Philosophy of Information Technology

Lecture 3

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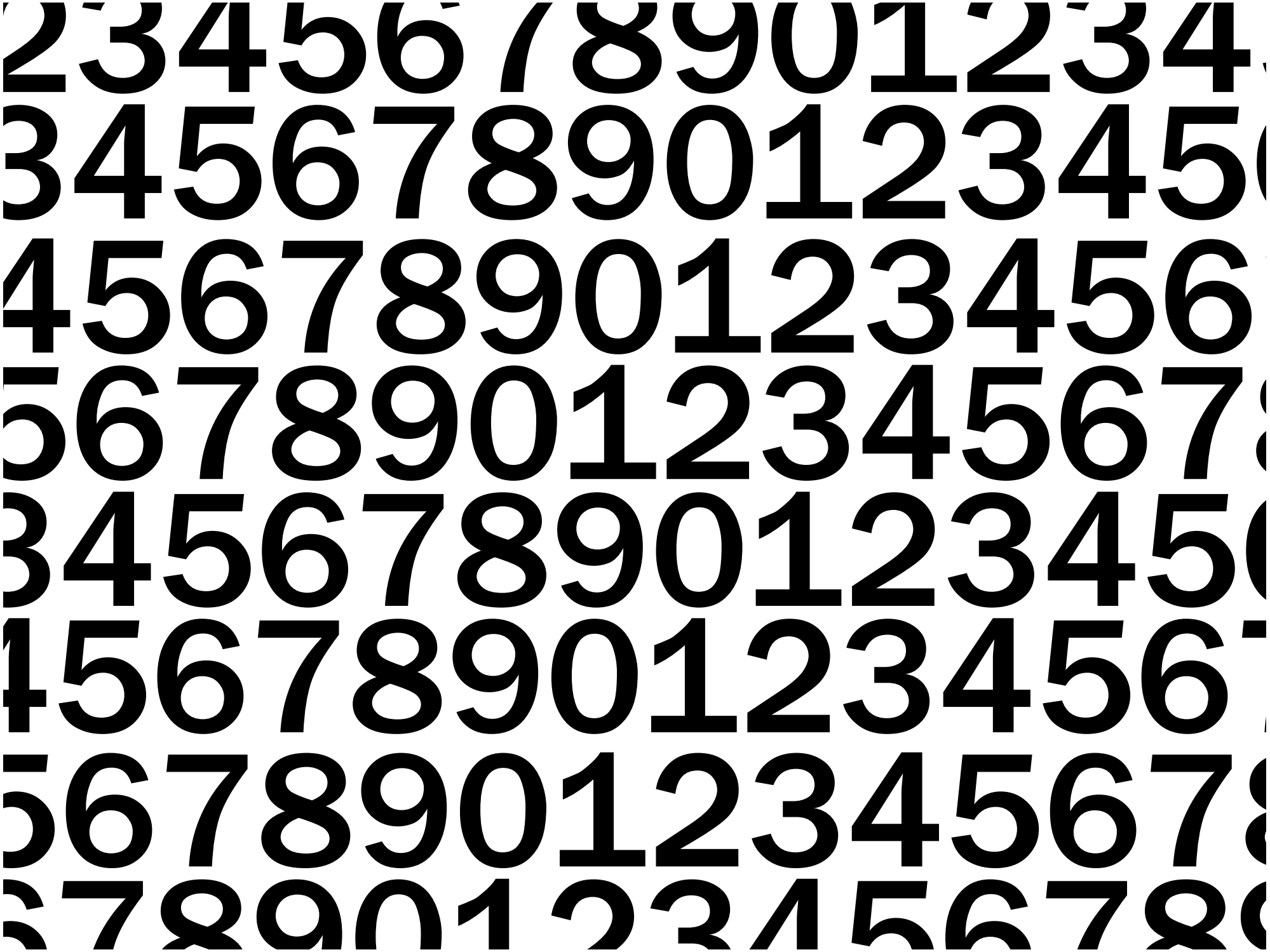
Università degli Studi di Bergamo

Academic Year 2025-2026


23456789012345
34567890123456
45678901234567
56789012345678
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56789012345678
78901234567890

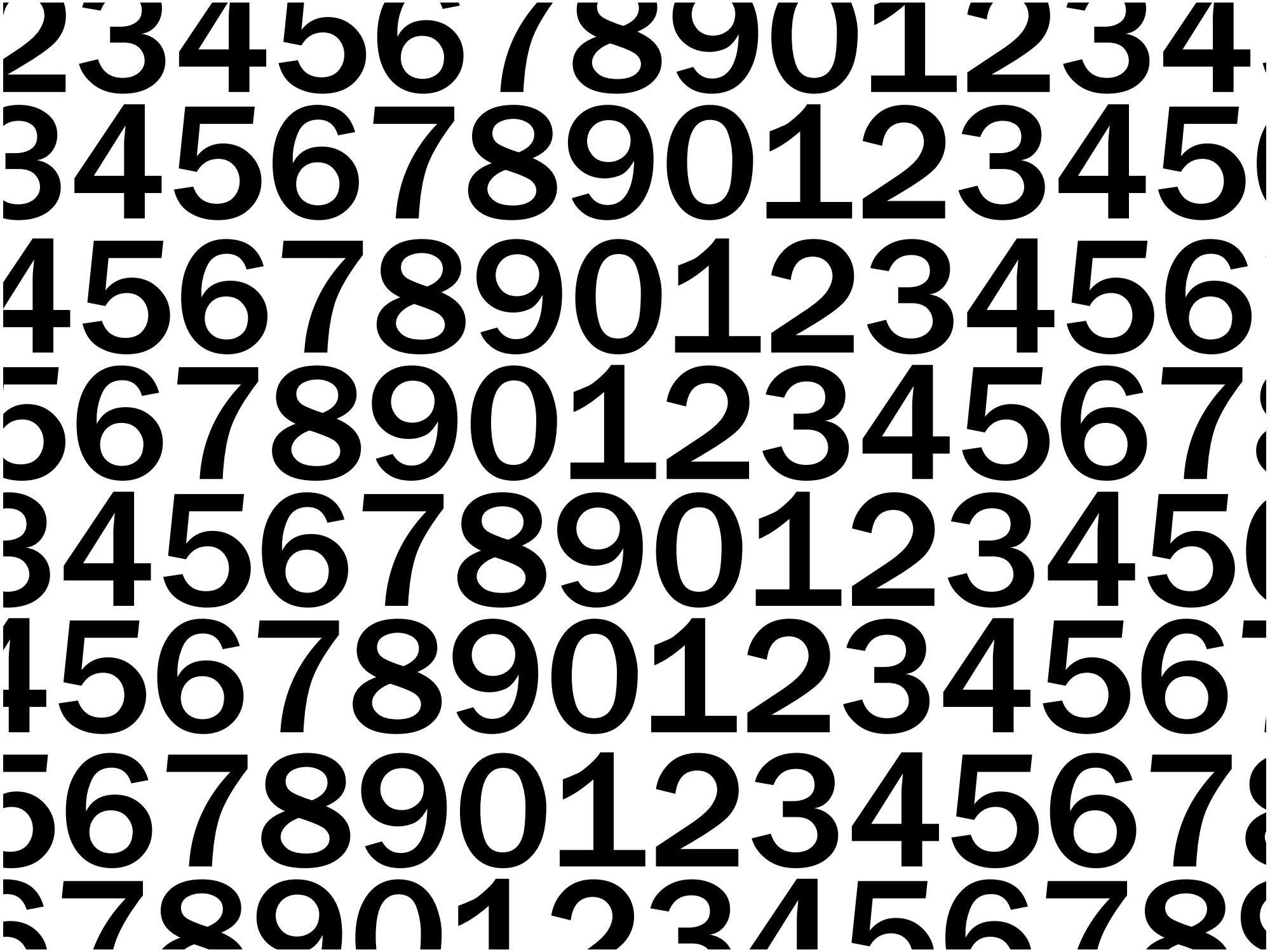

x y r g b
(9,14,245,133,167)

The encoding of texts is based on the encoding of the characters that compose them: if I match each letter and each punctuation mark with a number, I obtain a one-to-one correspondence between letters and numbers. For this correspondence to be useful, it must be known and shared by all those who want to use a computer to exchange the texts thus encoded.
This table shows a well-known encoding: UTF-8

SP	!	"	#	$	%	&	'	(	)	*	+	,	-	.	/
0020	0021	0022	0023	0024	0025	0026	0027	0028	0029	002A	002B	002C	002D	002E	002F
32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
0030	0031	0032	0033	0034	0035	0036	0037	0038	0039	003A	003B	003C	003D	003E	003F
48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
0040	0041	0042	0043	0044	0045	0046	0047	0048	0049	004A	004B	004C	004D	004E	004F
64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	^	_
0050	0051	0052	0053	0054	0055	0056	0057	0058	0059	005A	005B	005C	005D	005E	005F
80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
0060	0061	0062	0063	0064	0065	0066	0067	0068	0069	006A	006B	006C	006D	006E	006F
96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111
p	q	r	s	t	u	v	w	x	y	z	{	|	}	~	DEL
0070	0071	0072	0073	0074	0075	0076	0077	0078	0079	007A	007B	007C	007D	007E	007F
112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127

UTF-8

Universal Character Set Transformation Format – 8bit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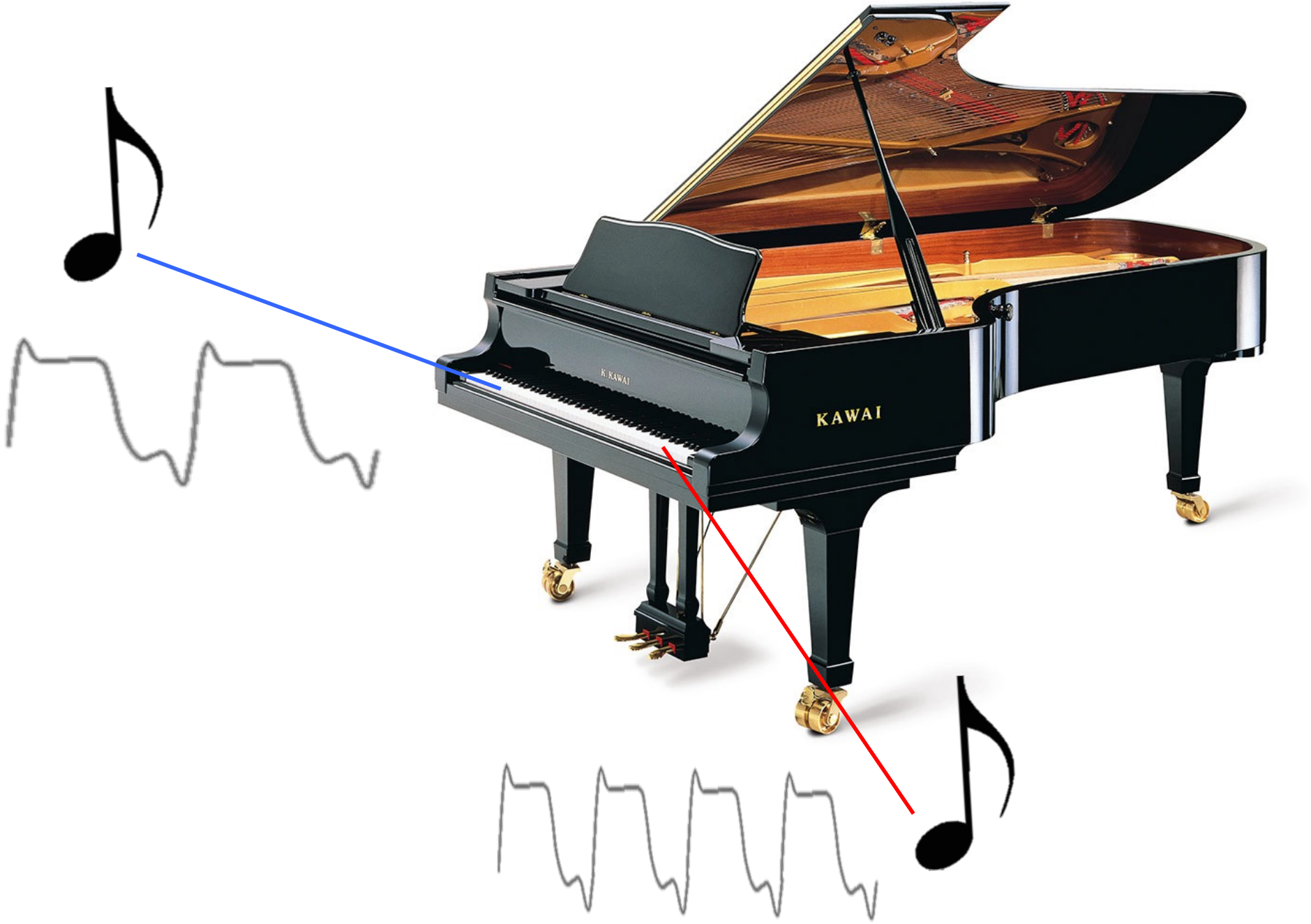
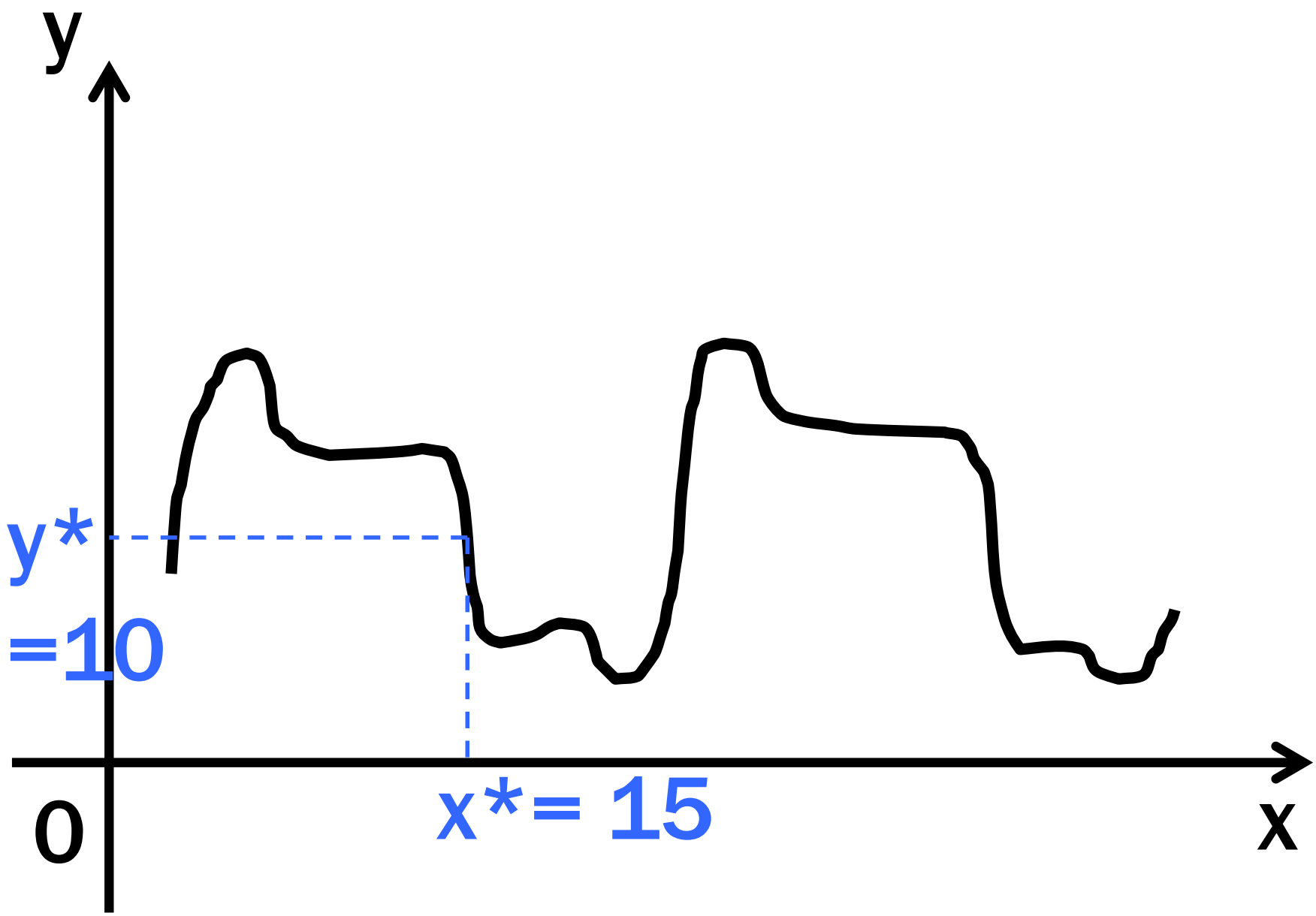
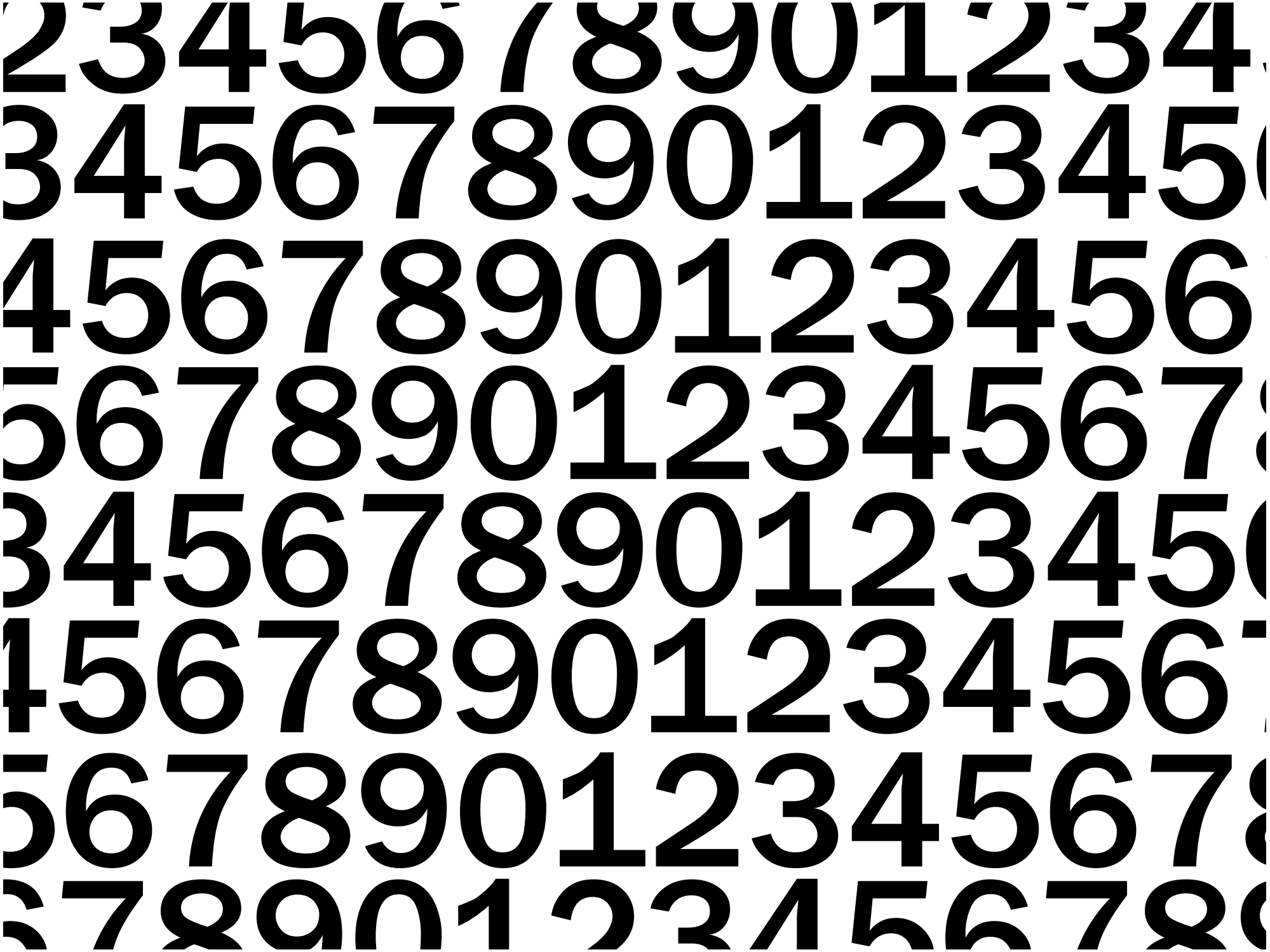

