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Úvod do kybernetiky
pro naprosté začátečníky

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učímeonline.cz

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vedoucí Katedry řídicí techniky FEL

garant programů SpaceMaster (EU)
a Kybernetika a robotika (FEL)

přednáší předmět Automatické řízení

výzkum: teorie, algoritmy a sw pro aut.
řízení, síťové systémy, formace, hejna

zakladatel několika firem

pracoval v Zurichu, Twente, Glasgow,
Padově, Torontu a v AV ČR

Pro Vládu ČR hodnotí výsledky výzkumu

Pro veřejnost komunikuje vědu a
propaguje změny ve vzdělávání

Obsah

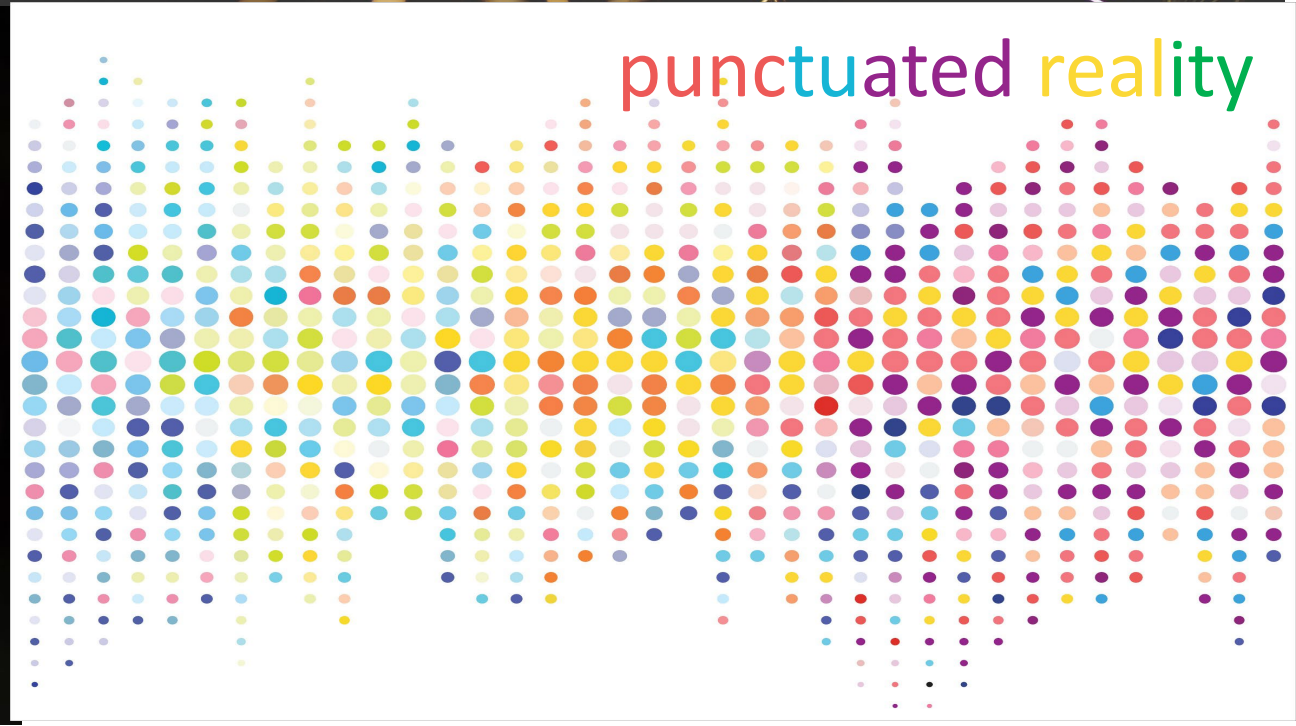
Úvod – co se to děje
Automatické řízení – zpětná vazba a spol.
Sítě - grafy, propojení, extrémy
Umělá inteligence - hluboké učení
Závěr – co jsme už nestihli

Jó, svět už není, co býval!

