^6$ barrel / day	$10 \cdot 10^6$ barrel / day
1. $8 \cdot 10^6$ barrel	Russia: $800 millions per day Saudi Arabia: $100 barrel, $800 millions per day (most profitable)	Russia: $850 millions per day Saudi Arabia: $85 barrel, $680 loss
2. $10 \cdot 10^6$ barrel / day	Russia: $680 millions per day loss Saudi Arabia: $85 barrel, $850 millions per day	Russia: $700 millions per day Saudi Arabia: $70 barrel, $700 millions per day

Price crashes because market is overwhelmed

John Nash

Nash Equilibrium
(although not the most profitable, most likely, as each country is terrified from being attacked)