KAWAI


y
y*
=10
0
x*= 15
x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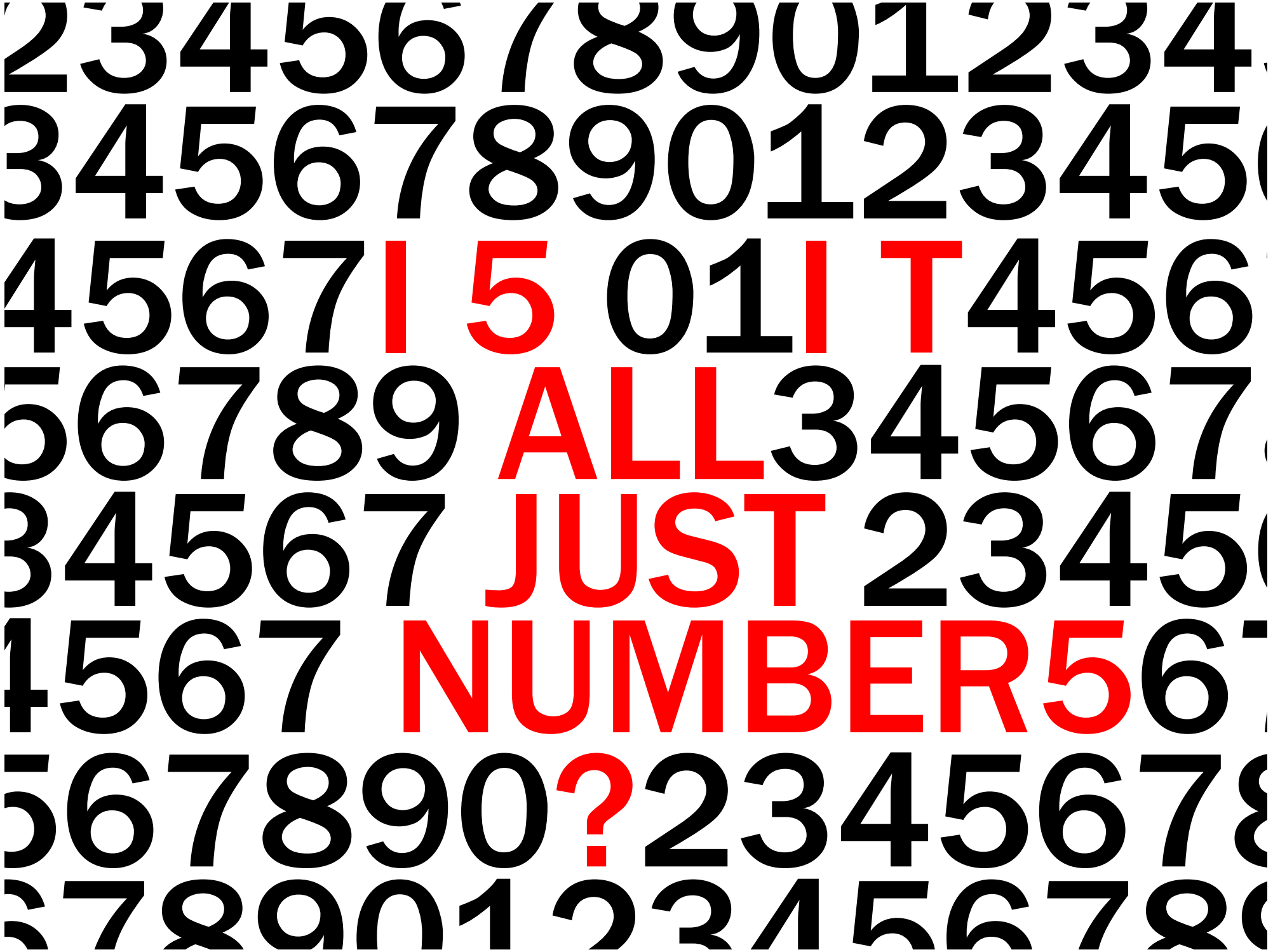
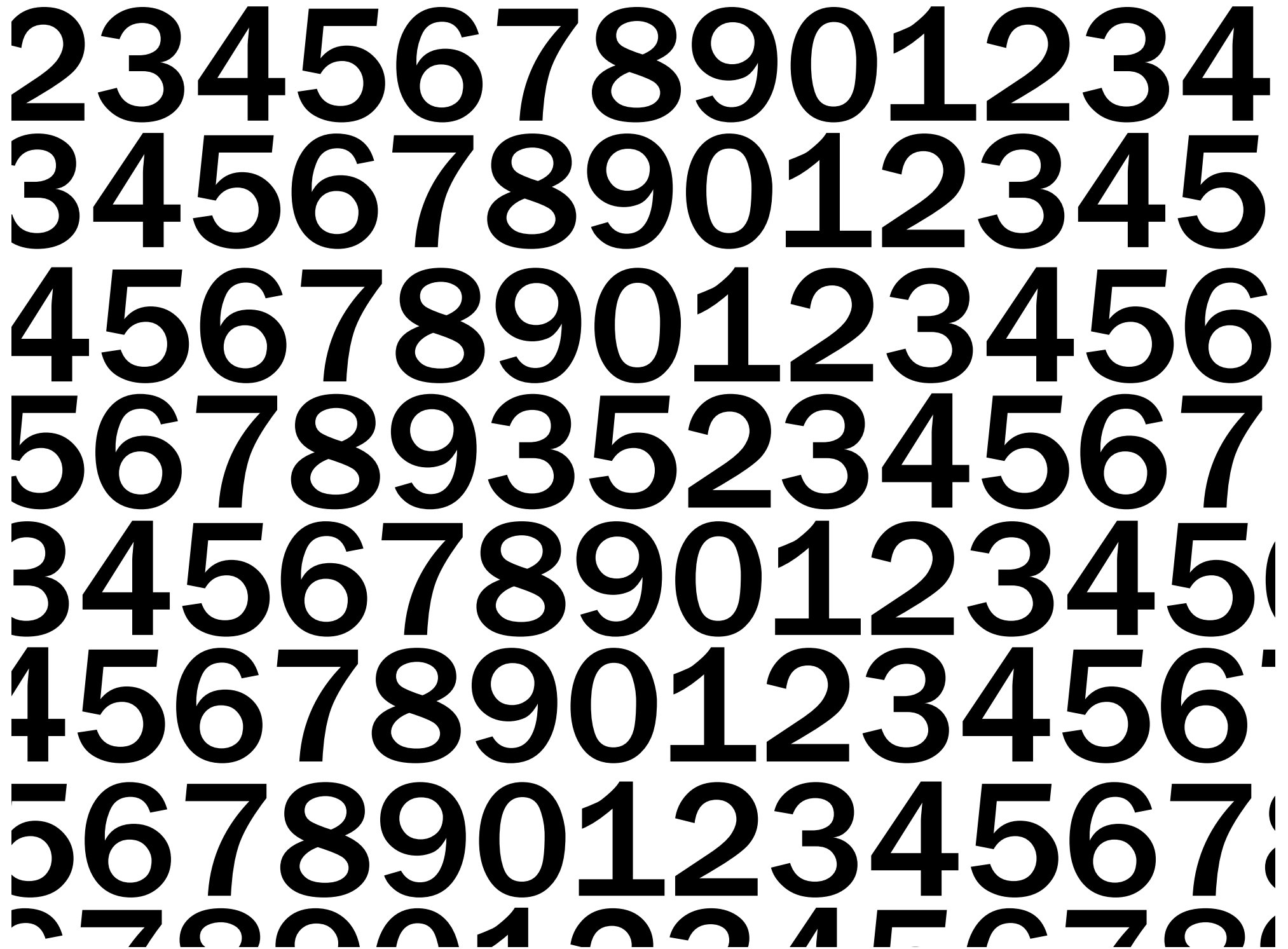

I 5 01I T
ALL
JUST
NUMBER5
?

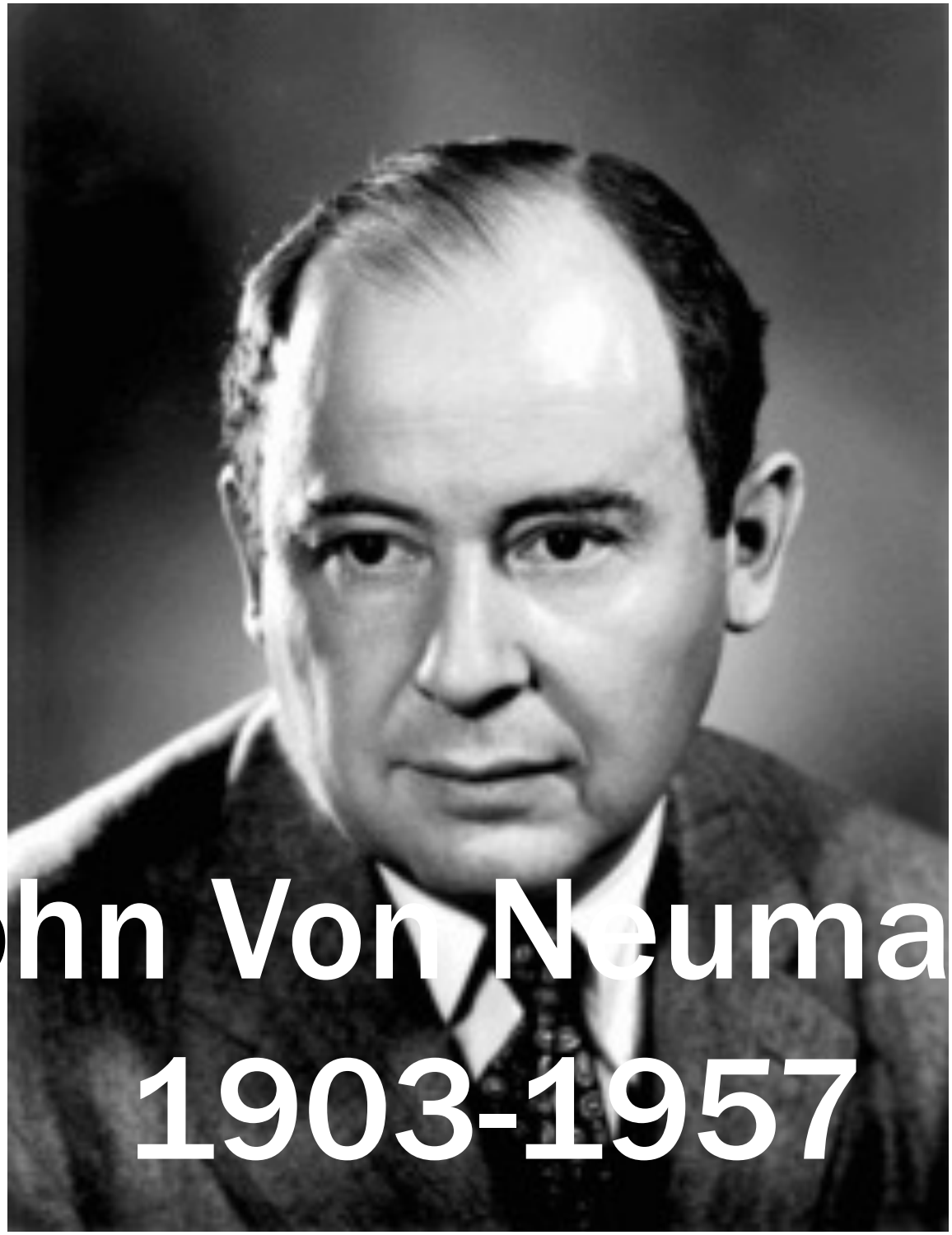
The answer is yes and no. No, because not everything happening inside a computer is numbers: there are also the operations that are made on those numbers (like addition, for example), and their execution is a transformation of numbers, that is not a number in itself. Yes, because the description of those operations (called instructions when they are inside a computer program) is inevitably based on an encoding, and so even the description of the operation of addition will exist inside a computer in the form of a number. However, this may be cause for confusion: how can we distinguishing, among the numbers inside a computer, those who are actual numbers to be processed (we call them data) from those that are representing the operations to be executed onto those numbers (also known as instructions)?

3+2

352


2345678901234
3456789012345
4567890123456
5678935234567
3456789012345
4567890123456
5678901234567

Enter John Von Neumann, a genius-level polymath who emigrated from Hungary to the USA (after studying in Swizterland) during the Nazi takeover of Europe before and during World War II. His actual name was different, and it is bizarre that he wanted to change his name into something that sounds like coming from a noble German family, given his hatred for that country and its regime back then. In the USA, he was part of the Manhattan project (he is also depicted in the "Oppenheimer" movie by Christopher Nolan) and was very keen to apply his mathematical skills to design missiles and increase their deadly impact. He wanted to bomb Kyoto, the cultural capital of Japan, but the then Secretary of War had very nice memories of his honeymoon there, so Hiroshima and Nagasaki were selected instead. By the way, experiments with nuclear bombs went on also after the end of World War II, and bikinis (scant swimsuits) are named after the islands in the Pacific Ocean where some experiments were conducted, because of their "explosive" effects. Von Neumann died young because of a cancer very likely caused by his excessive exposure to radioactive material. His most famous contribution to digital technology and computers, whose merit he has to share with some contemporaries like Turing, who worked on very similar ideas at the same time, and Maulchy and Eckert, who were part of his research team in the USA, is called "the stored program".



John Von Neumann
1903-1957


Von

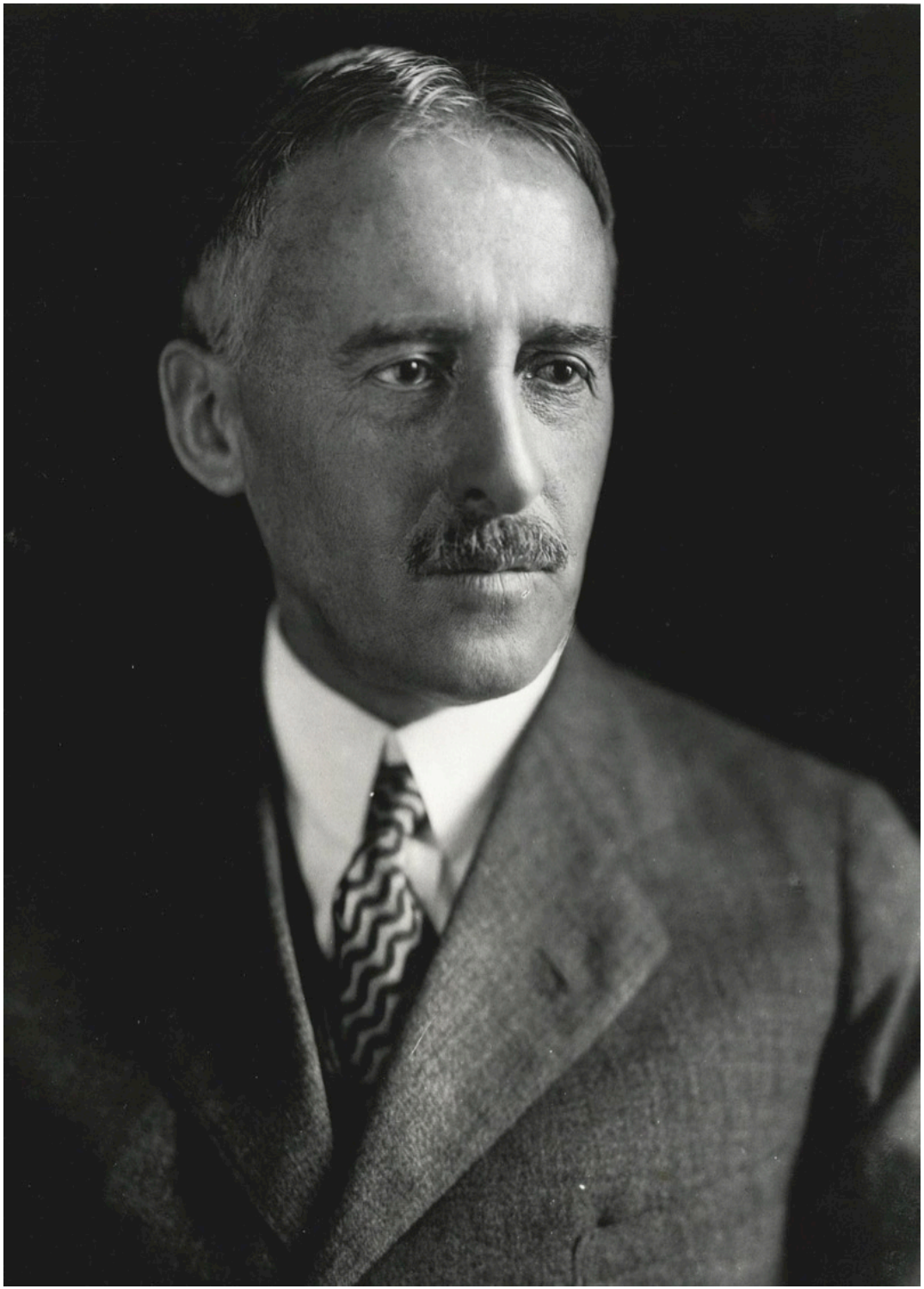
János Lajos Neumann

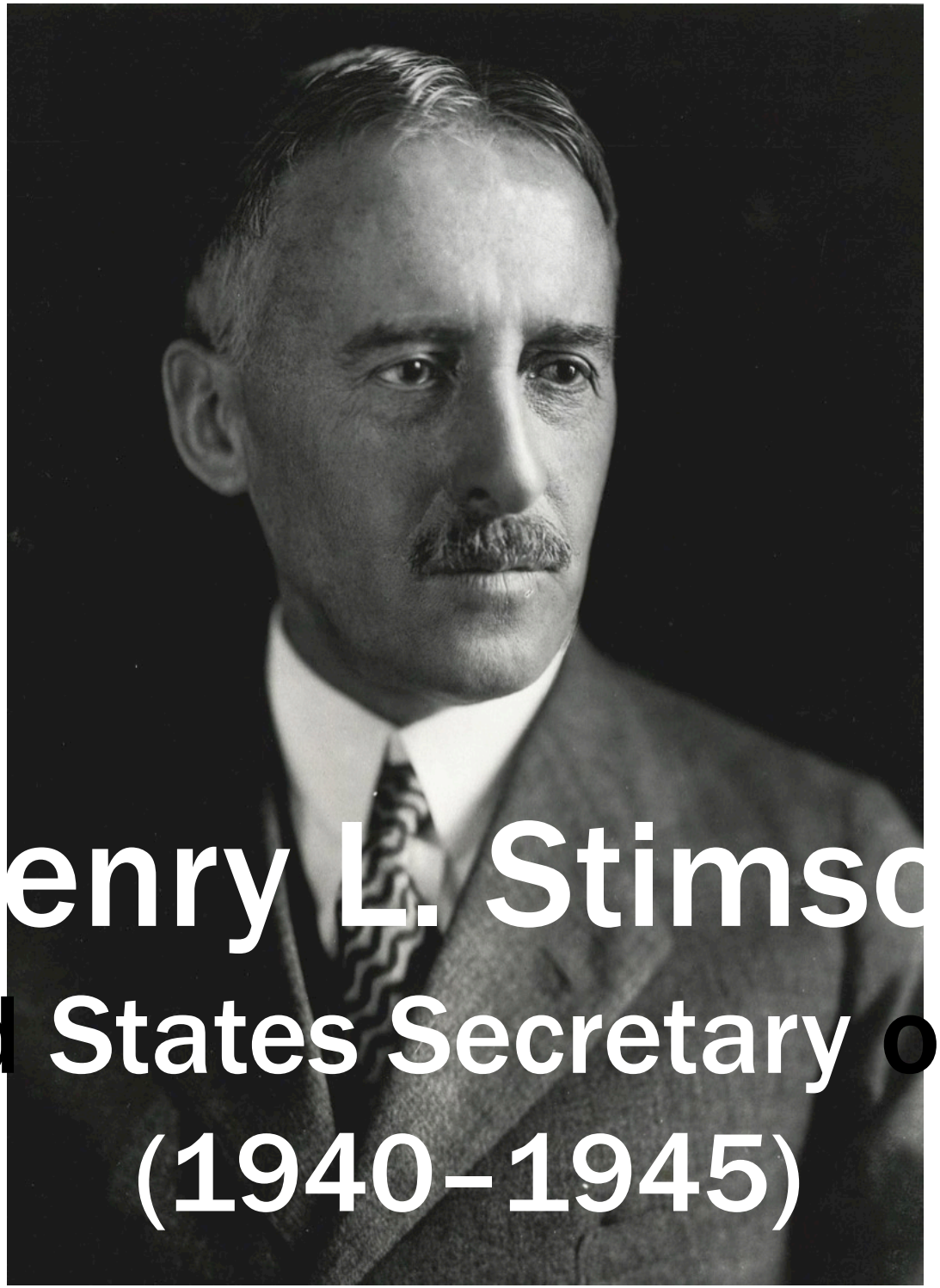
Nuclear bomb test (Bikini Atoll, Micronesia, 1946)

insidekyoto.com/honeymoon-in-kyoto

Honeymoon in Kyoto

Kyoto is an incredibly romantic city. With intimate restaurants, atmospheric lanes, superb accommodations and a thousand quiet gardens and temples, it's the perfect place to spend time with someone you love. Here's our full guide to honeymooning in Kyoto.



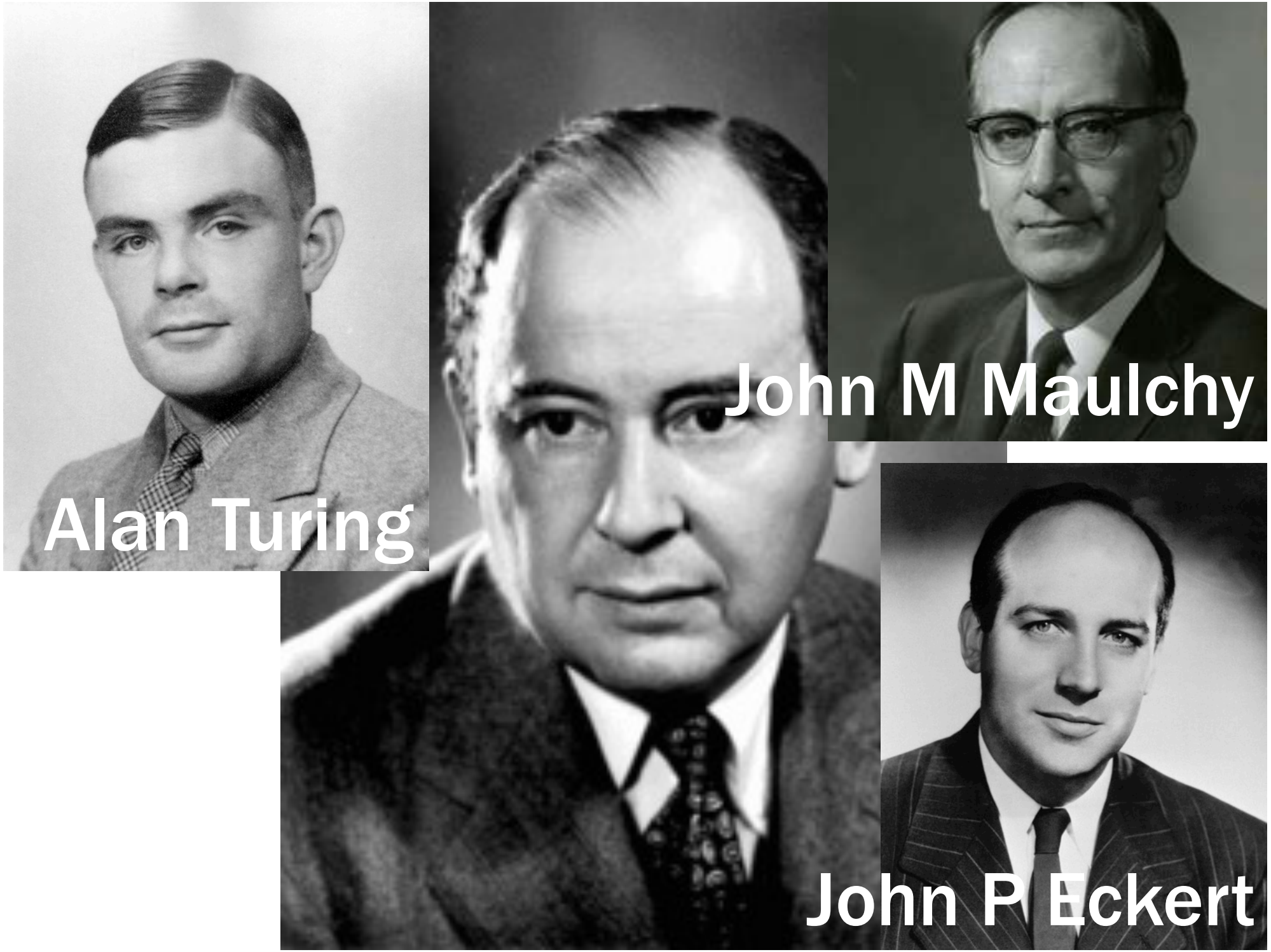


Henry L. Stimson

United States Secretary of War

(1940–1945)


Von


Alan Turing
John M Maulchy
John P Eckert


THE
STORED
PROGRAM

The stored program is a paradigm, a way to organize and manage how numbers are stored inside a computer. Its own name explains it: both the numbers representing operands (the data) and the numbers representing operations (the instructions, the program) are going to be stored in the same place. The paradigm is all about taking care of the fact that those two kinds of numbers do not get mixed inside the storage. For an easier visualization for us humans (computer obviously do not have any perceptions of colors, despite enabling their depiction on digital screens) we will use a color scheme in these slides to draw distinctions: data/operand numbers will be depicted in blue, instructions/operation numbers will be depicted in red. Green will be used to indicate the places where those numbers will be stored.

THE STORED PROGRAM

Both operations and operands can be stored in the same place.