změny
zrychlují

jiskry
výbuchy

bubliny


punctuated reality

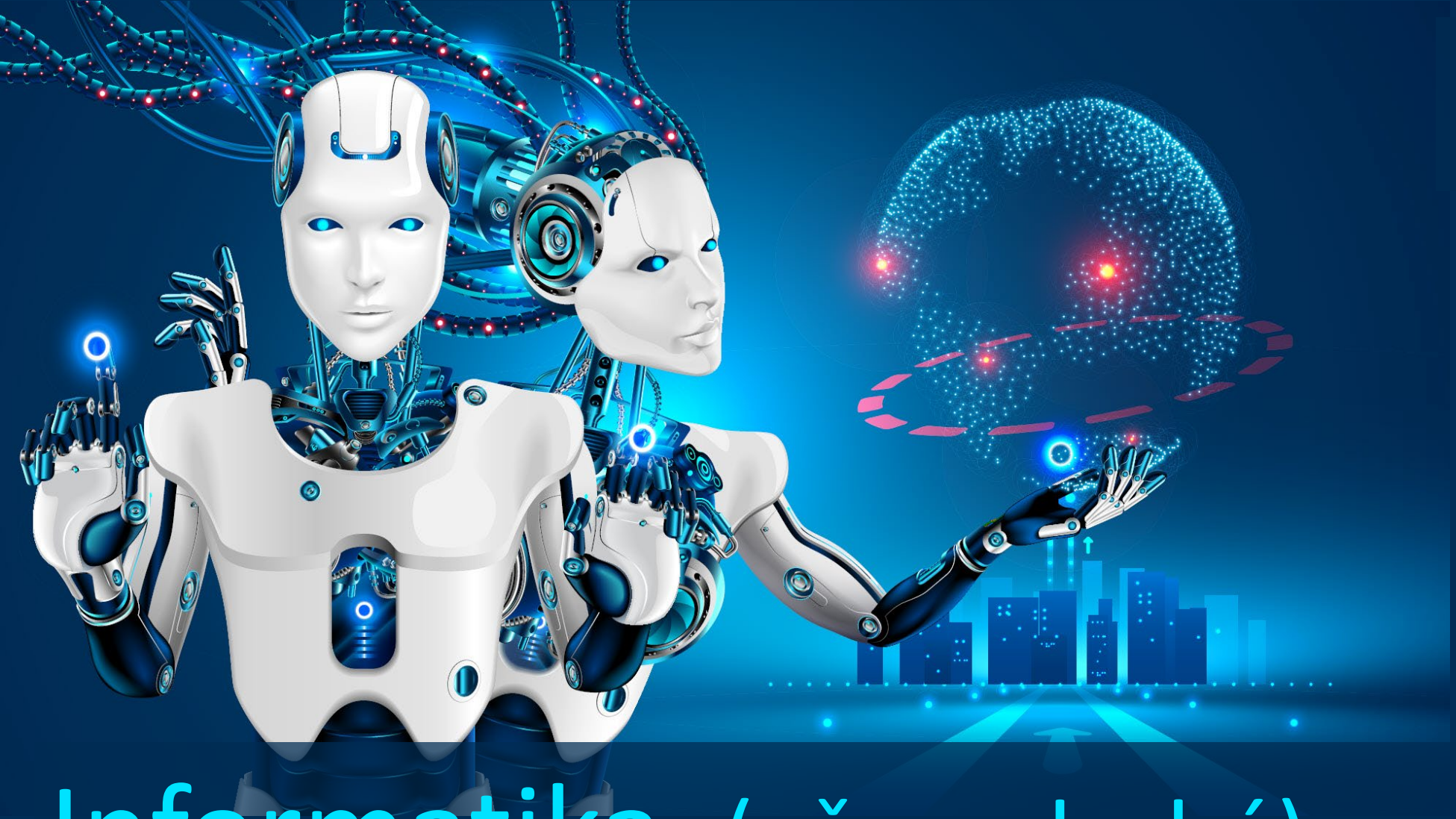
informace

disrupce

složitost

chaos

THE FUTURE AIN‘T WHAT IT USED TO BE



Proč?

Informatika (už po druhé)

Kybernetika (informatika + reálný svět)

Kybernetika (z řeckého κυβερνήτης = lodivod)

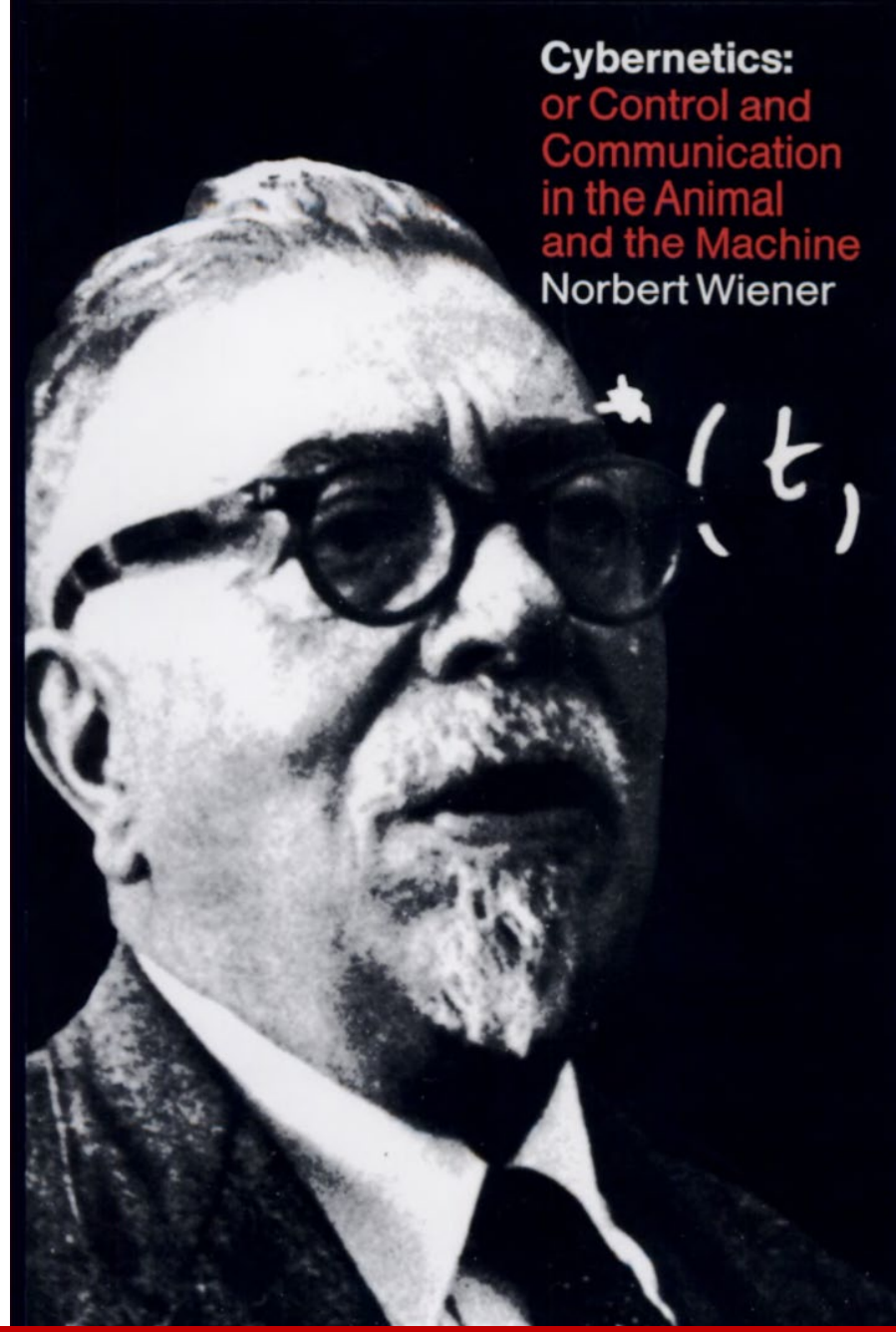
Věda o obecných principech řízení a přenosu informací ve strojích, živých organismech a společenstvích.

Název poprvé použil již v 19. stol. fyzik André-Marie Ampère pro vizi tehdy neexistující vědu o řízení lidské společnosti.

Zakladatelem oboru je americký matematik a filozof z MIT

Norbert Wiener (1894-1964)

Roku 1948 ve slavné knize poprvé použil termín "kybernetika" pro označení samoregulačních mechanismů a položil teoretické základy servomechanismů, automatické navigace, analogových počítačů, umělé inteligence, neurověd a spolehlivé komunikace.