THE STORED PROGRAM

Both operations and operands can be stored in the same place.

operations

operands

3+2

operations

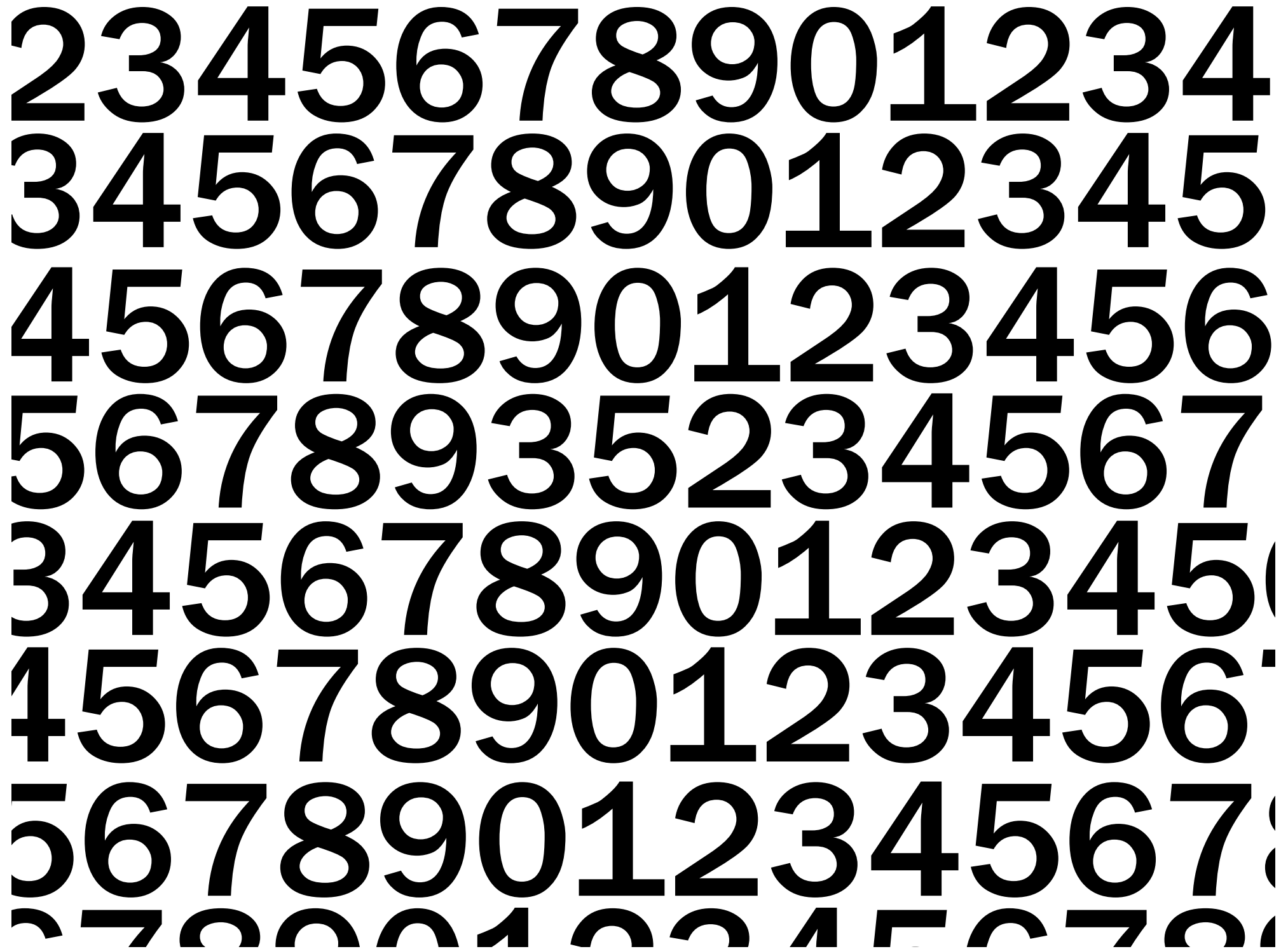
operands

352

operations

operands

place 352


2345678901234
3456789012345
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5678935234567
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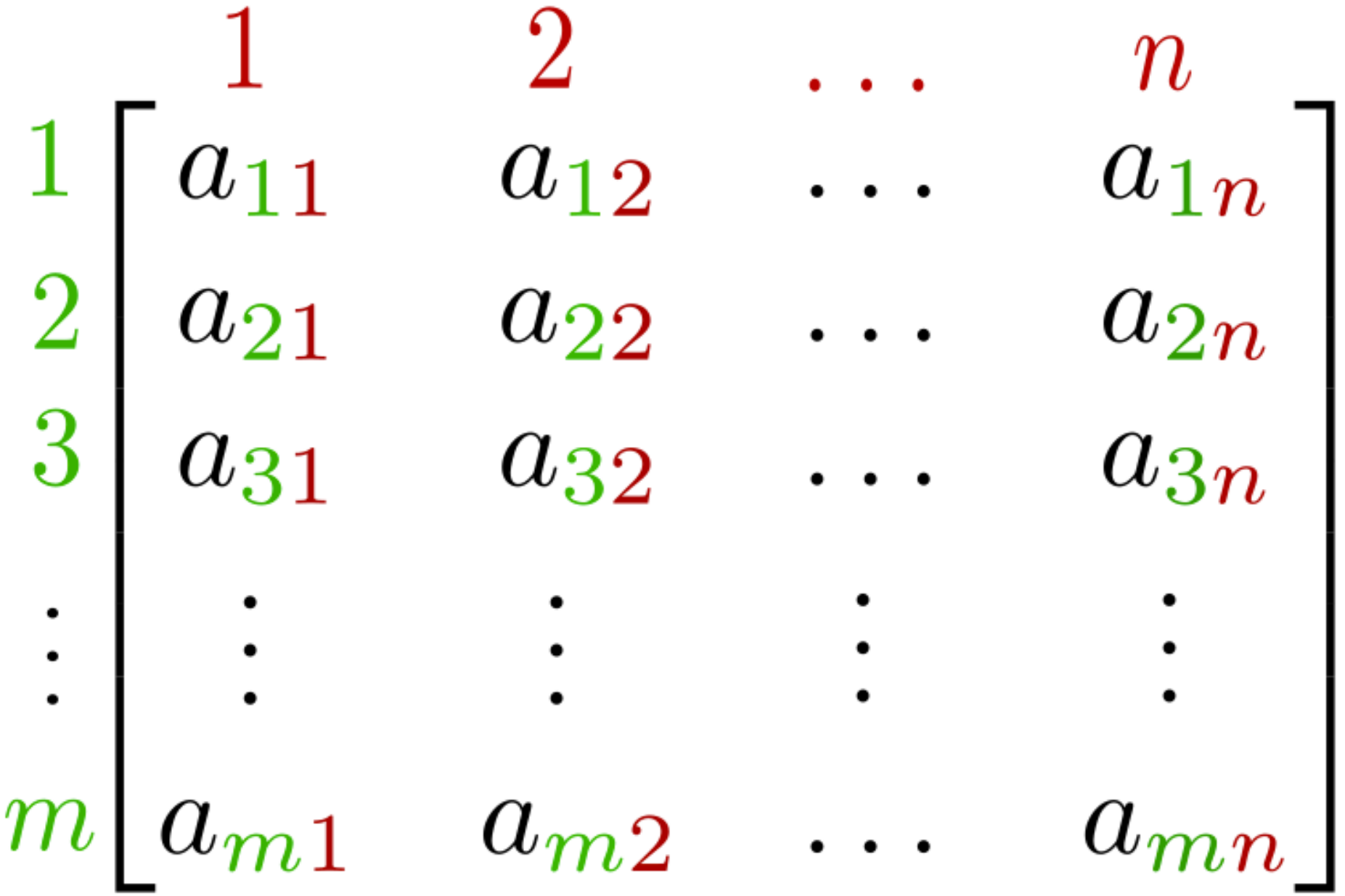
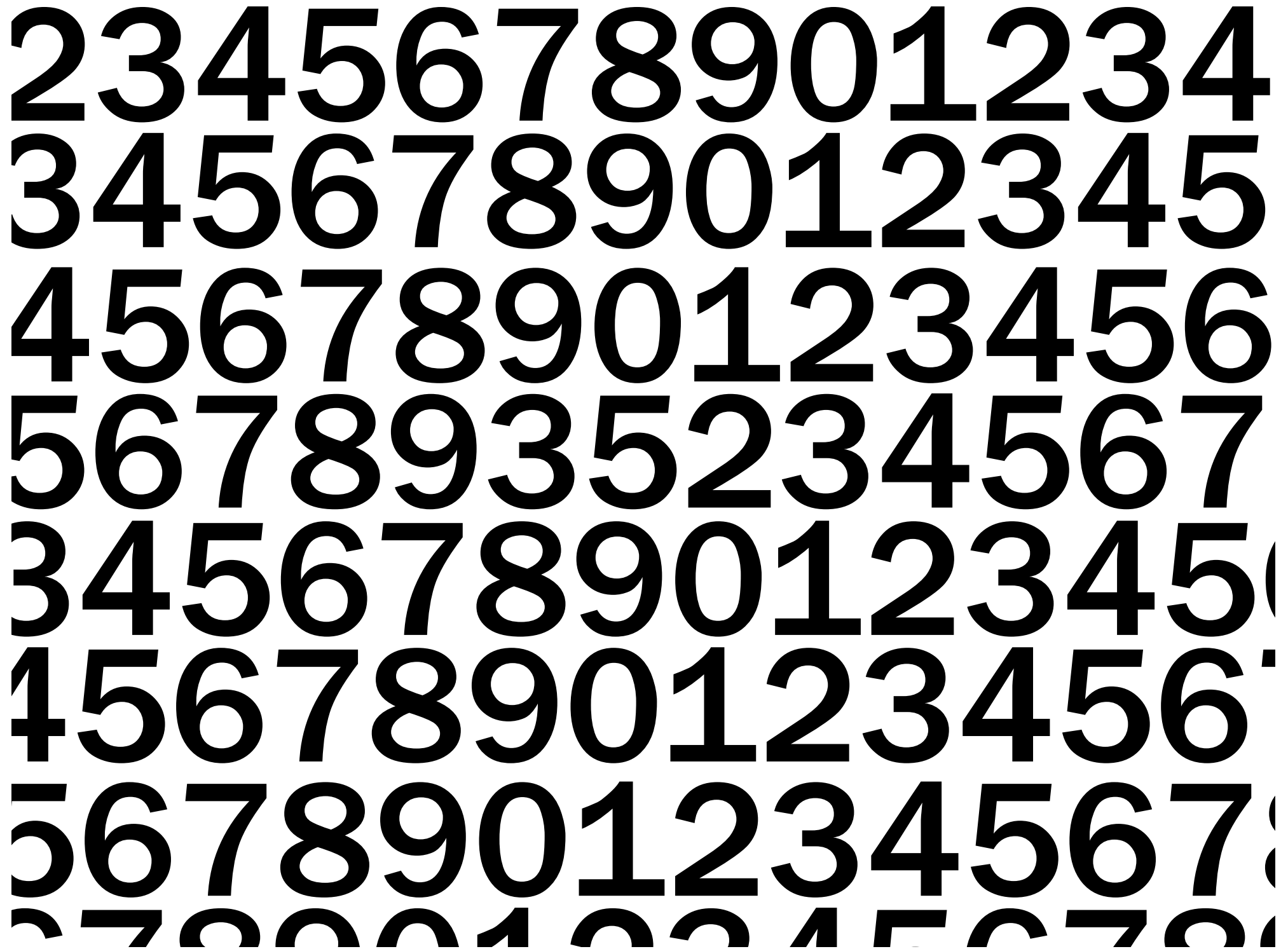
5678901234567


FREE YOUR MIND.
THE MATRIX


1 2 ... n
1 a11 a12 ... a1n
2 a21 a22 ... a2n
3 a31 a32 ... a3n
m am1 am2 ... amn


2345678901234
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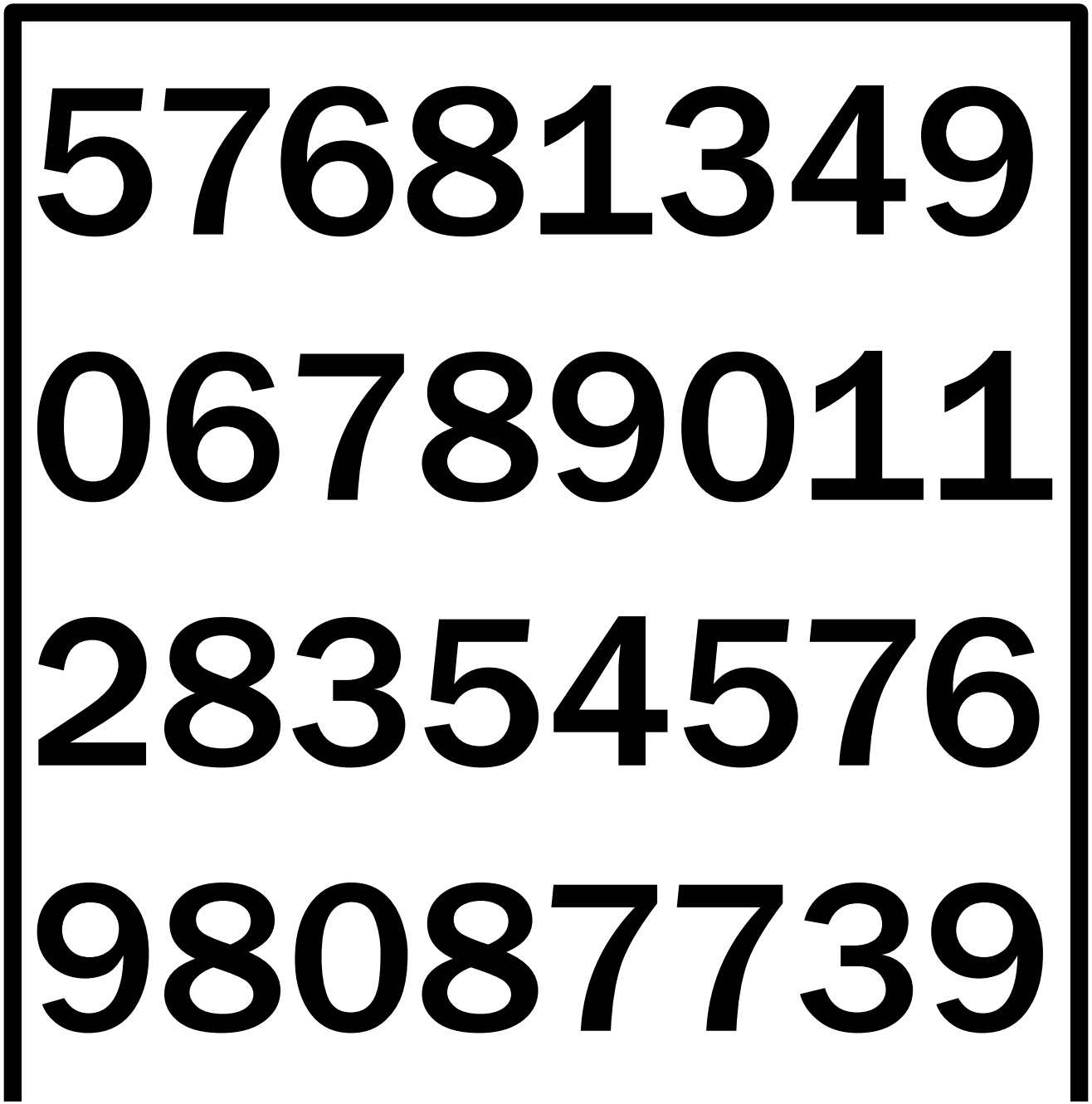
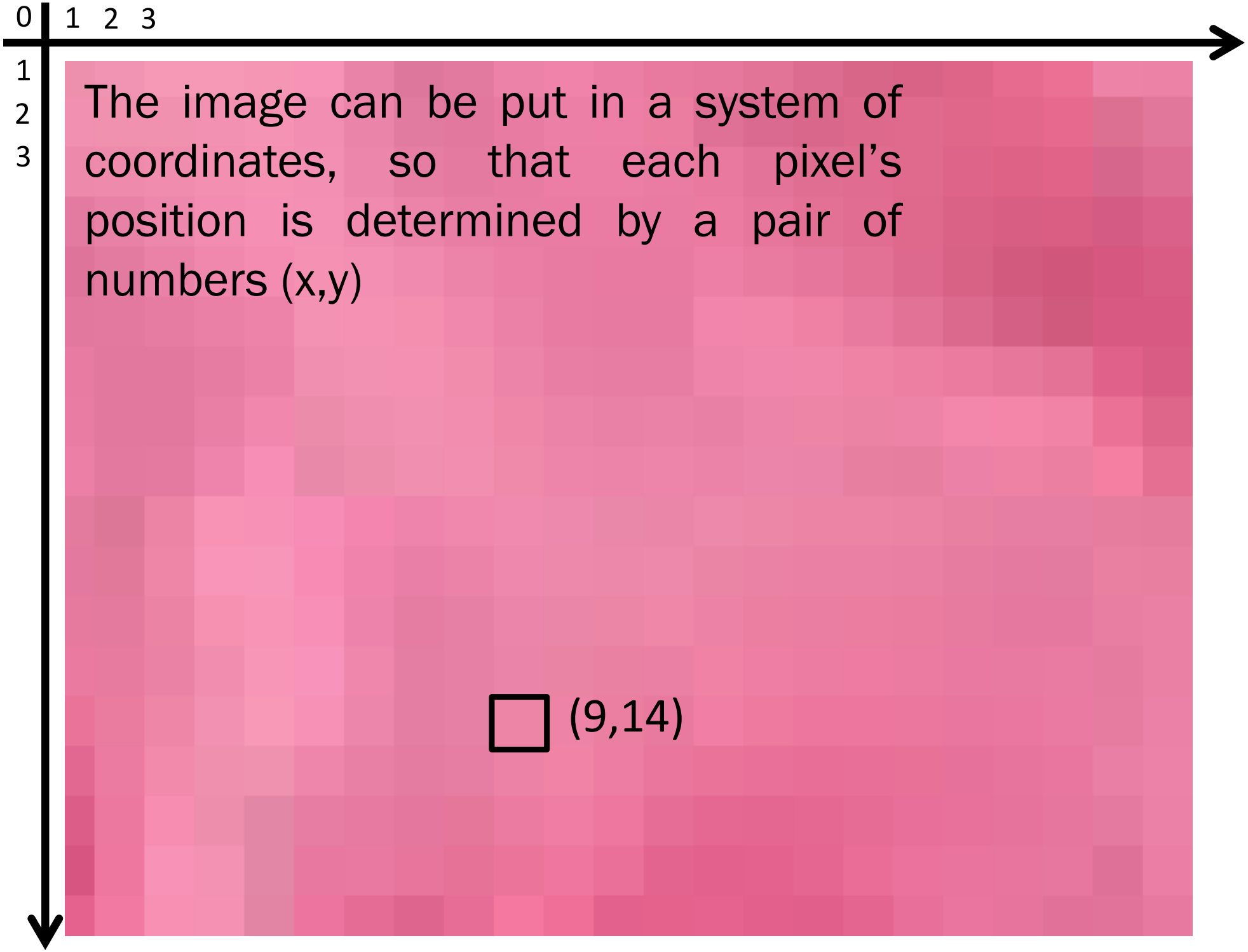
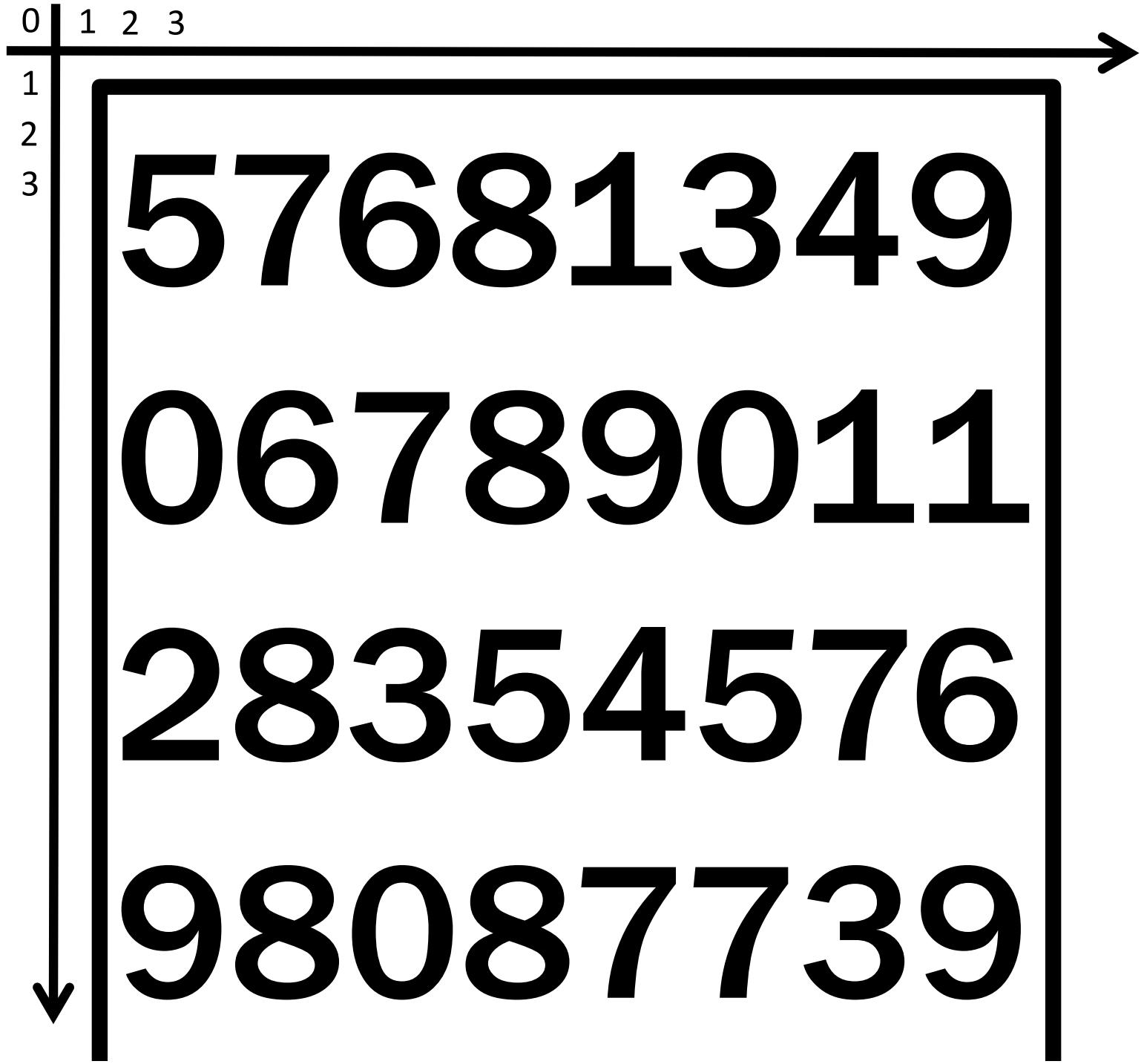
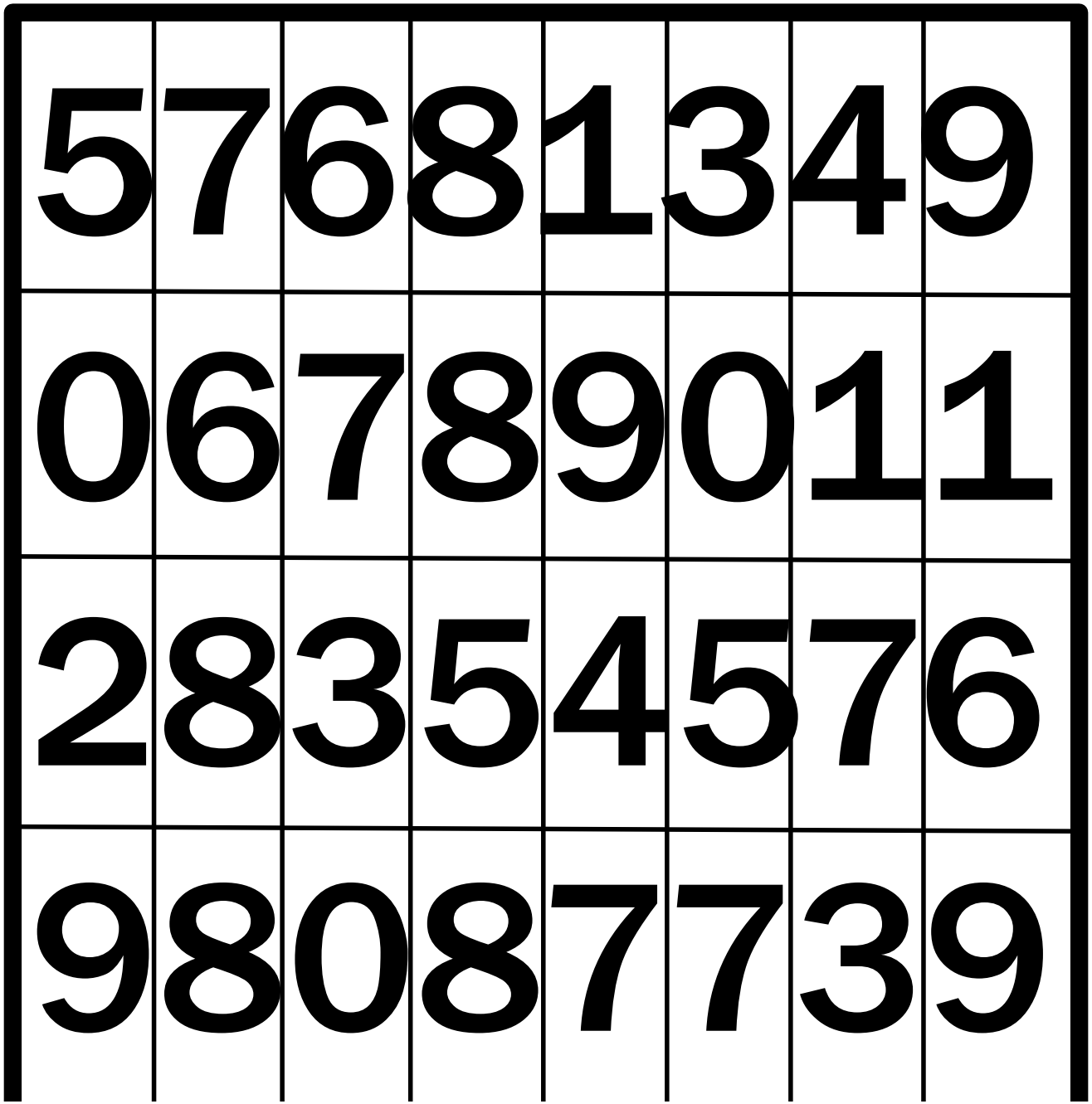
5678901234567

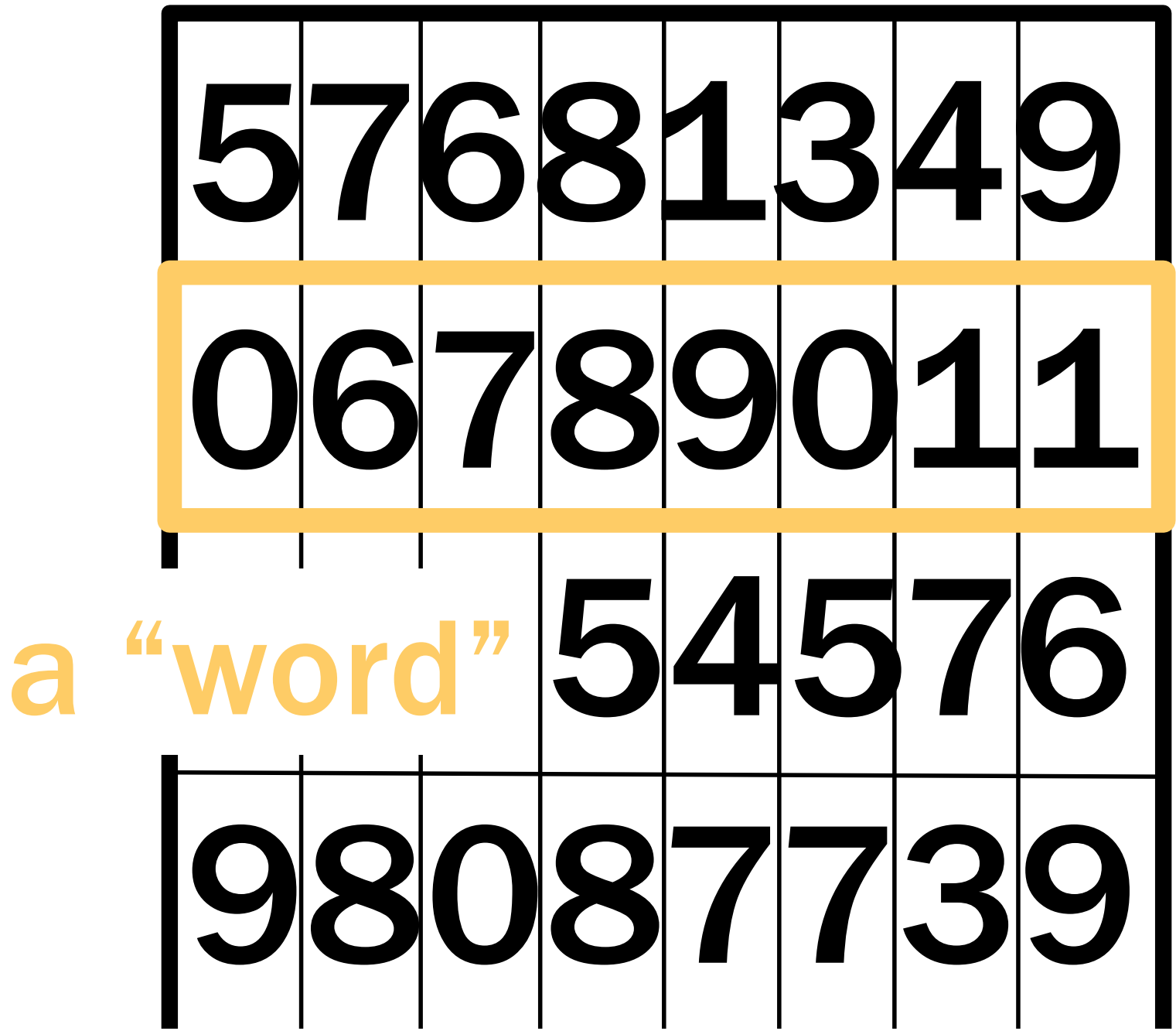

57681349
06789011
28354576
98087739

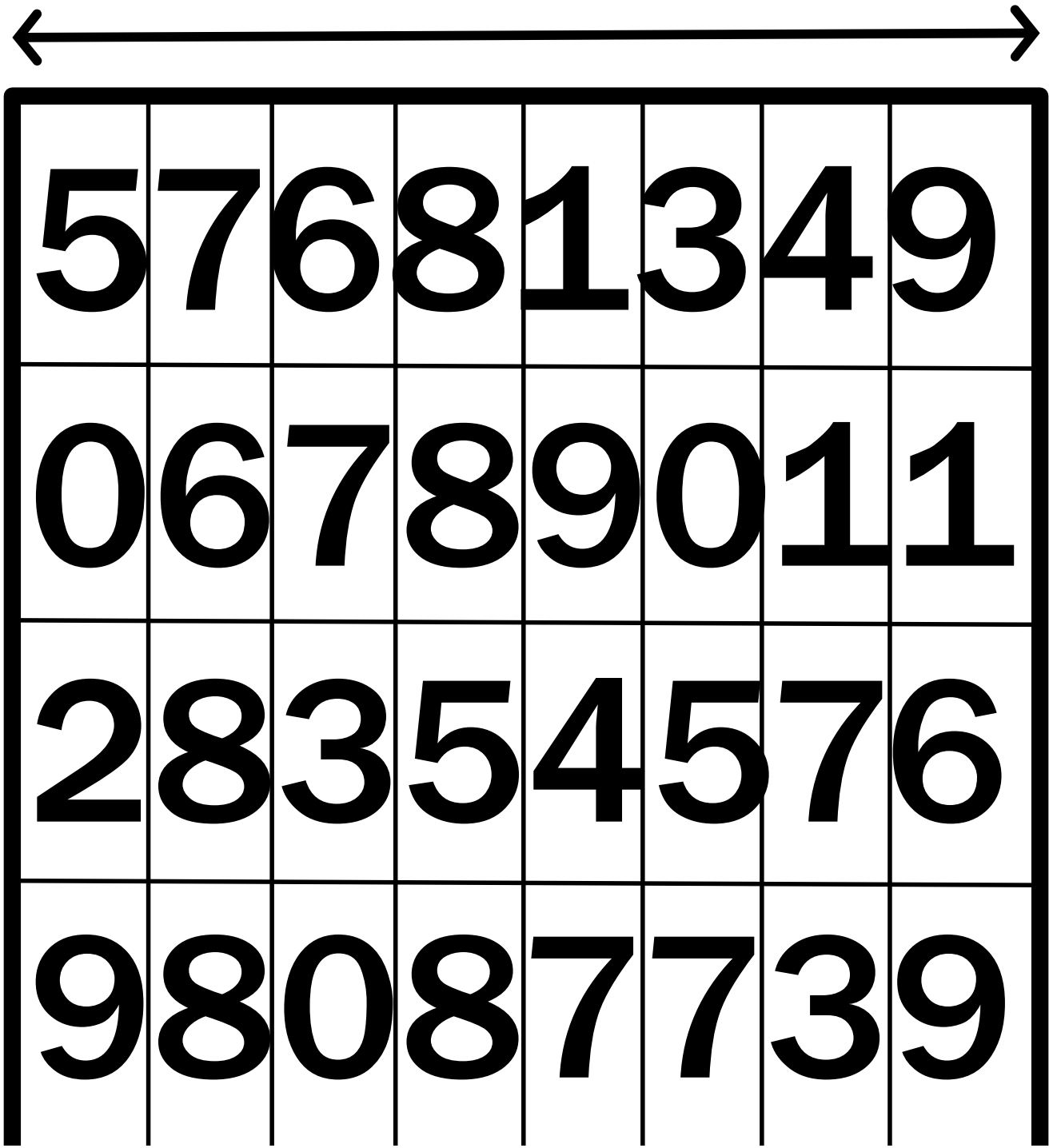
The matrix is again useful: not the movie, obviously, but the mathematical device that organizes numbers in a rectangular structure with rows and columns. We can imagine storing the numbers inside a computer inside a memory device that is organized like a matrix.

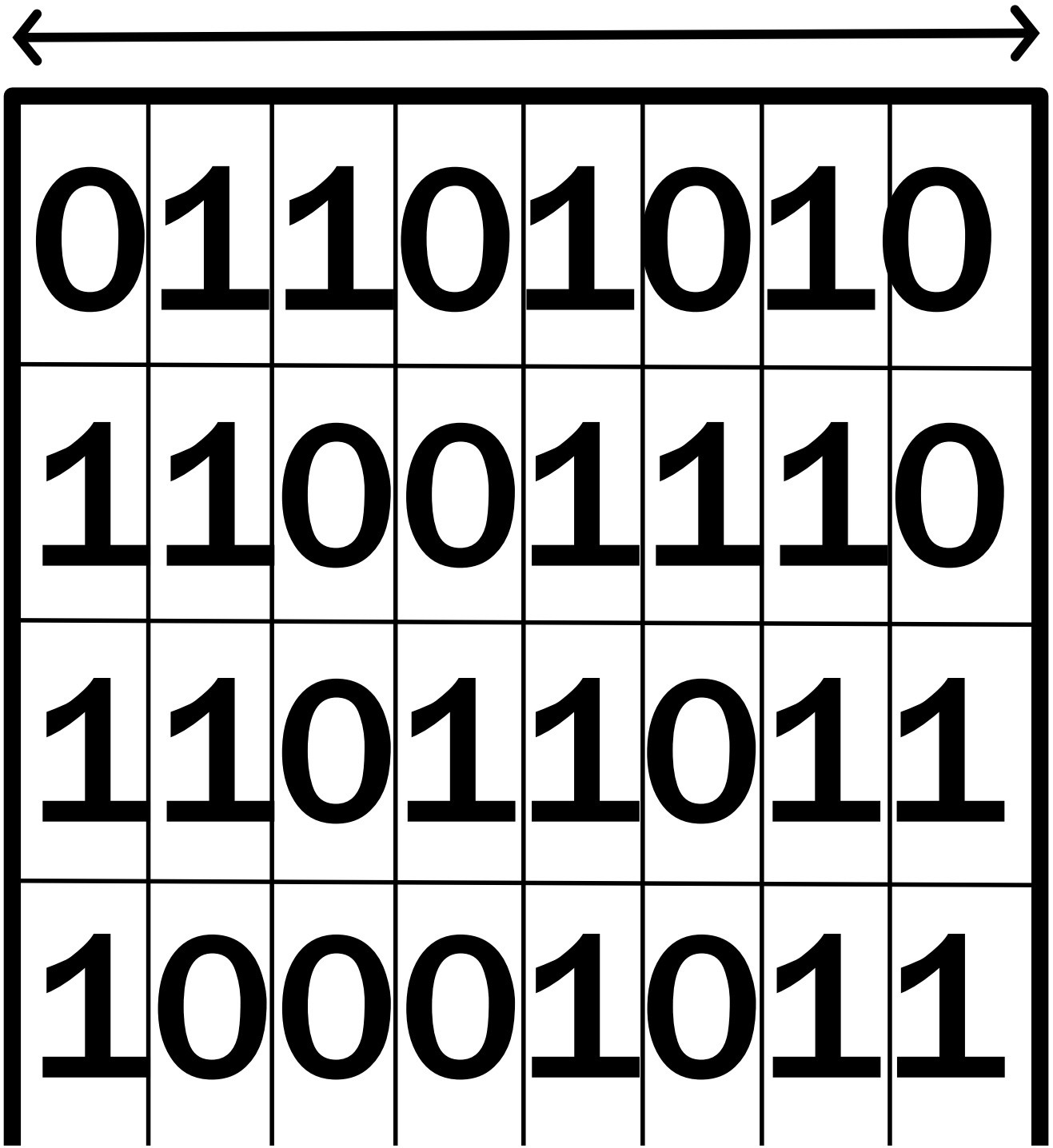

0 1 2 3
1
2
3
The image can be put in a system of coordinates, so that each pixel's position is determined by a pair of numbers (x,y)
(9,14)

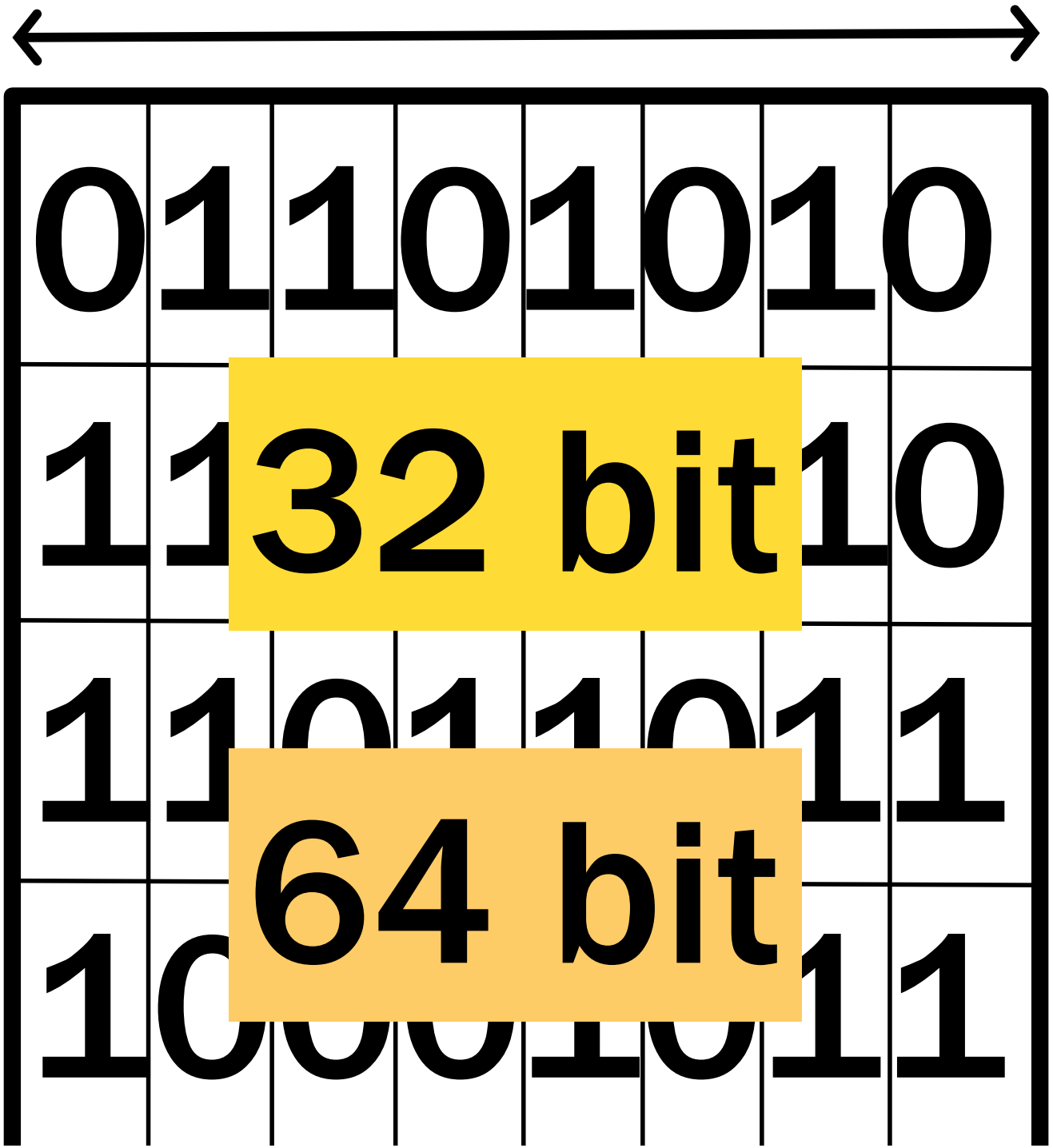

0 1 2 3
1
2
3
57681349
06789011
28354576
98087739

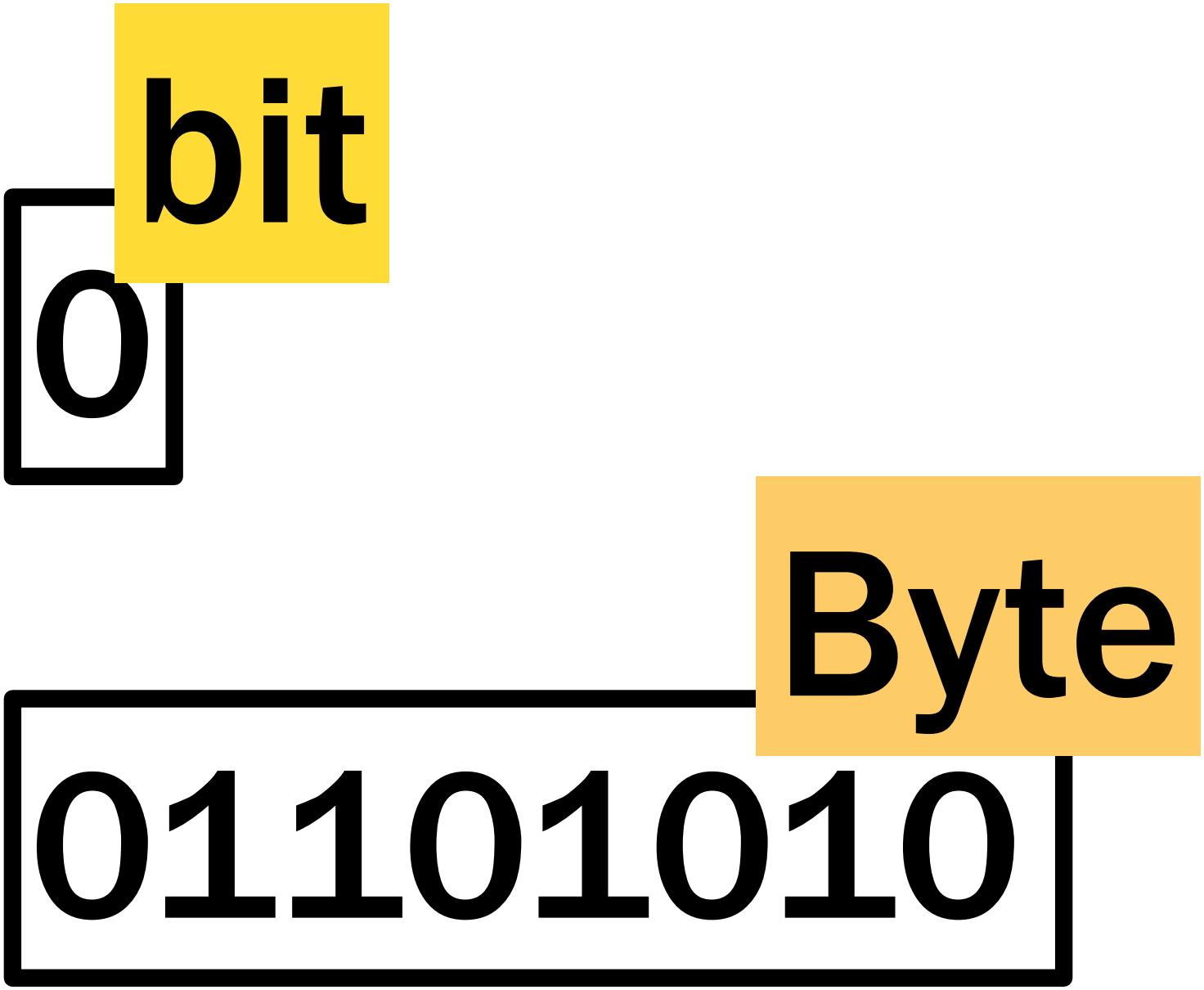

57681349
06789011
28354576
98087739


57681349
06789011
a "word"
54576
98087739


5768134 9
0678901 1
2835457 6
9808773 9


01101010
11001110
11011011
10001011


01101010
32 bit
64 bit

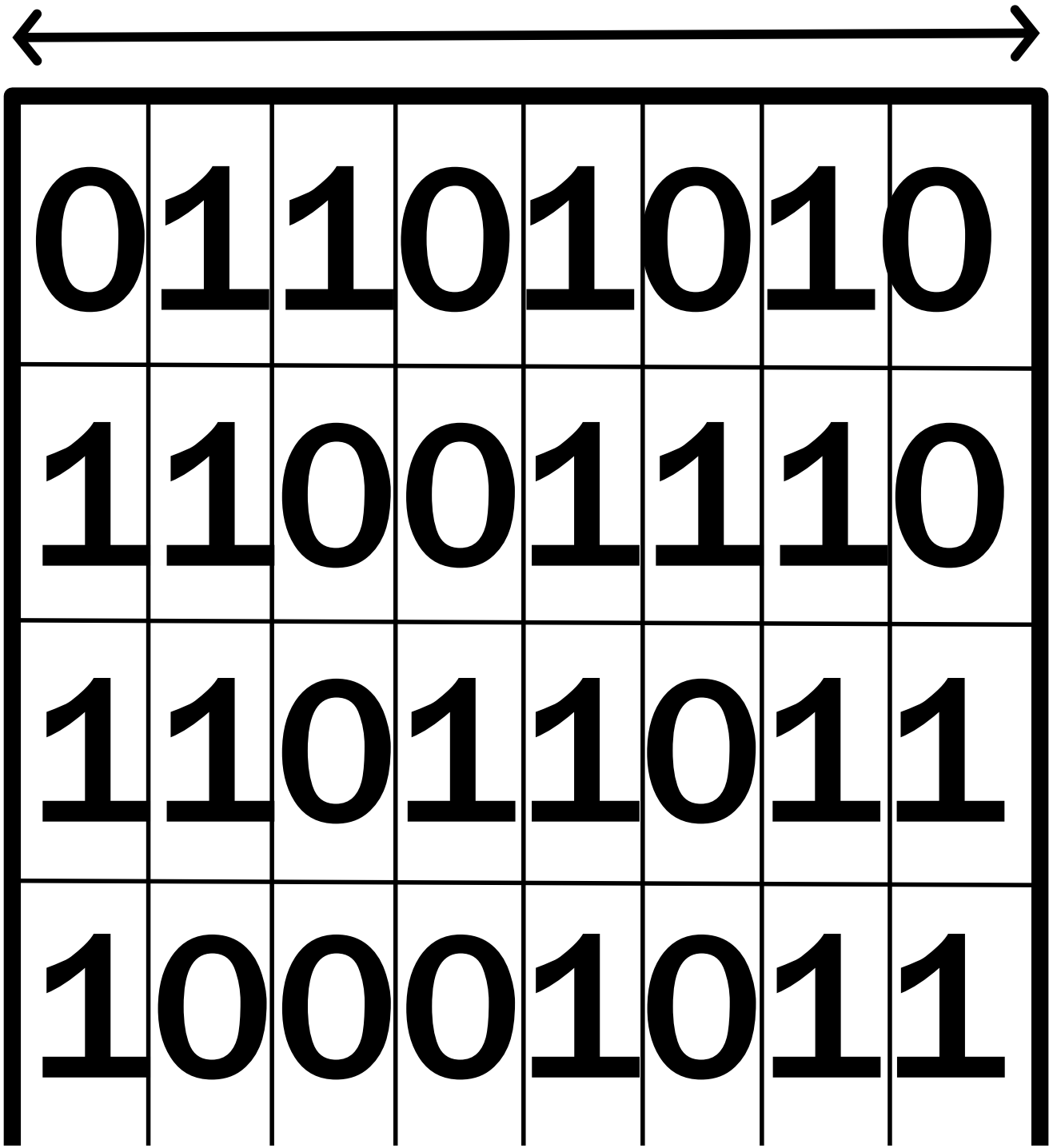

bit
0
Byte
01101010

Why is 1 Byte made of 8 bits?

Choices.