Norbert Wiener: Kybernetika aneb Řízení a komunikace u zvířat a strojů

Control
Systems
Model
Using
System
Modeling
Design
Vehicle
Organized
Predictive
Estimation
Approach
Robotics
Time
Application
Simulation
Control-Oriented
Care
Vehicles
Applications
Health
Algorithm
Technical
Committee
Models
Active
Robust
Via
Stability
Based
Method
Evaluation
Identification
Diesel
Vibration
Bio-Systems
Cell
Sliding
Magnetic
Output
Analysis
Engine
Feedback
Power
Linear
Force
Controller
Optimal
Sensing
Engines
Mobile
Fuel
Battery
Actuation
Tracking
Hybrid
Experimental
Stochastic
Adaptive
Combustion
Automotive
Dynamic
Wind
Electric
Dynamics
Data
Actuator
Robot
Unknown
Sensor
Study
Powertrain
Ground
Behavior
Internal
Multiple
Development
Autonomous
Input
Piezoelectric
Nonlinear
Advanced
Steering
Optimization
Validation
Generation
Multi-Agent
Monitoring
Processes
Motion
Detection
Torque
Planning
State
Turbine
Mode
Management
Networks
Discrete-Time
Performance
Compensation
Two
Friction
Prosthetic
Tire
Process
Mechanical
Order
Agents
Time
Path
Impedance
Intelligent
Valve
Preliminary
Muscle
New
Load
Human
Differential
MIMS
Surface
Reduction
Avoidance
Actuators
Lateral
Sensors
Subcommittee
Robotic
Transient
Regulation
Variable
Distributed
Fusion
High
Dynamic
Observer
Filter
Torque
Turbine
Strategy
Driving
Real-Time
Energy
Static
Varying
Robots
Controllers
Processes
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Steering
Optimization
Actuators
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Hybrid
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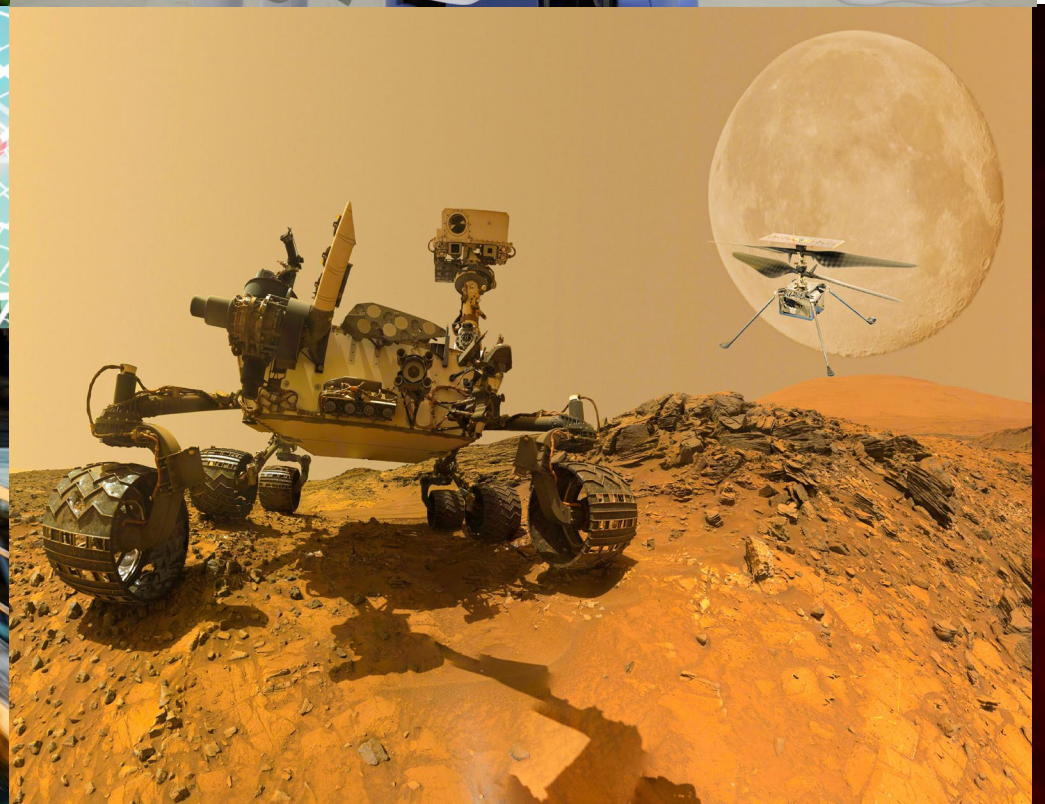
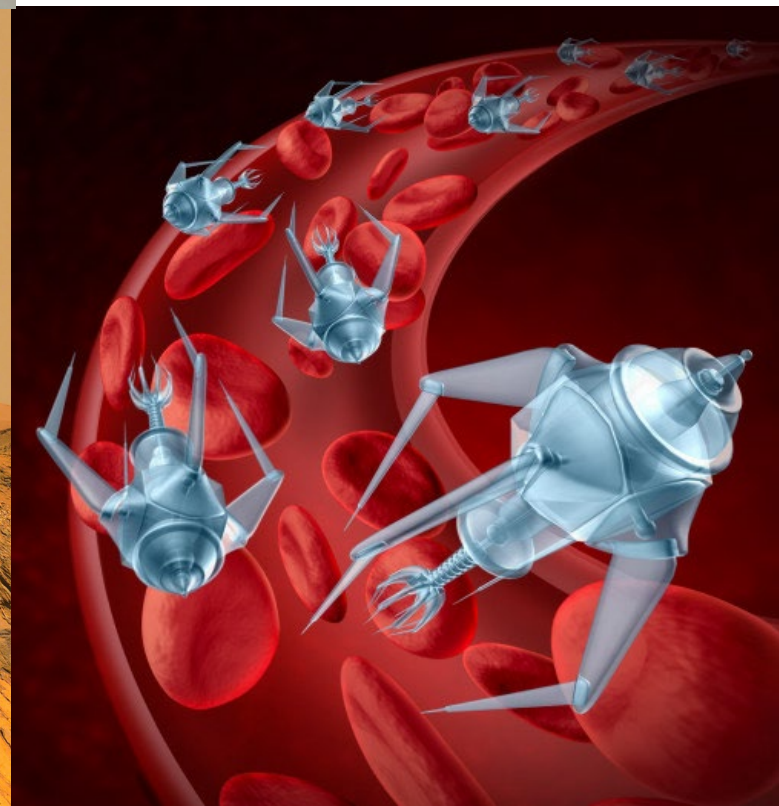
Stochastic
Adaptive
Combustion
Automotive
Dynamic
Wind
Electric
Dynamics
Data
Actuator
Robot
Unknown
Sensor
Study
Powertrain
Ground
Behavior
Internal
Multiple

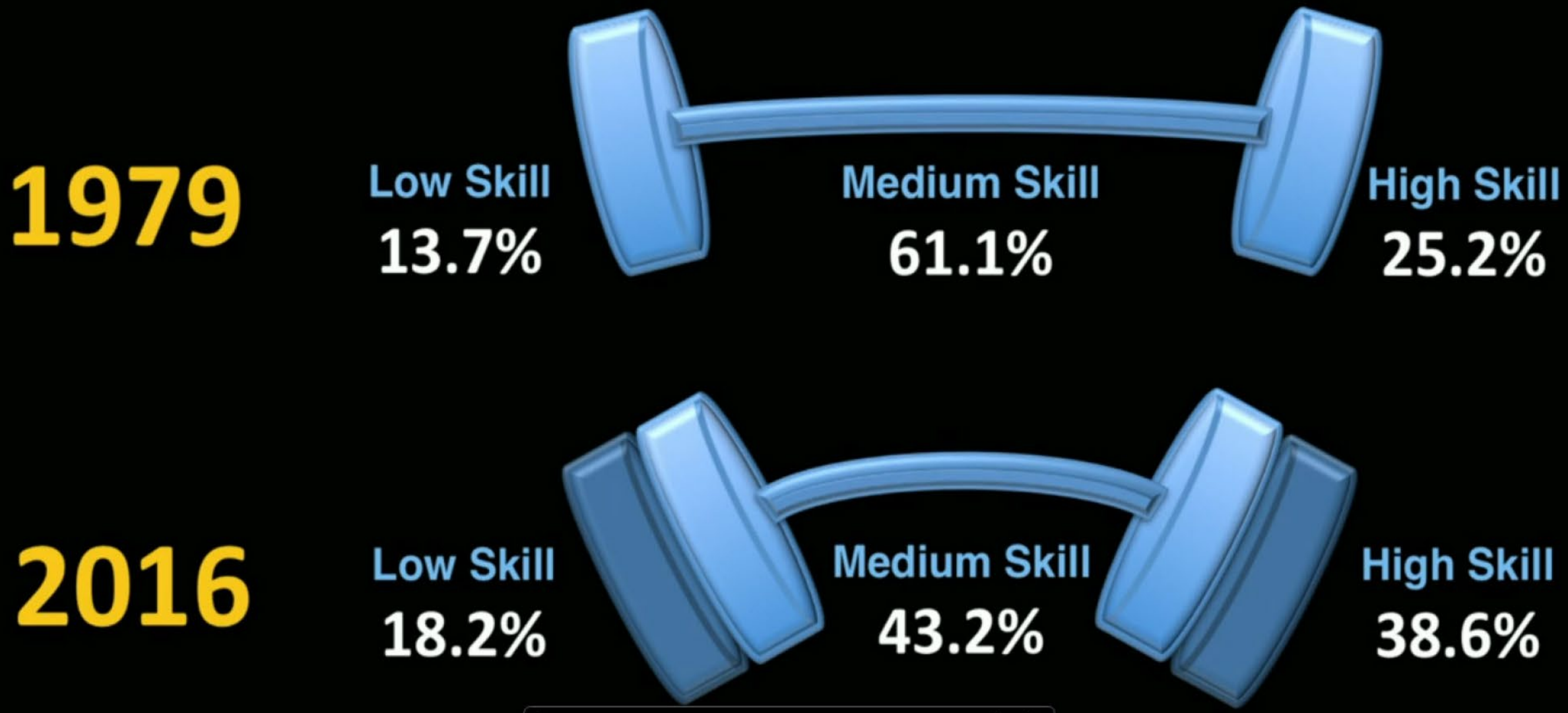
AUTONOMOUS
ROBOT

ROBEAR





Share of U.S. Workers in Low, Medium, and High Skill Occupations: 1979 and 2016



robots

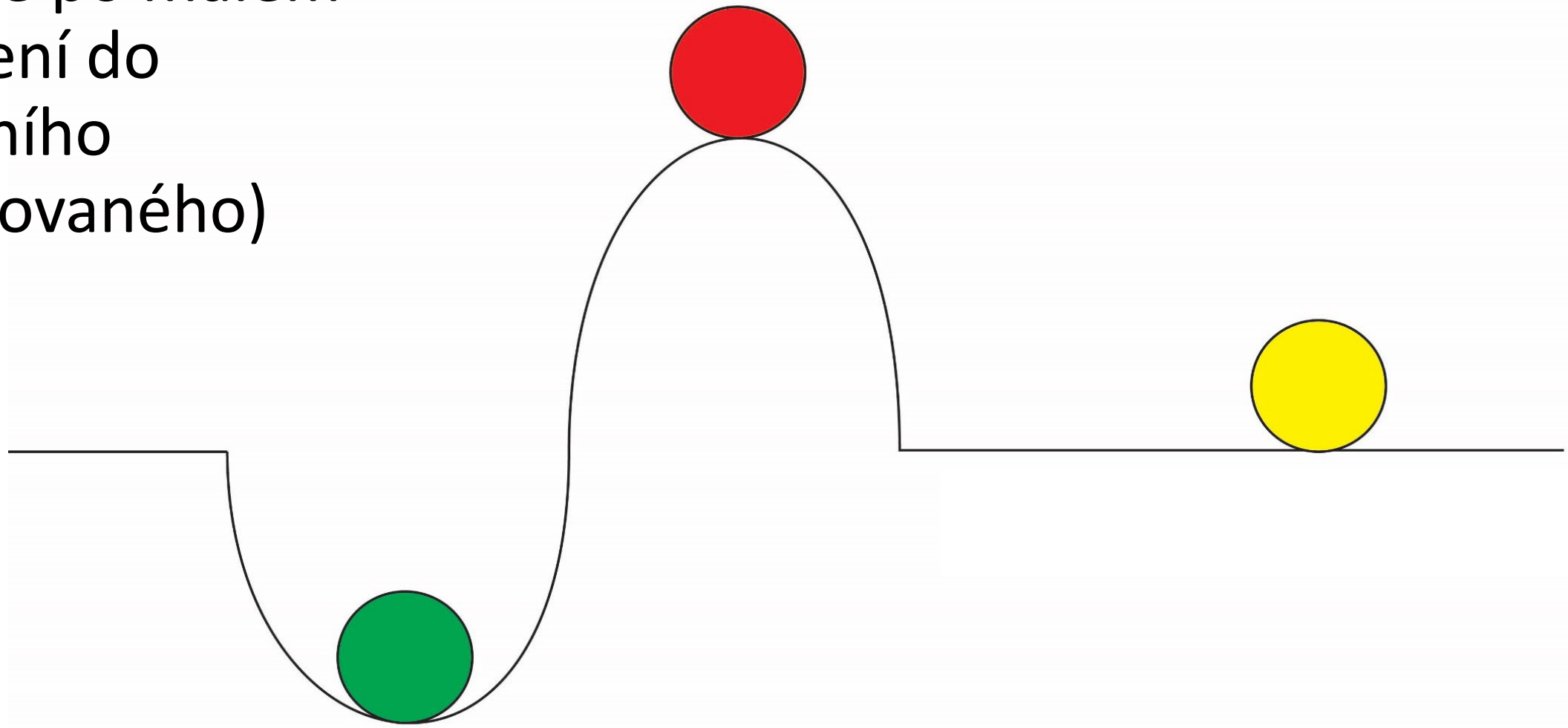
Performance

udržet hodnotu, polohu, rychlost
změnit, přemístit, nasměrovat
sledovat, opakovat činnost
zachovat chování při změně
potlačit nebo vyrušit vliv okolí
zrychlit, zpomalit, zpřesnit činnost
optimalizovat, zlevnit, zrychlit
zvýšit odolnost, bezpečnost,
zotavení z poruch
umožnit, aby vůbec fungovalo …