Federico Faggin, Marcian “Ted” Hoff Jr., and Stanley Mazor
with the pioneering microprocessor they created in the early 1970s, the Intel 4004

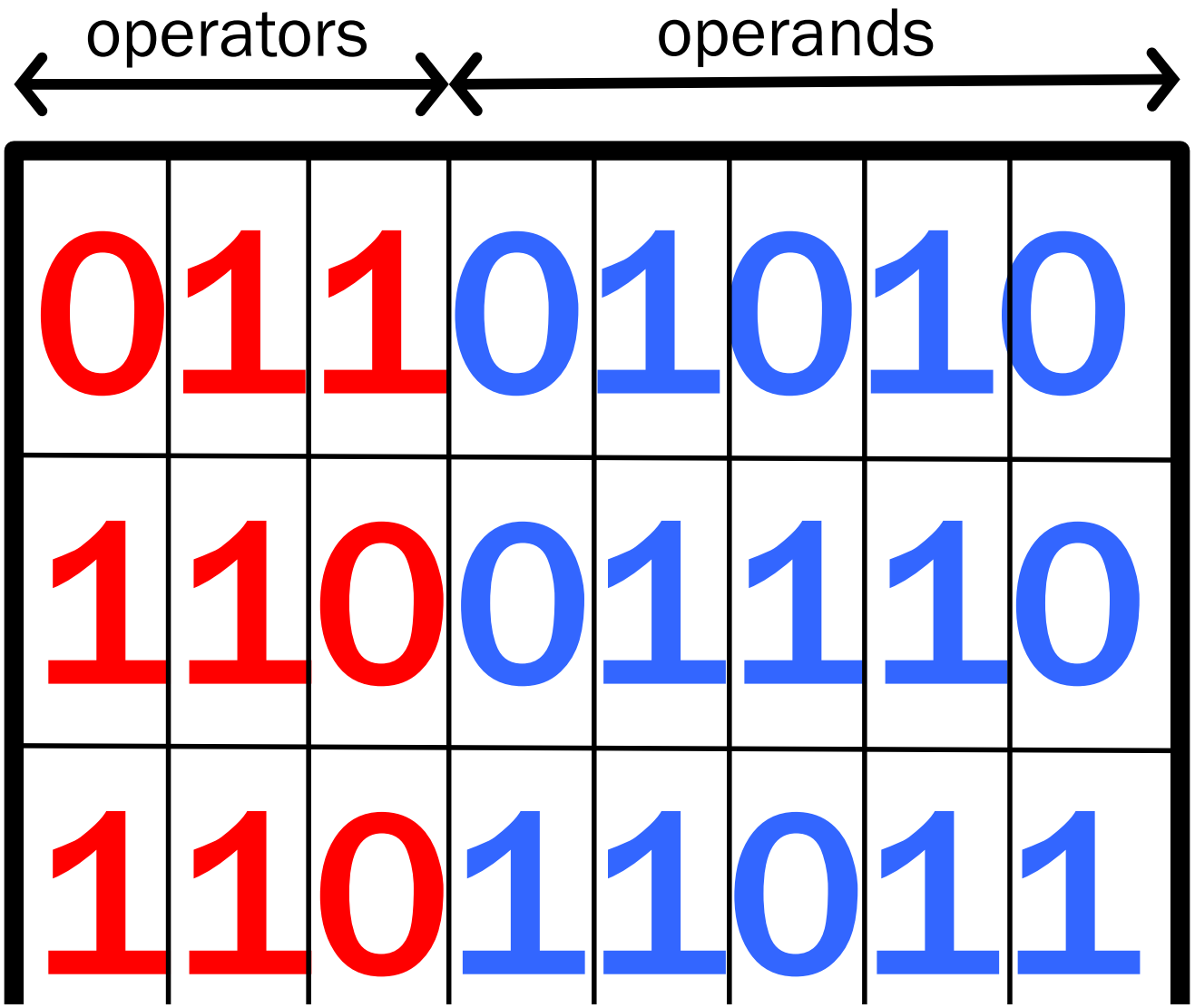
Each row of this matrix-like structure in which numbers are stores is called “word” in the IT jargon. The length of a word is one of the characteristics that determines how a computer’s storage works. We must not forget that the only “numbers” inside a computer are binary digits (or “bits” in short), because for each position in the matrix we will have a high or low level of electrical tension, which gets interpreted as a 1 or a 0, respectively. Computer nowadays have words that are 32 bits or 64 bits long. Since 8 bits form what we call a byte (bits are “b” with a lowercase b, while bytes are “B” with an uppercase B), a word is typically 4 or 8 bytes long. The proportion between bits and bytes is a remnant of a design choice made by computer chip designers in the 1970s.


01101010
11001110
11011011
10001011

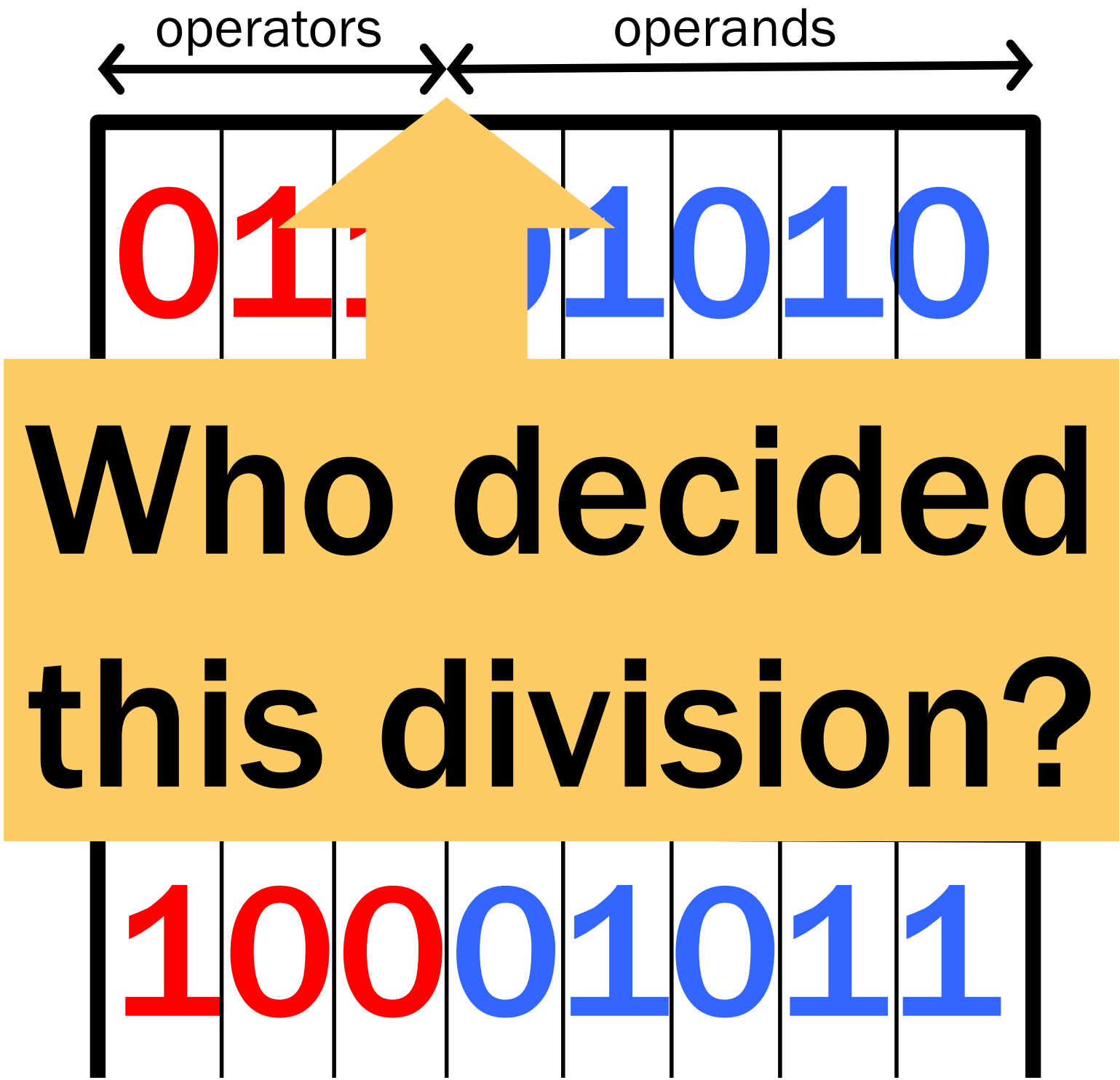
operations

operands

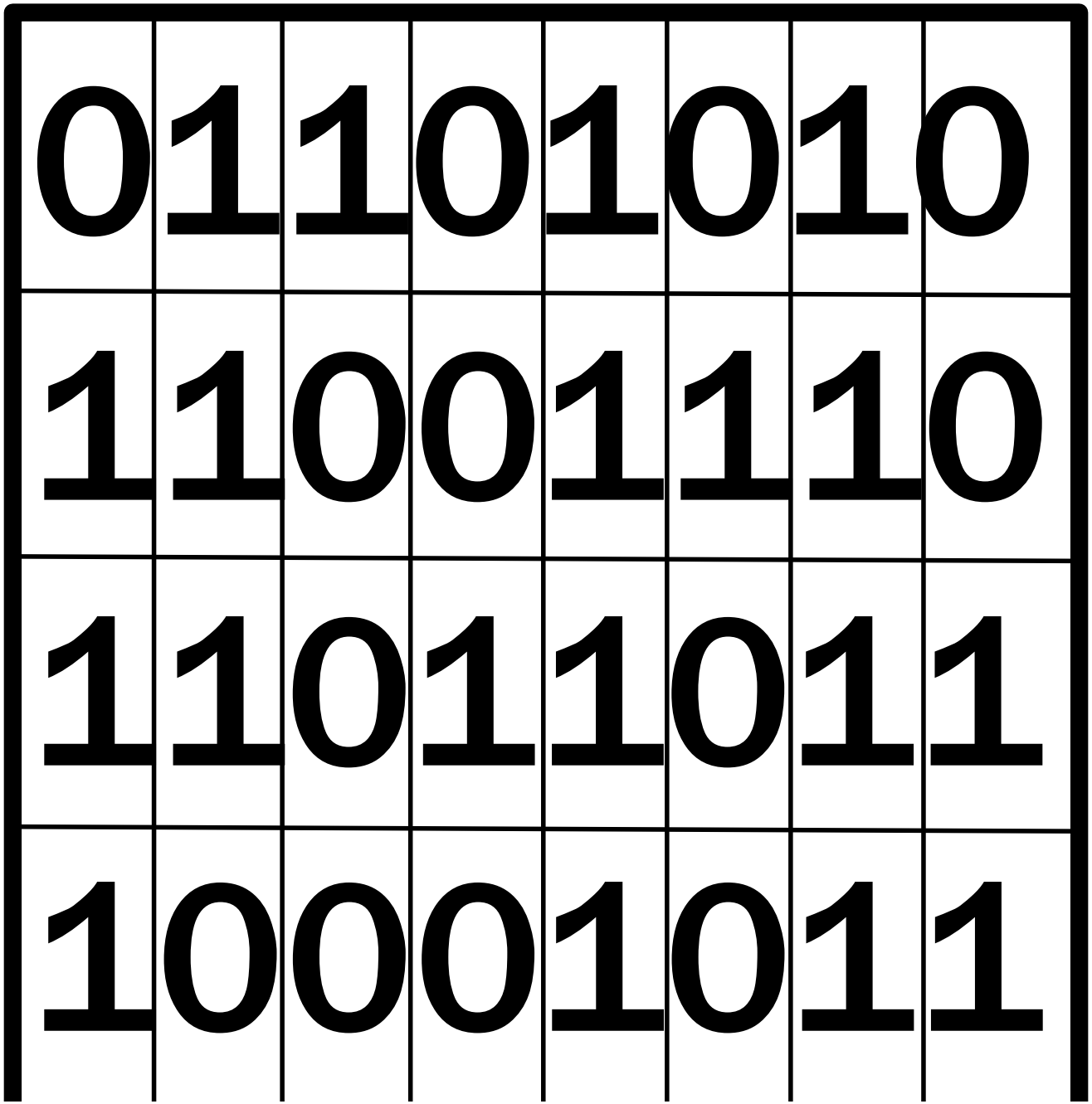
352



The stored program prescribes the following, to keep operations and operands neatly separated: all words in the storage should be used with a division; the bits before the division are operation bits, and the ones after the division are operand bits. Again, the position of the division is an arbitrary design choice.


operators
operands
01
1010
Who decided this division?
10001011

Again, choices.


01101010
11001110
11011011
10001011

THE STORED PROGRAM

Both operations and operands can be stored in the same place.

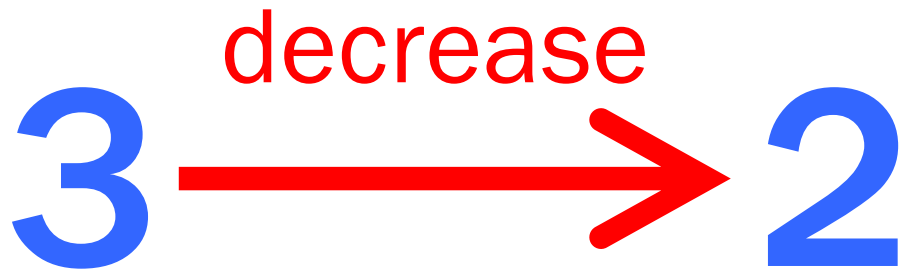
THE STORED PROGRAM

Both operations and operands are bits stored inside words.

A great advantage in having both operands and operations stored as bits is that we can apply the same processing techniques to both. Hence, in the same way as we modify operands with operations, we can also modify the operations themselves. This is why today you can easily update your apps on your mobile phones, for instance: it is just about bits inside the storage being changed accordingly.

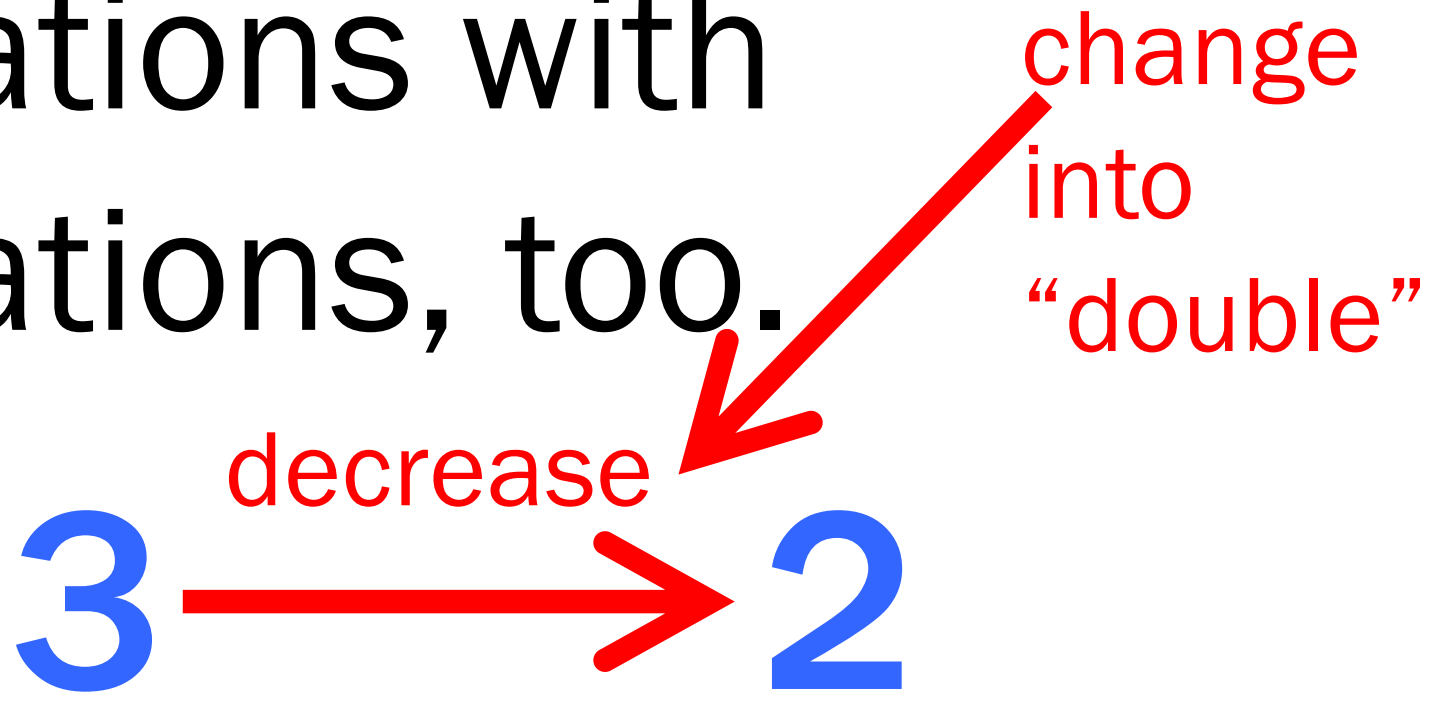
THE STORED PROGRAM

We manipulate operands with operations.



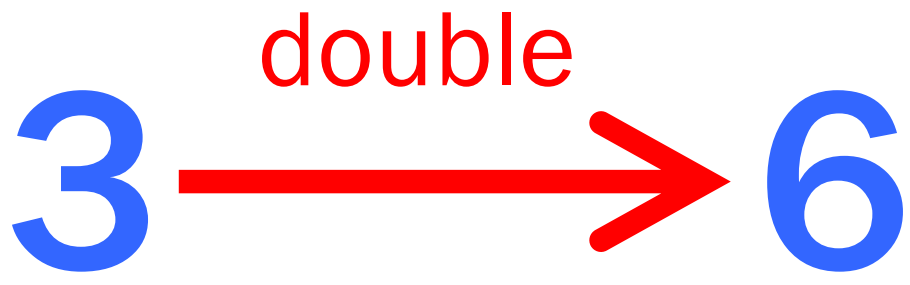
THE STORED PROGRAM

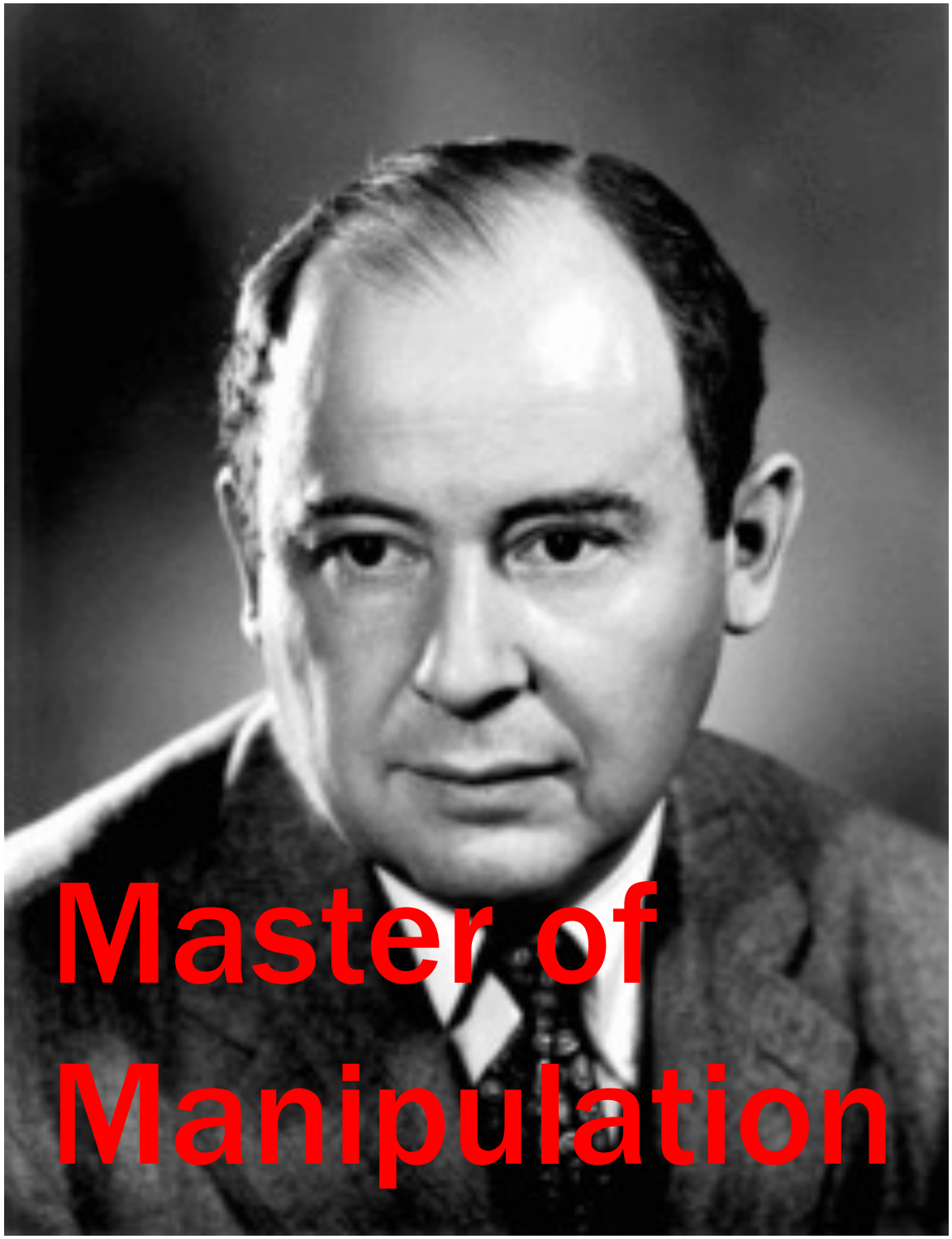
We can manipulate operations with operations, too.



THE STORED PROGRAM

We can manipulate operations with operations, too.

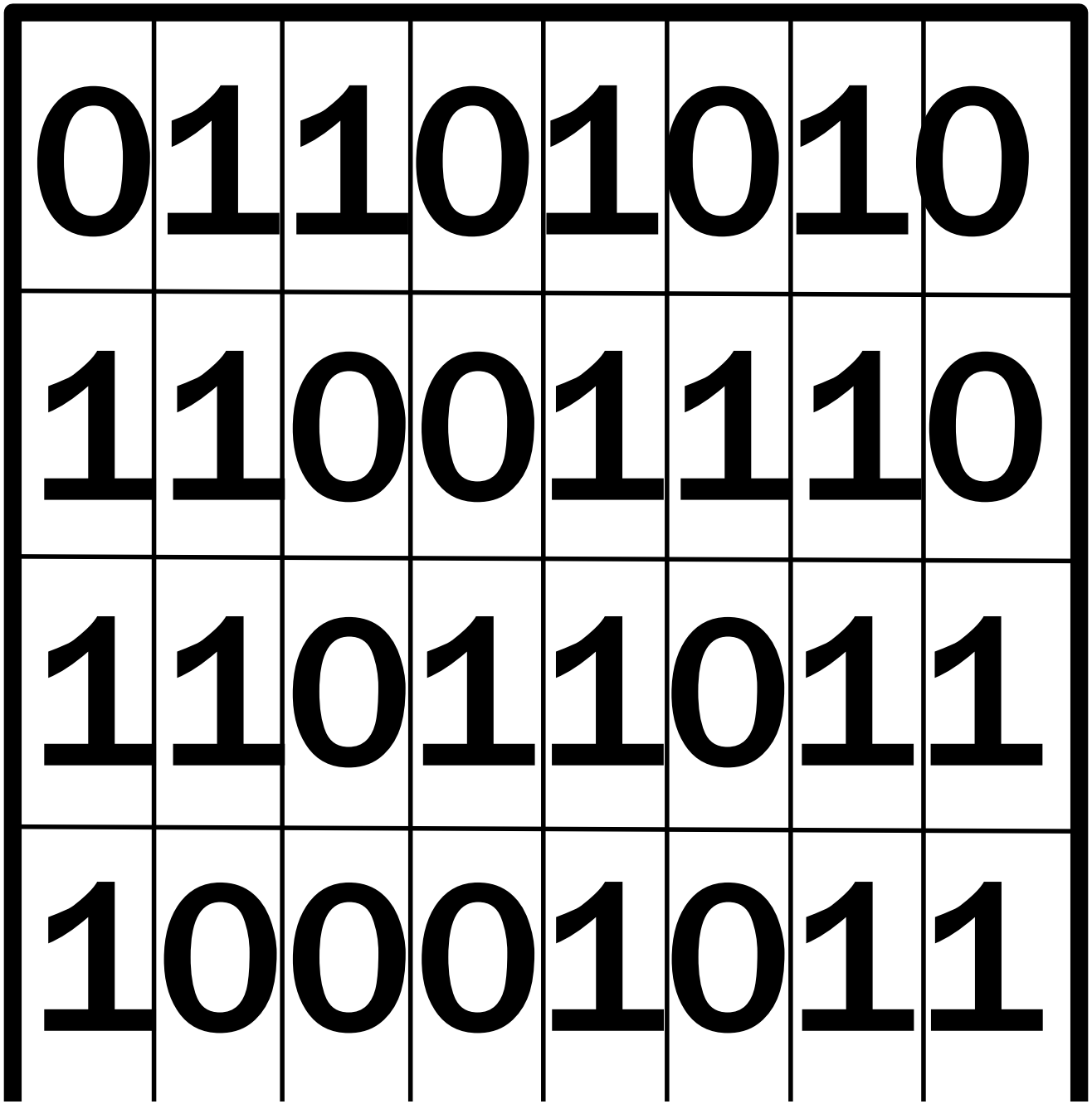


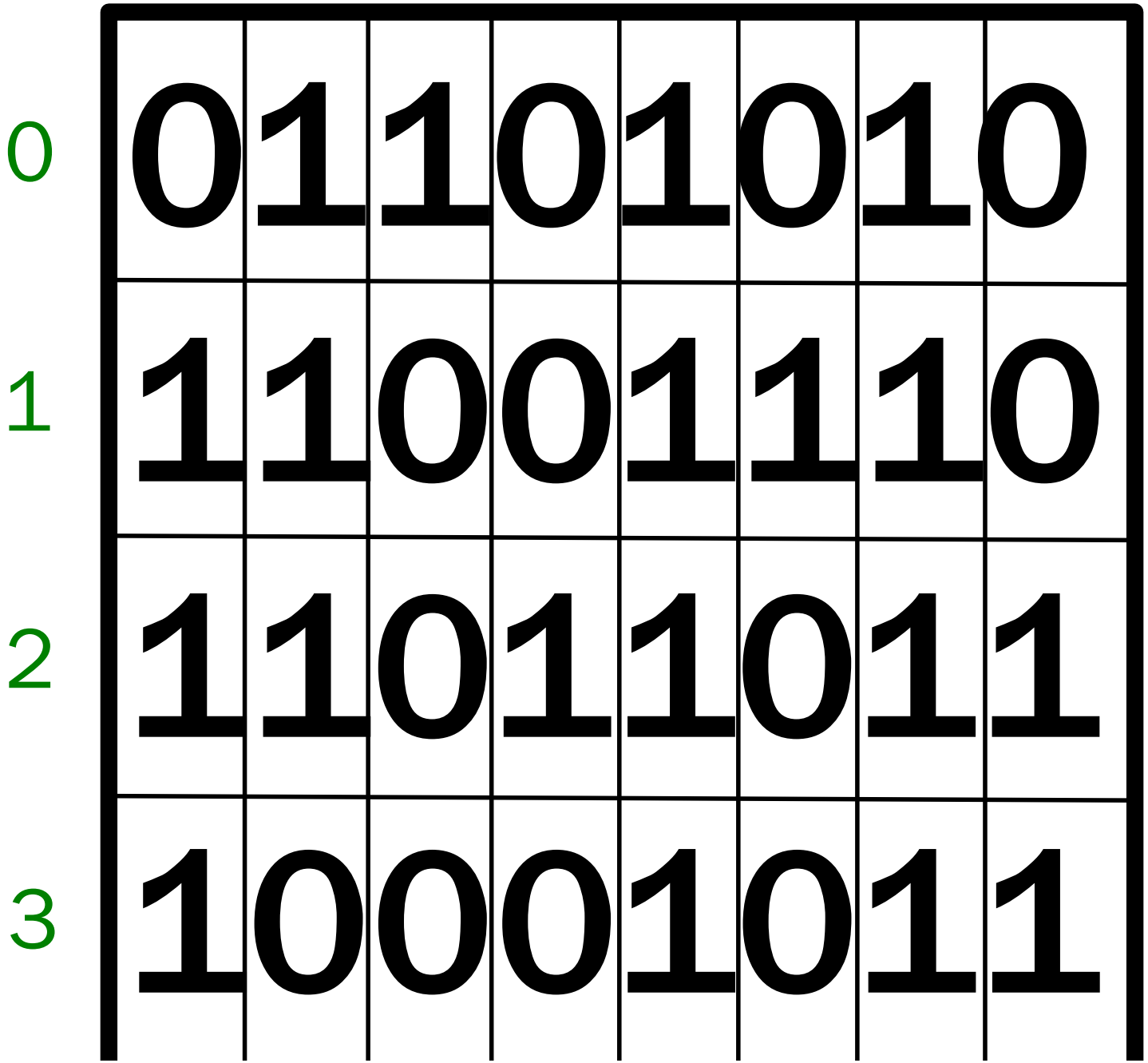

Master of
Manipulation

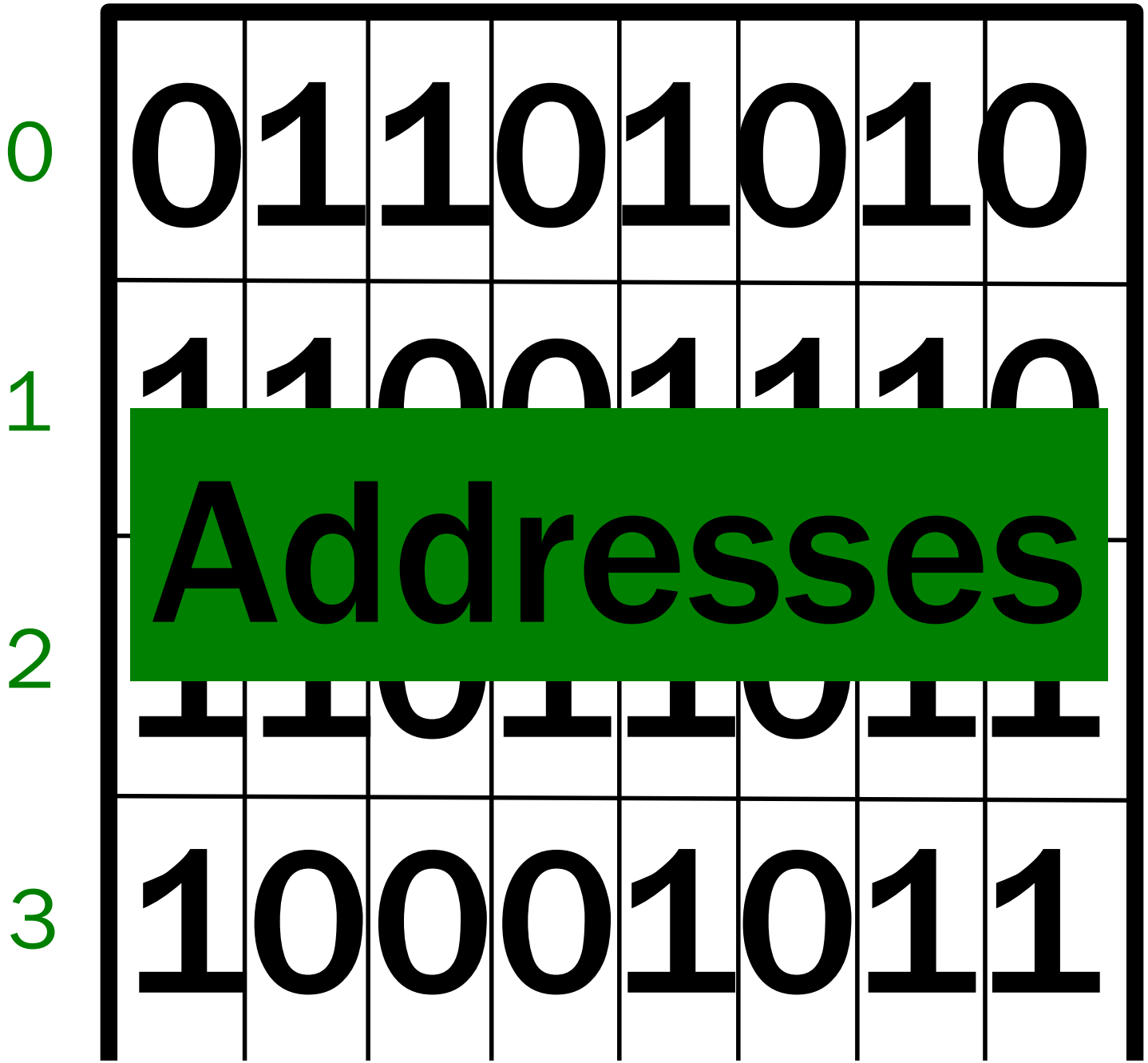
operations

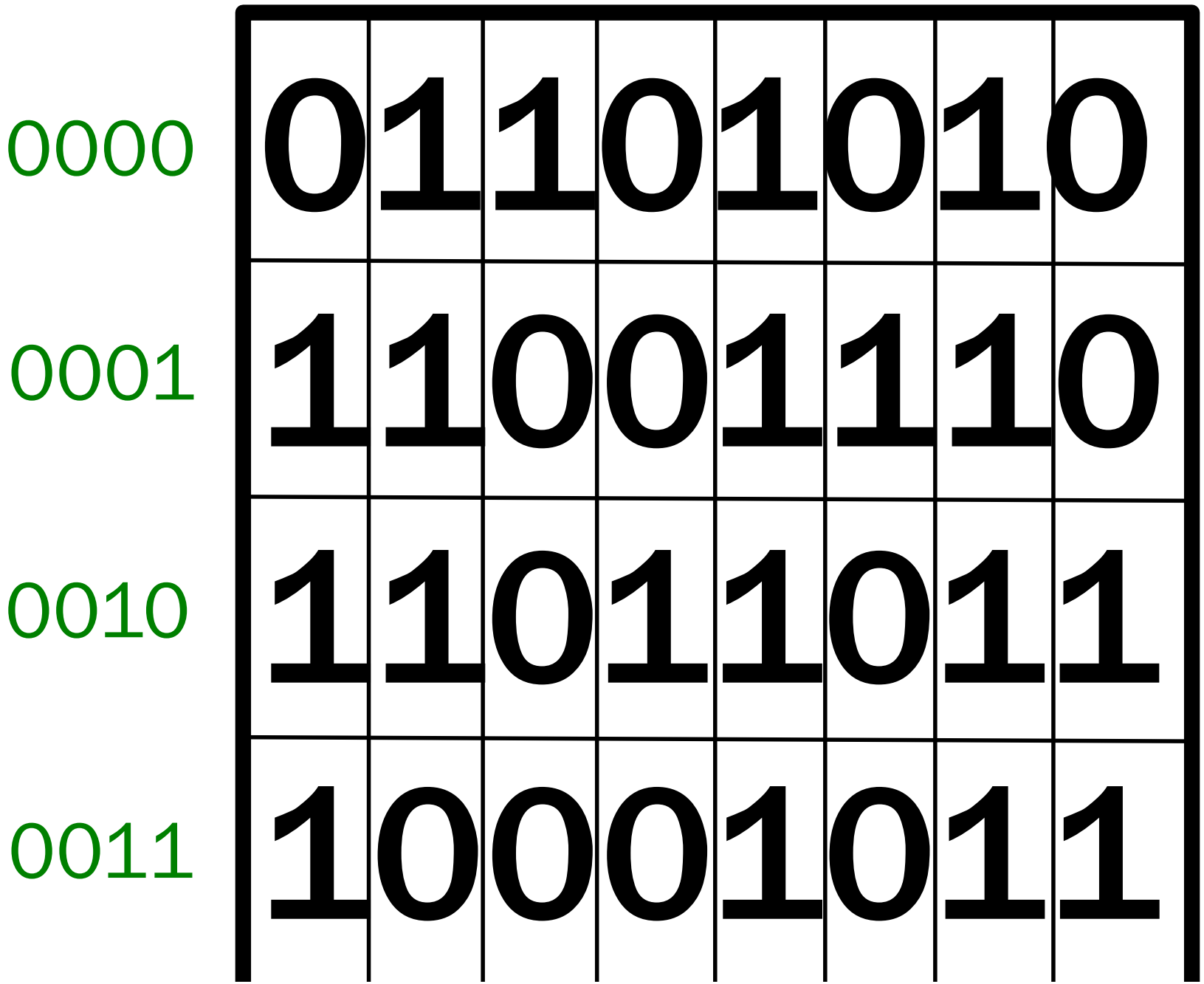
operands

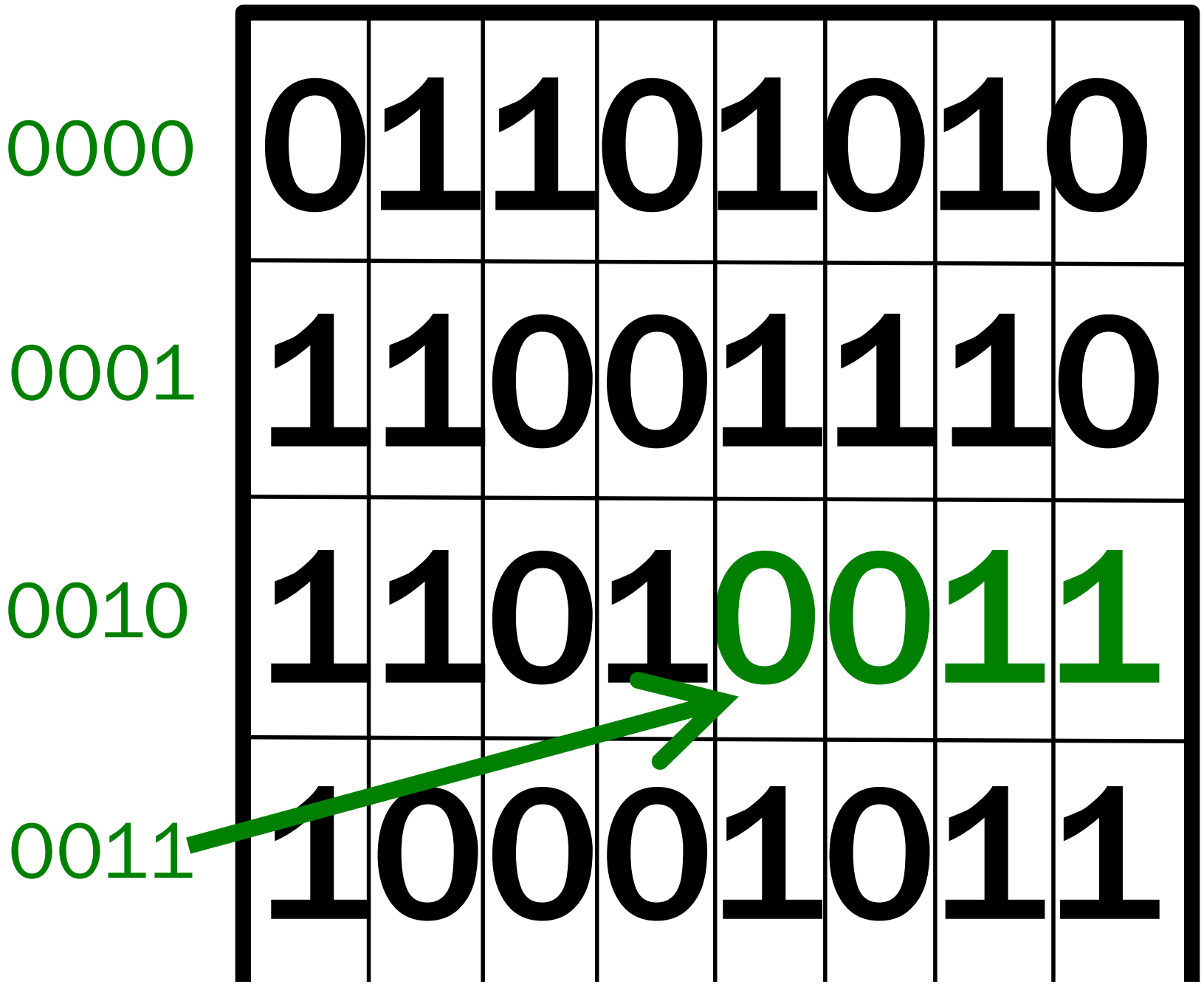
place 352


01101010
11001110
11011011
10001011


0
1
2
3
01101010
11001110
11011011
10001011


0
1
2
3
01101010
Addresses
10001011


0000
01101010
0001
11001110
0010
11011011
0011
10001011


0000
0001
0010
0011
01101010
11001110
11010011
10001011

We introduced the green color code to refer to numbers dealing with the places where operands and operations are stored. The storage is enriched with an address system, which associates a number (an address) to each word in the matrix. Of course, addresses are also expressed in terms of bits that can be stored themselves in the memory.

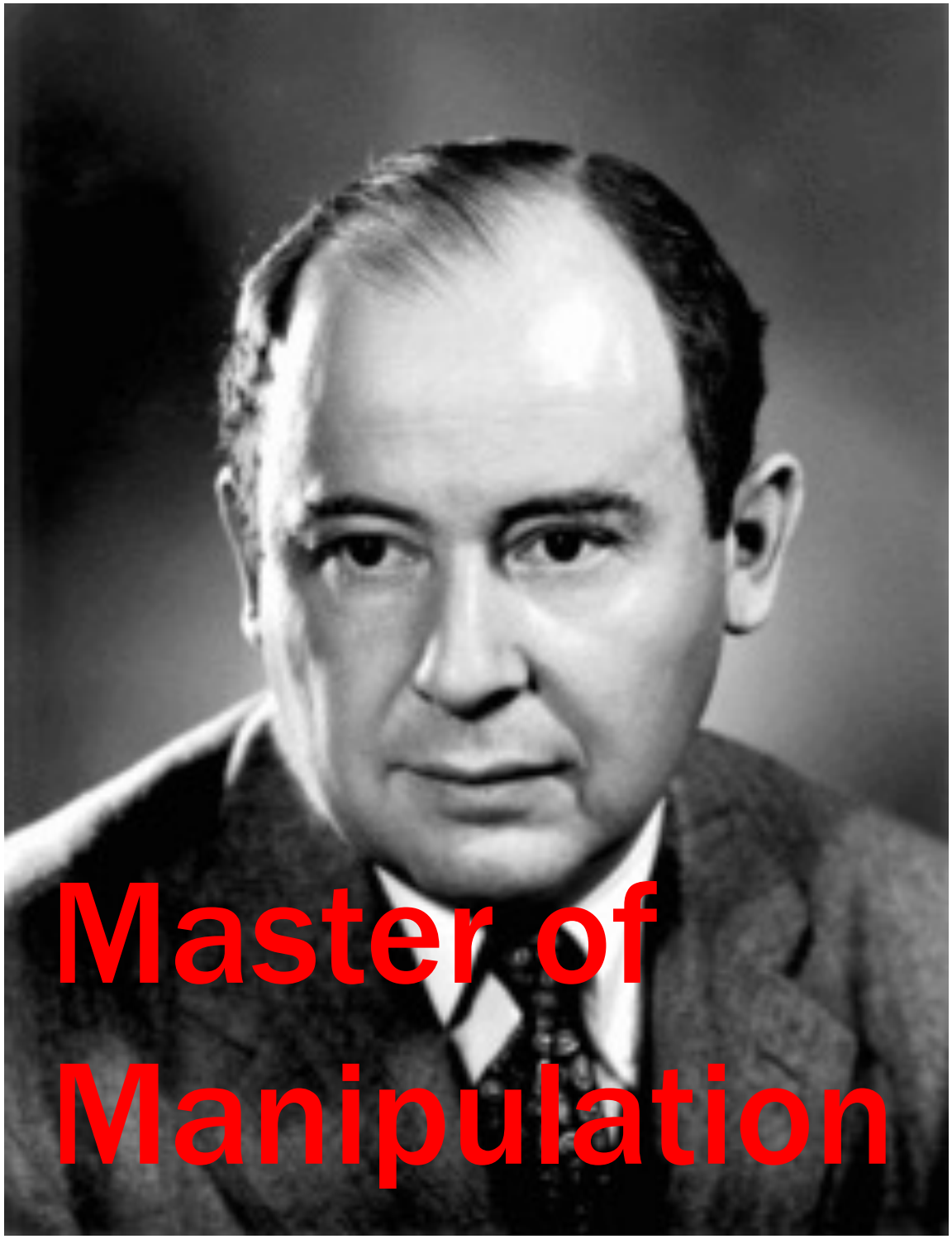
operations

operands

place 4527

THE STORED PROGRAM

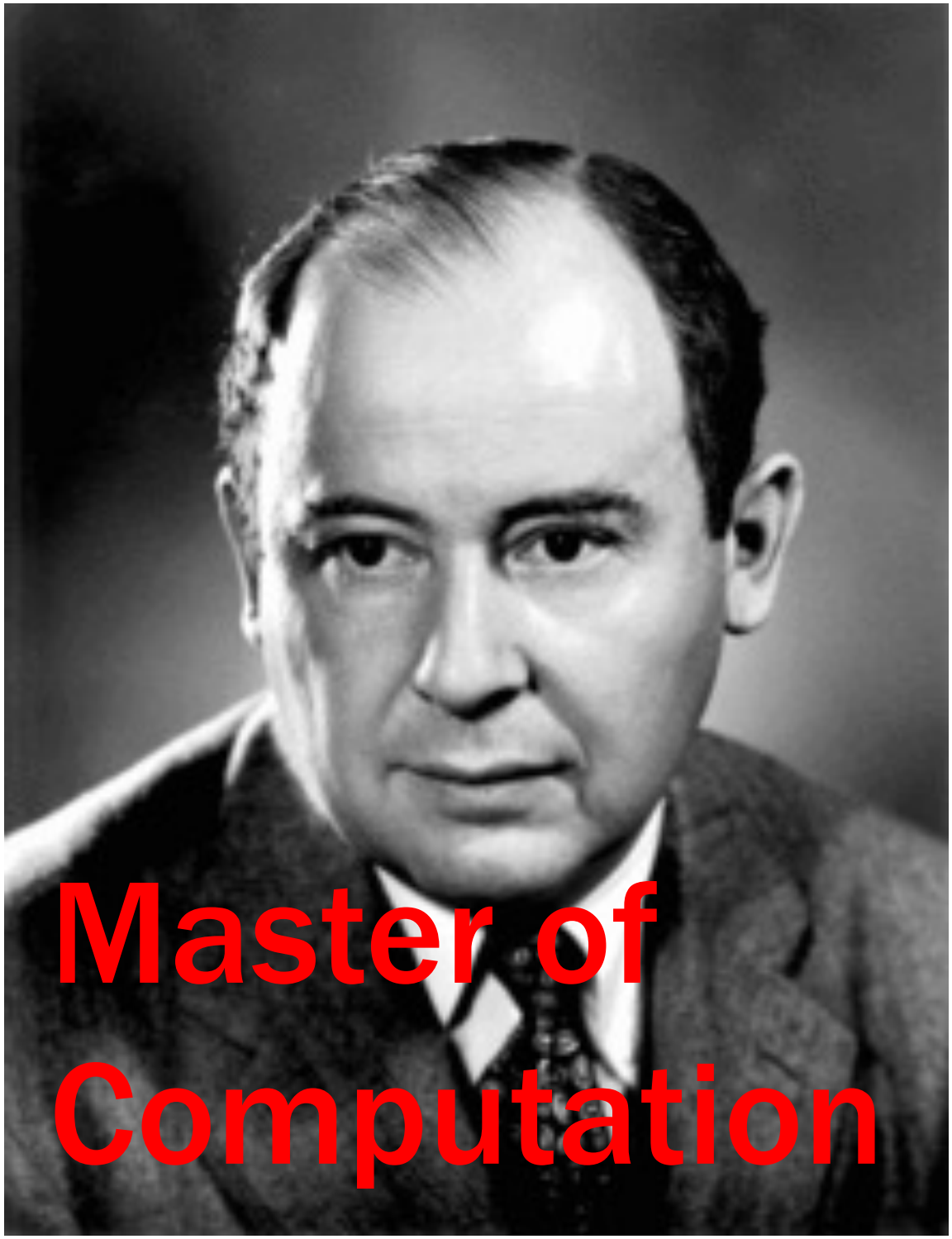
- We manipulate operands.
- We manipulate operations.
- We manipulate addresses.