a stabilita

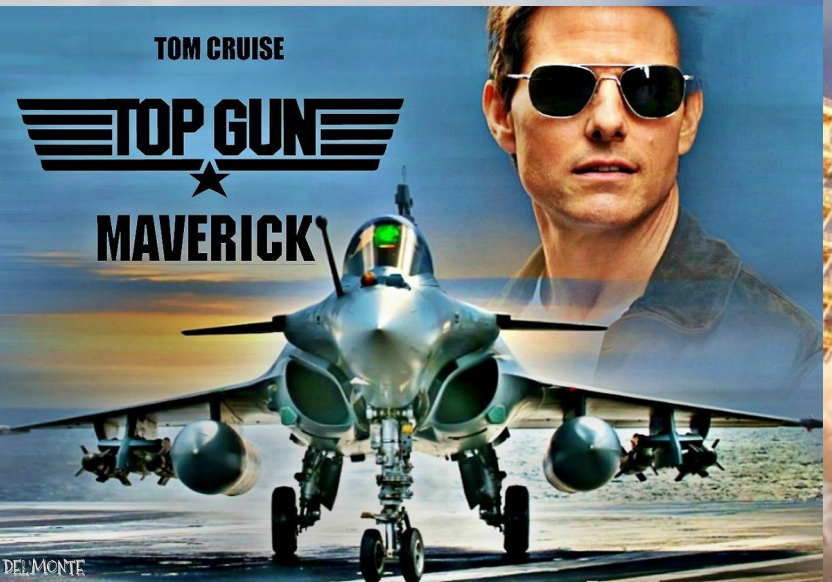
Stabilita

schopnost systému vrátit se po malém vychýlení do původního (požadovaného) stavu



UN
STABLE

AIRBUS A380
A380


TOM CRUISE
TOP GUN
MAVERICK
DEL MONTE

feedback
leads
convincing
present
time
input
sign
mention
causal
enzyme
authors
regulation
environmental
reinforcement
Jensen
loops
may
event
many
good
contrast
lead
practical
ordinary
actual
utility
based
rather
component
regeneration
positive/negative
use
incentive
output
current
According
range
negative
information
positive
amplifier's
made
Overview
usually
bad
effect
action
change
amplifiers
Ramaprasad
mechanisms
Black
example
hormones
value
exists
introduction
represent
interested
much
term
idea
tends
parts
laureate
conditions
theorists
psychology
termed
non-reward/punishment
pendulum
Nyquist
nerve
using