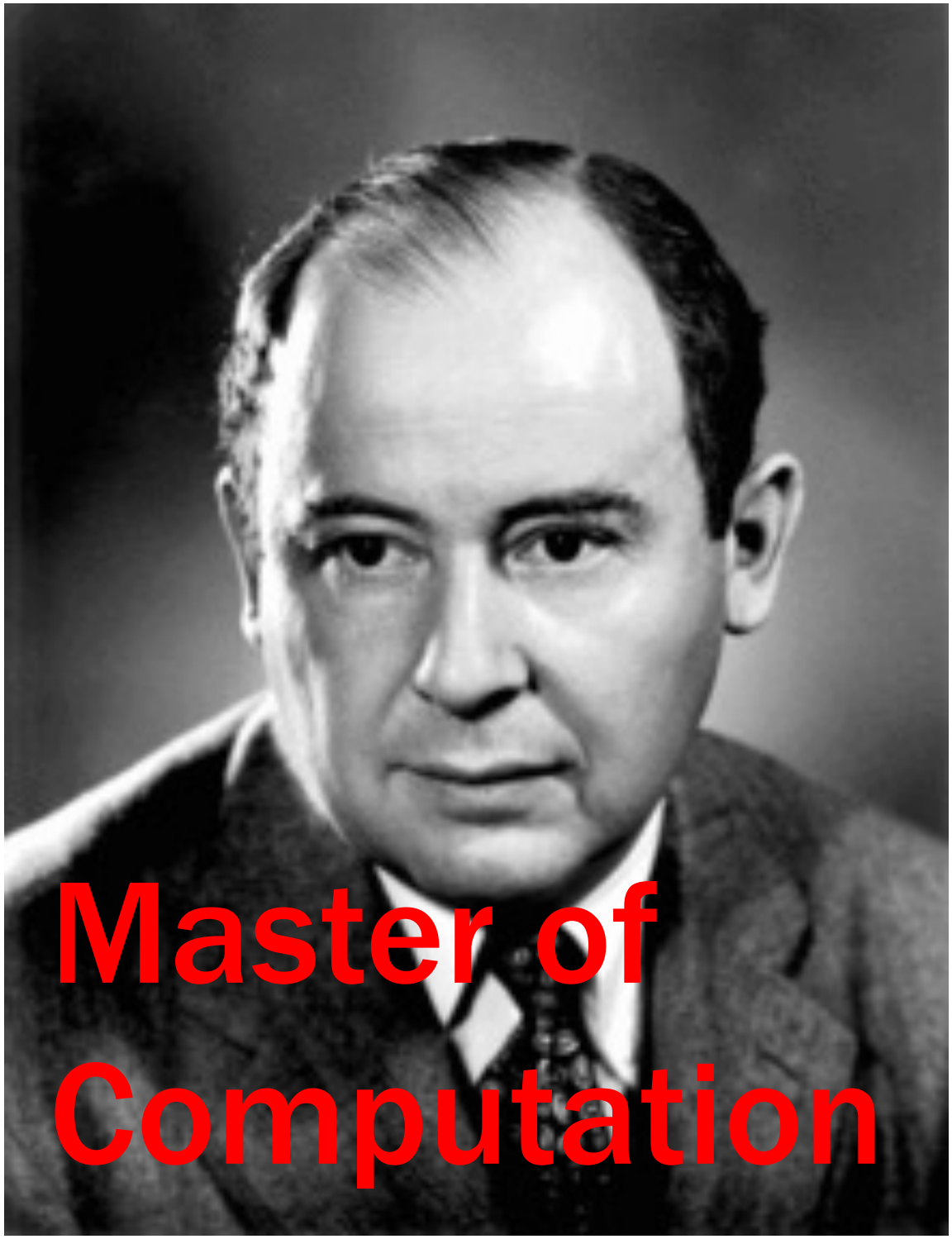

Master of
Manipulation

THE STORED PROGRAM

- We elaborate data.
- We create and modify programs.
- We transfer data and programs.

The stored program paradigm, thus, enables us to store and manipulate all sorts of numbers: data, software, and also the addresses indicating where the data and the software are stored. Managing addresses is a fundamental part of the system that enables transfers of data from one part of the computer to another, and also between computers.


Master of
Computation



(Still
an awful
person.)

Typically, we are used to transferring files (from your computer to a USB drive, or from your computer to another computer via email as an attachment, or from your smartphone to your computer via Bluetooth, etc.). Files are conceptually treated as units (a document, an app, a song, etc. visually and textually distinguished by the so-called "file extension" at the end of their name), but they actually are a sequence of bits inside a computer's storage system. As with physical file cabinets in real life, we need a manager for taking care of the system. In IT terms, this is what we call a "file system". A file system keeps track of all the addresses of all the files inside a computer, to be able to find them and work with them.

The Digital in
Digital A...ion.docx

The Digital in
Digital A...ion.docx

PROGRAM

DATA

PROGRAM DATA

FILES

A file cabinet.

Google

secretary file cabinet

Smiling Vintage Secretary ...
123rf.com

Female secretary or assistant checking ...
alamy.com

Classic Solid Wood Secretar...
dutchcrafters.com · In stock

Secretary filing cabinet Sto...
masterfile.com

Smiling secretary searchi...
canstockphoto.com

Secretary desks, File cabinet desk ...
pinterest.pt

Female secretary or assistant checking ...
alamy.com

2 Drawer File Cabinet Solid Oak ...
amazon.com

Free Filing Cabinet Drawer ...
stockunlimited.com

File cabinet desk ...
pinterest.com

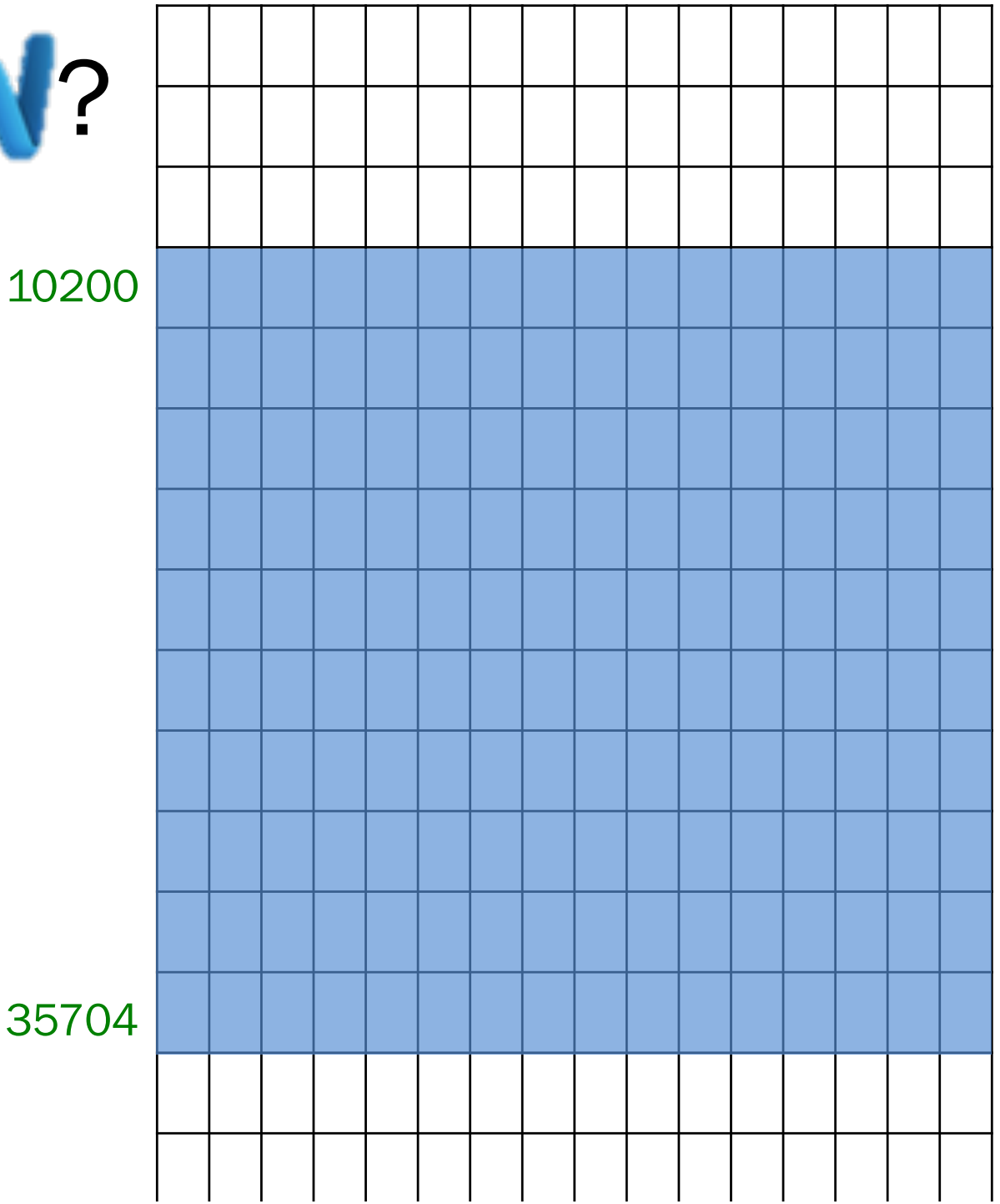
Female secretary or assist...
alamy.com

Oak secretary, file cabinet...
pinterest.it

Where is  ?

Where is W?

From word 10200 to word 35704.



11 Save Your Tears.m4a

enso.JPG

The Digital in Digital A...ion.docx

PROGRAM DATA

FILES

FILES

- A file is a group of bits that are logically treated as a unit.
- A file may be comprised of data, program instructions, or addresses.

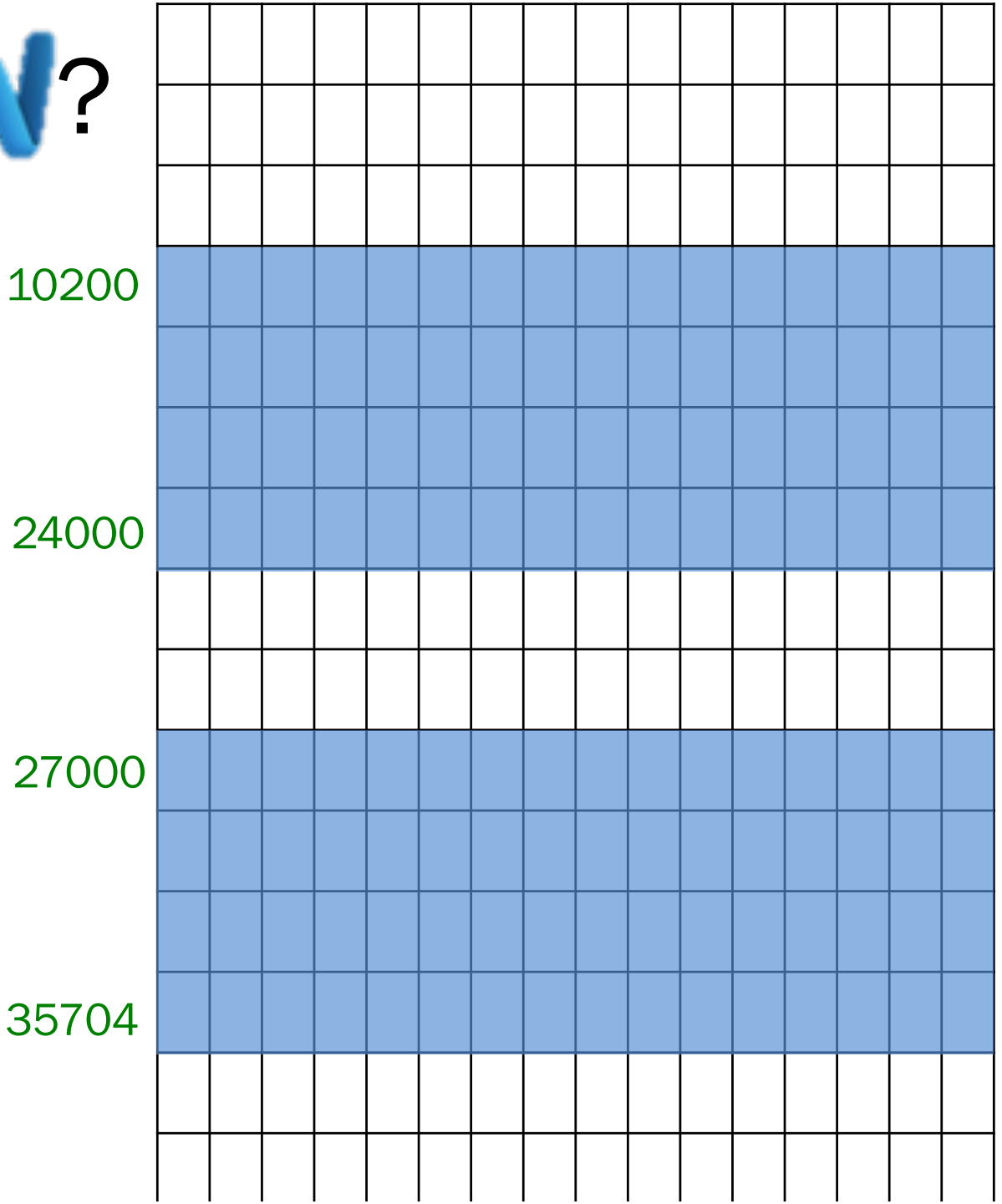
FILES

- A file is a group of bits that are logically treated as a unit.
- A file may be comprised of data, program instructions, or addresses.

Files are “logical” unit, meaning that they are treated as a whole, but in the physical reality of the storage unit inside a computer, they may be widespread throughout the storage in different pieces. It is a task of the file system to keep track of the addresses of all these pieces to retrieve them and compose them and use them as a unit when needed. One particular kind of file is a file containing not data (like “my_thesis.docx”), not instructions (like Microsoft Word), but addresses. These are called “folders” and they are presented to you, the end users, with a visual metaphor depicting a folder containing other files, but it is actually just a bunch of addresses pointing at those files.

Where is W?

From word 10200 to word 24000 and from word 27000 to 35704.



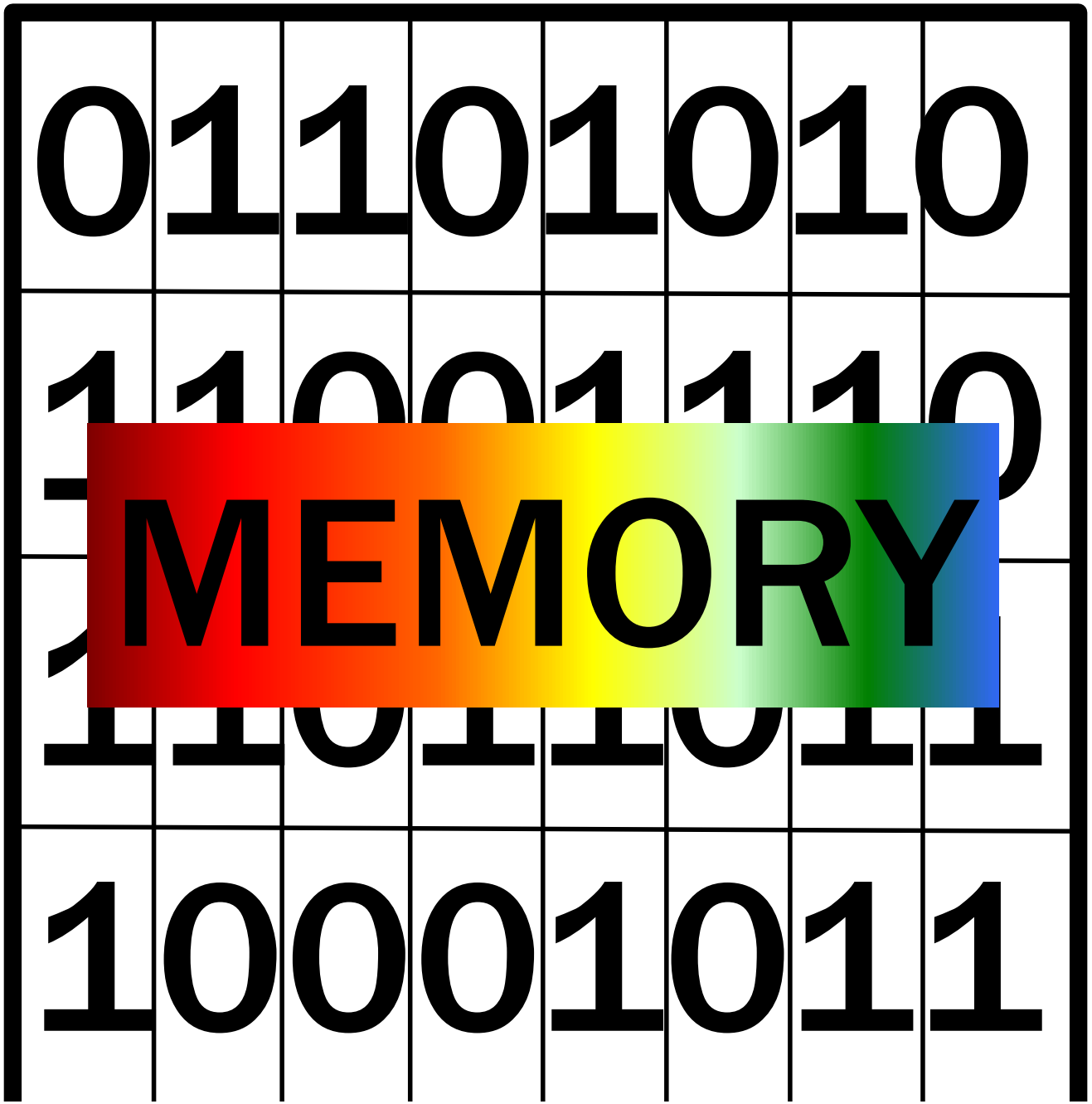
FILES

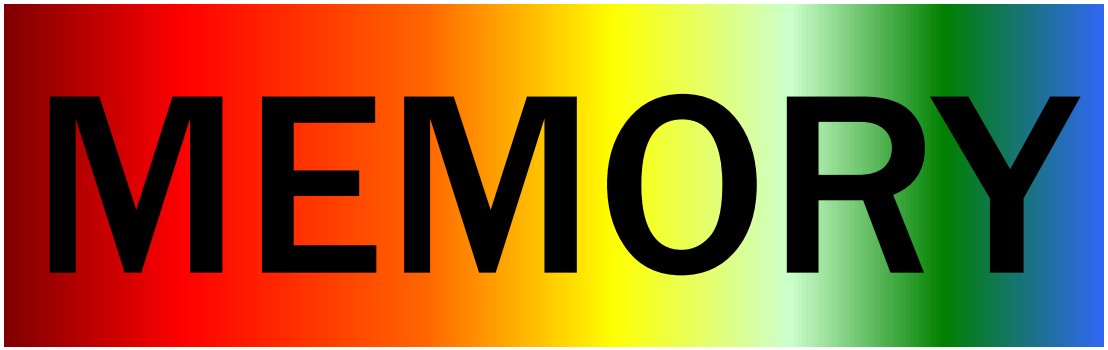
- A file is a group of bits that are logically treated as a unit.
- A file may be comprised of data, program instructions, or addresses.

Digital Humanities
@UniBG

Digital Humanities
@UniBG

FOLDER


01101010
MEMORY
10001011


MEMORY

Memory < (Greek) Mimnesko < mnè < men [the mind]

Memory < (Greek) Mimnesko < mnè < men [the mind]

Record < (Latin) Re-cordis < cor < [the heart]

Memory < (Greek) Mimnesko < mnè < men [the mind]

Record < (Latin) Re-cordis < cor < [the heart]

Memory < (Greek) Mimnesko < mnè < men [the mind]

Record < (Latin) Re-cordis < cor < [the heart]

Memory < (Greek) Mimnesko < mnè < men [the mind]

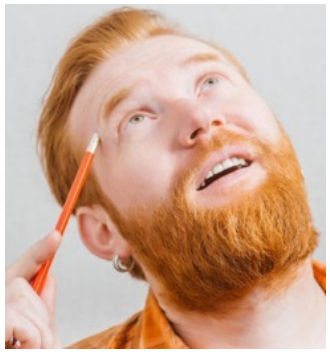
Record < (Latin) Re-cordis < cor < [the heart]

Memory < (Greek) Mimnesko < mnè < men [the mind]

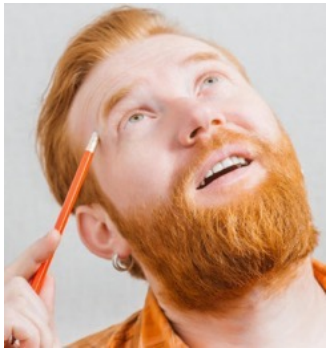
Record < (Latin) Re-cordis < cor < [the heart]

Re

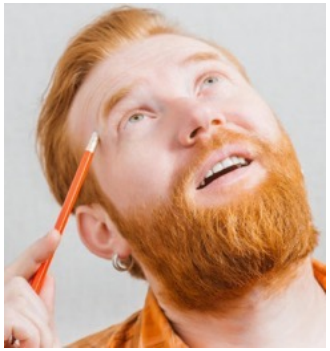
What “Re” is about.



What “Re” is about.

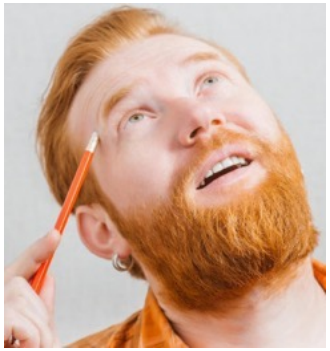


What “Re” is about.



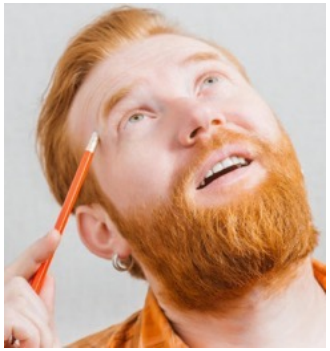
What “Re” is about.

time



What “Re” is about.

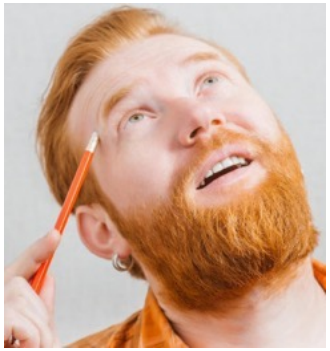
time



past
event

What "Re" is about.

time



past
event

remembering

now

What "Re" is about.

- An event

What "Re" is about.

- An event

- A description of the event

What "Re" is about.

- An event

- A description of the event

- A person who accesses the description

What is this, really?

- An event

I've been calling the place where bits are stored inside a computer "storage", but its most common name is obviously "memory". I've tried to avoid use this name too often, because its name derives from a metaphor that compares the sotrage of bits inside a computer to the memory that humans use to remember the past. There are some differences and some analogies that deserve further analysis. Whether we remember with our minds or with our hearts, it is obvious that a computer has neither, so the comparison must be drawn with care.

One funamental component of memory is time: we remember the past and not the future; we are able to remember a past event because we have somem sort of description of that event that we keep and access to reminisce. Here the subjective experience of a human and the objective, mathematical models used by computers show their difference once again. We could digitize descriptions of past events only in those aspects that can be digitized: images, sounds, and texts, but not tastes or smells.

- An event

- A description of the event

On this slide, they are both descriptions of an event.

- An event

- A description of the event

The only event here is that I am showing this slide.

- An event

An event happens.
There are people in a place,
with their bodies, their faces,
their voices.
There is music, there is dancing.
There is food, there are flowers.
There are tastes, there are smells.

- A description of an event

An event happened.
There were people in a place,
with their bodies, their faces,
their voices.
There was music, there was dancing.
There was food, there were flowers.
There were tastes, there were smells.

What "Re" is about.

- An event

- A description of the event

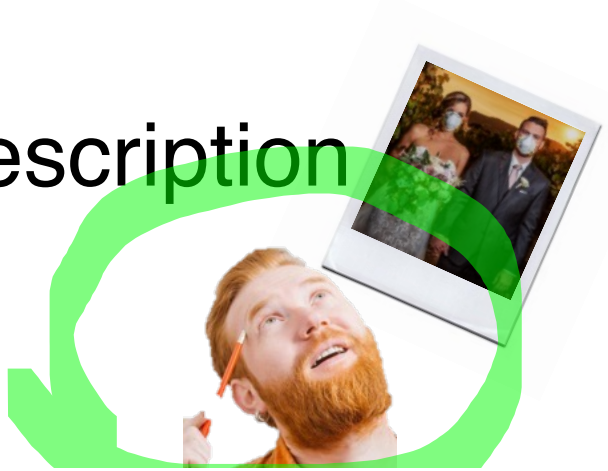
- A person who accesses the description

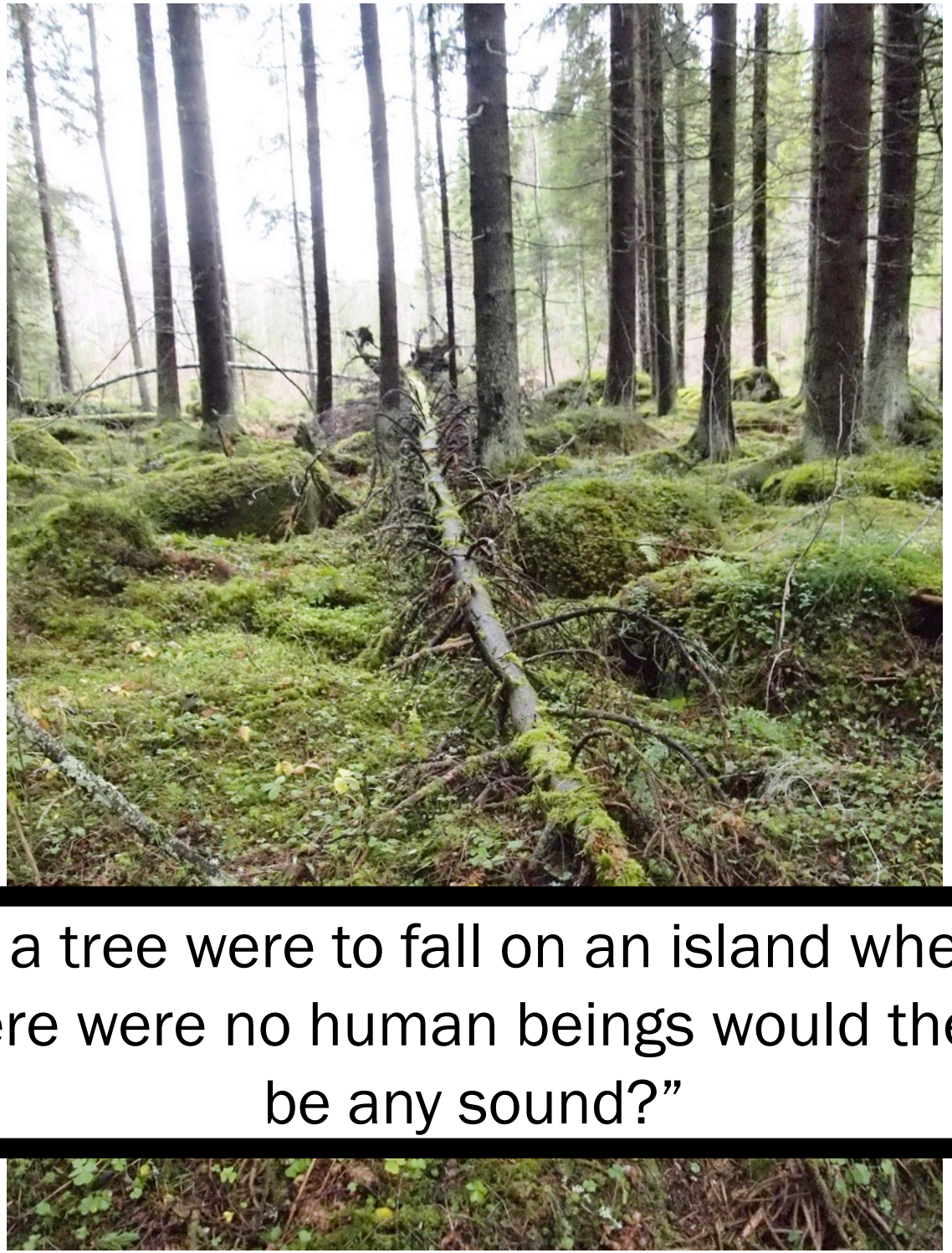
What about the person?

- An event

- A description of the event

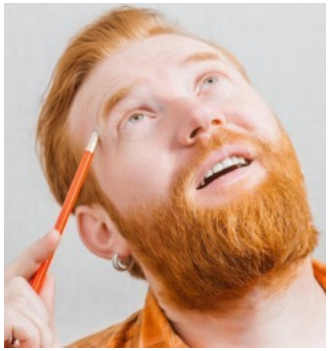
- A person who accesses the description





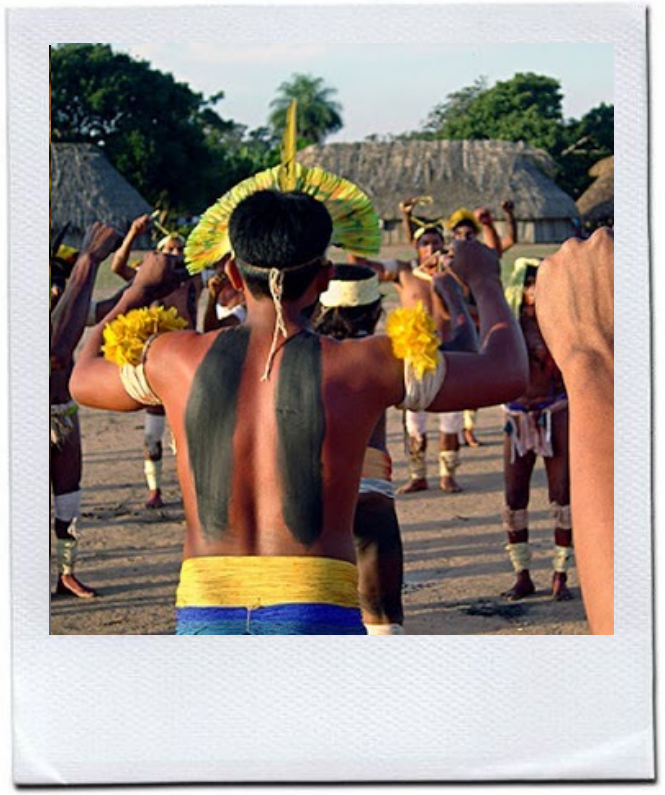
“If a tree were to fall on an island where there were no human beings would there be any sound?”

“If a Polaroid picture were to be on an island where there were no human beings would there be any memory?”



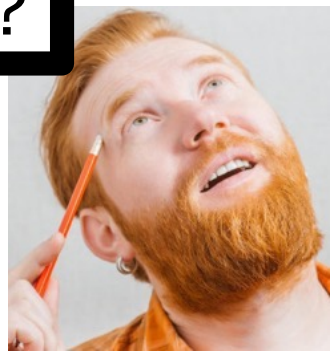
1. There is a relation between the person accessing the description and the content of the description

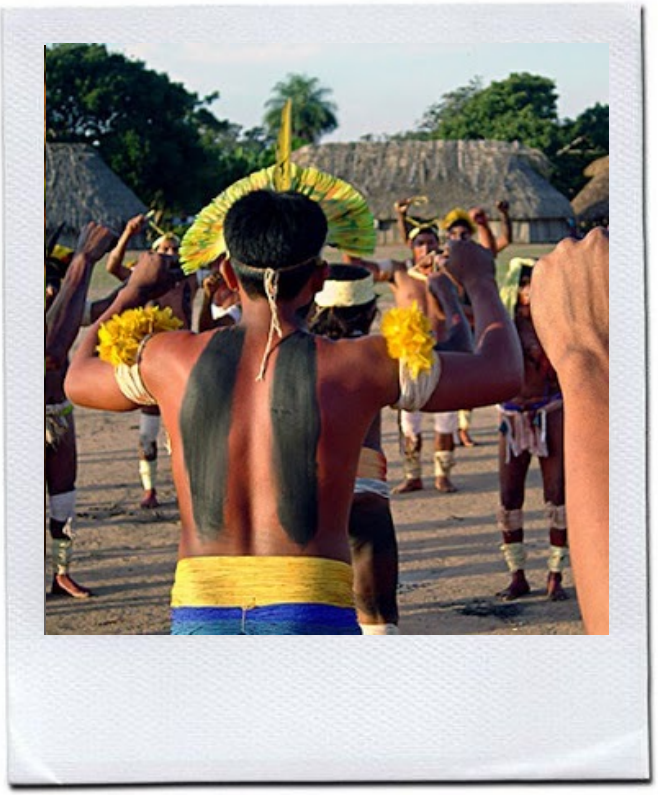
When it comes to memories in terms of a person who remembers and a memory support that helps such act of remembering, there are two important relations that deserve further analysis. The first one is between the person who remembers and the event that is remembered: it is a relation that defines the act of remembering; in other words, just like a tree that falls on a deserted island does not produce a sound (because a sound is a relation between the soundwaves produced by the fall and a functioning ear that catches them) so a person must have attended an event for them to be able to remember it.



?

?

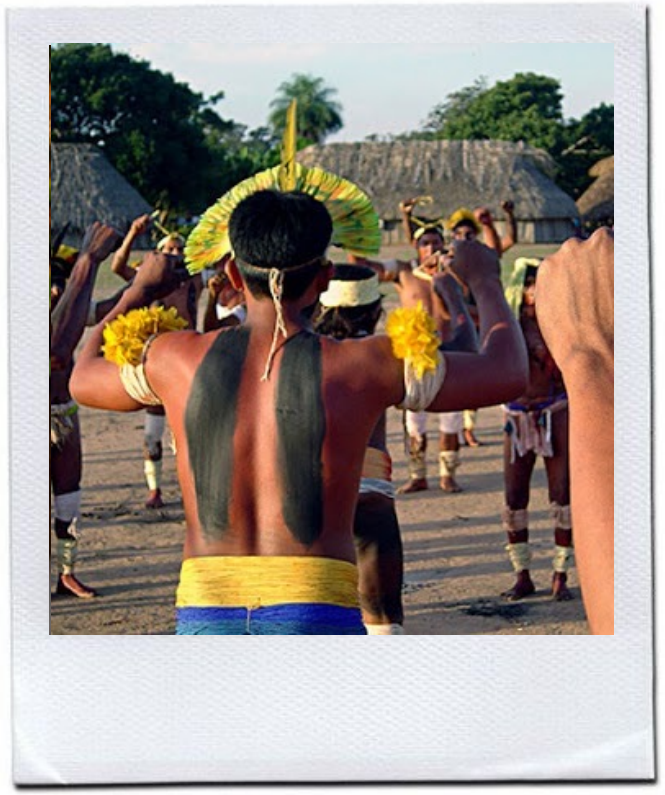




«A person cannot remember an event in which they didn’t participate!»

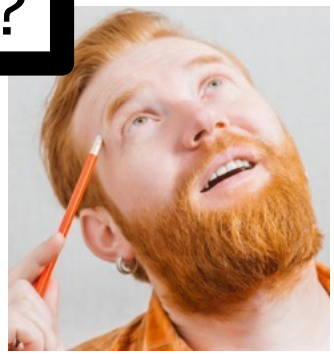
MEMORY

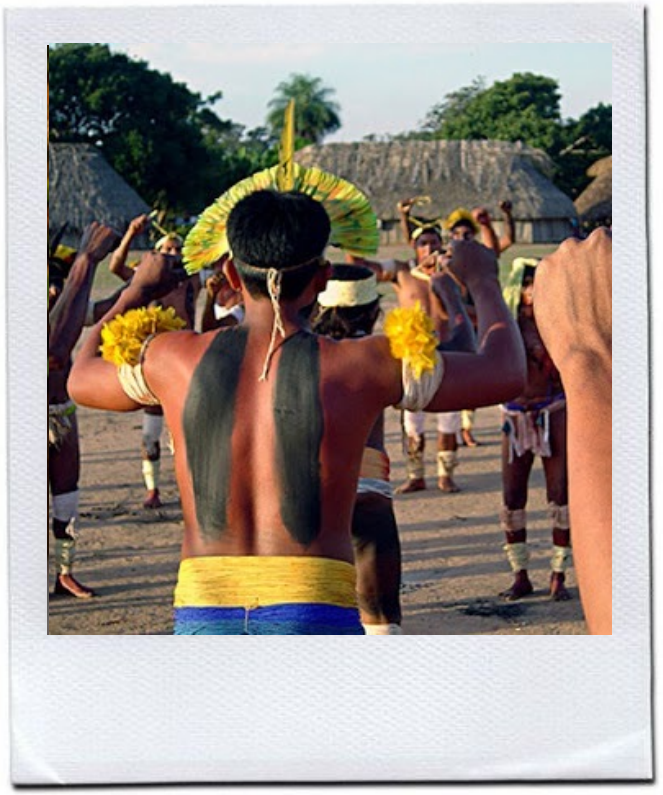
Memories are not only about a single person. Memories can be about a family, a nation, a culture, the human race.



?

?





!

!

time

past
event

remembering
now

The other relation is between the person who remembers and the memory support that helps them remember. It is not about the content of the description of a past event, but about the container. Technological issues rise here: of how much use can a faded Polaroid be in helping someone remember about a past event? Memory devices like disks, USB keys, hard drives are supposed to keep the bits that describe past events (in terms of texts, images, sounds) for a very long time, but there is not yet a guarantee that they can stand the test of time.

time

past
event

remembering
in the future

time

past
event

remembering
in the far future

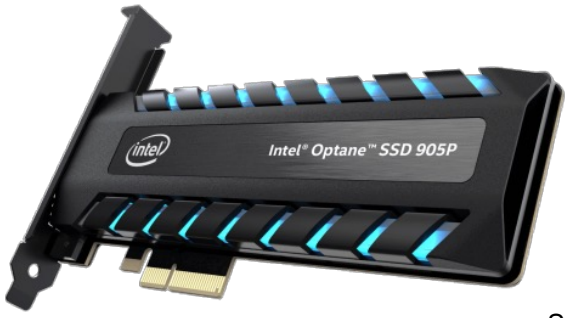
2. There is a relation between the person accessing the description and the container of the description


time

Is a person still able to access the description of an event? Will the container of that description stand the test of time?

Digital Memory Devices

USB key



Solid State Disk

RAM

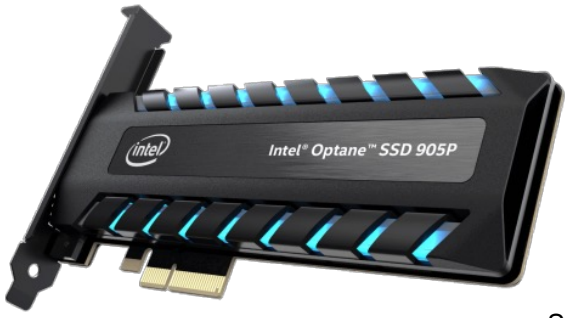
CD/DVD

Magnetic
Hard Disk

SD card

Digital Memory Devices

USB key



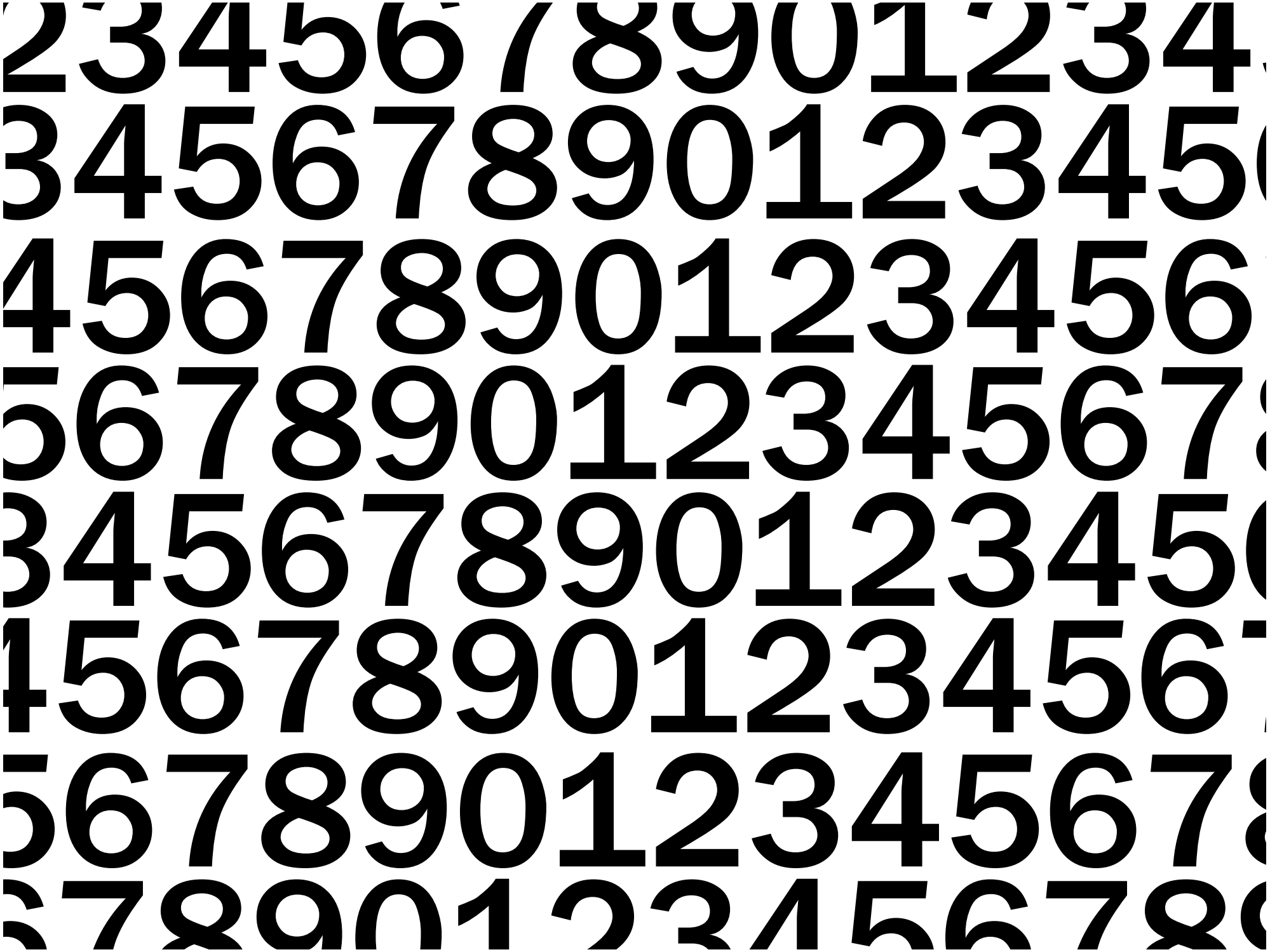
Solid State Disk

RAM

CD/DVD

SD card

Magnetic
Hard Disk


23456789012345
34567890123456
45678901234567
56789012345678
34567890123456
45678901234567
56789012345678
78901234567890

We must not forget that all these devices are digital memory devices, which means that all texts, images, and sounds are encoded into digits first, and then stored in them. This means that not only we are facing the challenge of building devices that can stand the test of time by not breaking down and keeping on functioning for the years, centuries, millenia to come. We must also make sure that the computers of the future that we will use to access these memory devices are going to be compatible with them. Imagine: will there be a USB port in the eyewear/computer of the year 3500 (if we ever get there)? All digitization processes are based on agreements on encodings (like ASCII, JPG, MP3 etc.) that need to be kept in the future, if we want files encoded in the present to be still readable in a 1000 years from now.


LACIE


LACIE


TECLAST


LACIE

This is why memory devices that are meant to last for many millennia are conceived in a way that does not depend on any encoding standard or digital technology. Nuclear waste repositories around the worlds contain material that will be harmful for humans for at least 10,000 years. If we put signs in various languages to warn people to stay away, we are assuming that those languages are going to be understood in 10,000 years, which cannot be taken for granted (think of how much we understand of ancient languages of a few thousand years ago). The collective memory of the danger of nuclear waste will likely be lost. Thus, to scare future people away from those dangerous sites, many think that communication based on signs and encodings won't be possible, but rather we will have to rely on a physical barrier with characteristics that are intrinsically repellent to people, because of how they can do to their bodies rather than of what message they carry.

USASCII code chart

Bits: b_7 b_6 b_5					0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
b_4	b_3	b_2	b_1	Row ↓ Column →	0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	DLE	SP	0	@	P	`	p
0	0	0	1	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	2	STX	DC2	"	2	B	R	b	r
0	0	1	1	3	ETX	DC3	#	3	C	S	c	s
0	1	0	0	4	EOT	DC4	$	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	&	6	F	V	f	v
0	1	1	1	7	BEL	ETB	'	7	G	W	g	w
1	0	0	0	8	BS	CAN	(	8	H	X	h	x
1	0	0	1	9	HT	EM	)	9	I	Y	i	y
1	0	1	0	10	LF	SUB	*	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	[	k	{
1	1	0	0	12	FF	FS	,	<	L	\	l	|
1	1	0	1	13	CR	GS	-	=	M	]	m	}
1	1	1	0	14	SO	RS	.	>	N	^	n	~
1	1	1	1	15	SI	US	/	?	O	_	o	DEL

USASCII code chart

Bits b_7 b_6 b_5 →	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
b_4 b_3 b_2 b_1 ↓ Row ↓ Column →	0	1	2	3	4	5	6	7
0 0 0 0 0	NUL	DLE	SP	0	@	P	`	p
0 0 0 1 1	SOH	DC1	!	1	A	Q	a	q
0 0 1 0 2	STX	DC2	"	2	B	R	b	r
0 0 1 1 3	ETX	DC3	#	3	C	S	c	s
0 1 0 0 4	EOT	DC4	$	4	D	T	d	t
0 1 0 1 5	ENQ	NAK	%	5	E	U	e	u
0 1 1 0 6	ACK	SYN	&	6	F	V	f	v
0 1 1 1 7	BEL	ETB	'	7	G	W	g	w
1 0 0 0 8	BS	CAN	(	8	H	X	h	x
1 0 0 1 9	HT	EM	)	9	I	Y	i	y
1 0 1 0 10	LF	SUB	*	:	J	Z	j	z
1 0 1 1 11	VT	ESC	+	;	K	[	k	{
1 1 0 0 12	FF	FS	,	<	L	\	l	|
1 1 0 1 13	CR	GS	-	=	M	]	m	}
1 1 1 0 14	SO	RS	.	>	N	^	n	~
1 1 1 1 15	SI	US	/	?	O	_	o	DEL

USASCII code chart

Bits b7 b6 b5	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
b4 b3 b2 b1 / Row ↓ Column →	0	1	2	3	4	5	6	7
0 0 0 0	0	NUL	DLE	SP	0	@	P	`	p
0 0 0 1	1	SOH	DC1	!	1	A	Q	a	q
0 0 1 0	2	STX	DC2	"	2	B	R	b	r
0 0 1 1	3	ETX	DC3	#	3	C	S	c	s
0 1 0 0	4	EOT	DC4	$	4	D	T	d	t
0 1 0 1	5	ENQ	NAK	%	5	E	U	e	u
0 1 1 0	6	ACK	SYN	&	6	F	V	f	v
0 1 1 1	7	BEL	ETB	'	7	G	W	g	w
1 0 0 0	8	BS	CAN	(	8	H	X	h	x
1 0 0 1	9	HT	EM	)	9	I	Y	i	y
1 0 1 0	10	LF	SUB	*	:	J	Z	j	z
1 0 1 1	11	VT	ESC	+	;	K	[	k	{
1 1 0 0	12	FF	FS	,	<	L	\	l	|
1 1 0 1	13	CR	GS	-	=	M	]	m	}
1 1 1 0	14	SO	RS	.	>	N	^	n	~
1 1 1 1	15	SI	US	/	?	O	_	o	DEL

time

time

Proposal for marker of nuclear waste repository.
("Into Eternity", by Micheal Madsen, 2010)

10000 years