gain
terms
feed-back
Feedback
modification
see
either
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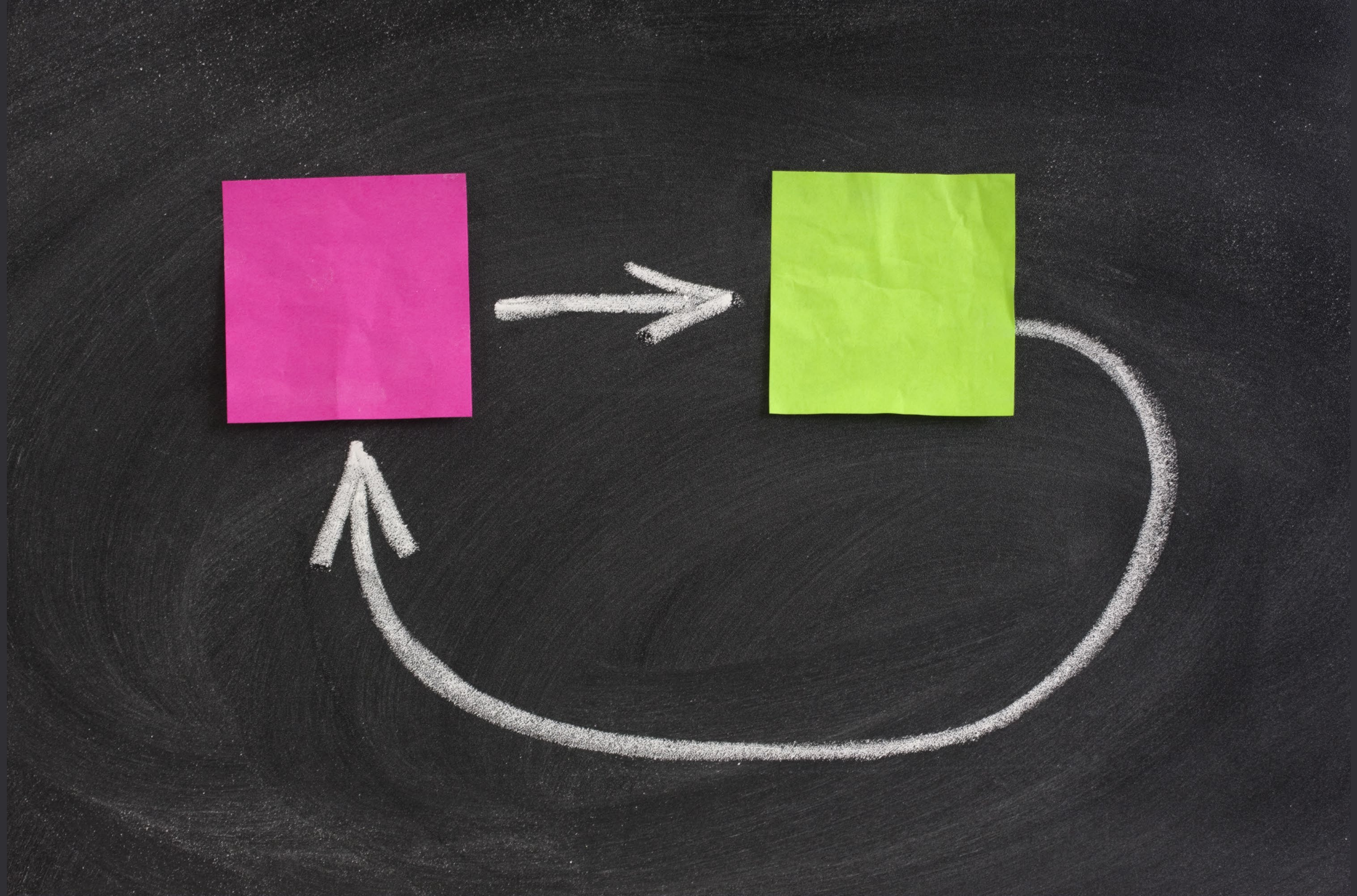
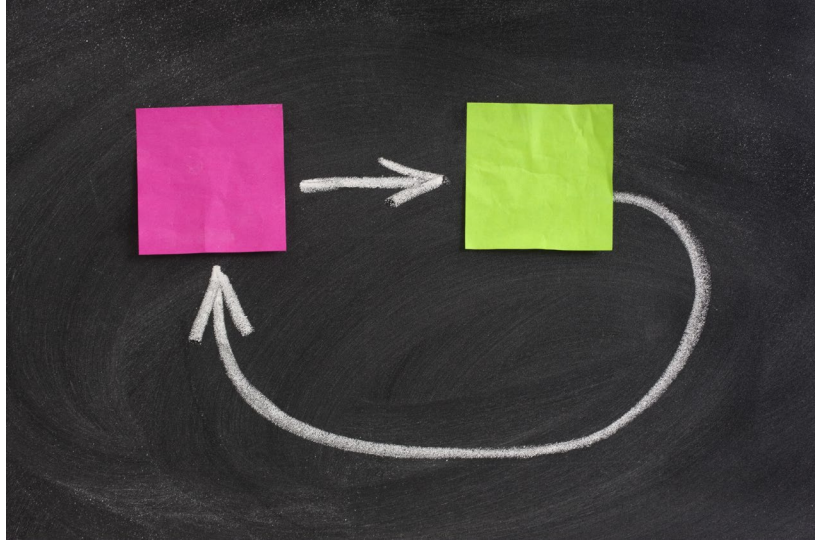
external
controlled
via
biological
boost
1920s
view
respectively
reference
electronic
within
applied
definition
system
systems
context
contexts
confusion
James
certain
coupling
also
loop
signal
blushing
whether
causing
circuits
back
proteins
cause
circuit
prior
theory
regulatory
changes
values
sugar
process
components
widening
metabolic
part
narrow
level
tells
self-reinforcing/self-correcting
even
position
first
existed
optimal
two
slow
distinction
case
reward
feed
often
types
described
Allosteric
trouble
rise

Dojdu tam i poslepu?



Feedforward a Feedback



Vazba přímá, dopředná

řízení jen na základě požadavků a případně informací zvenku

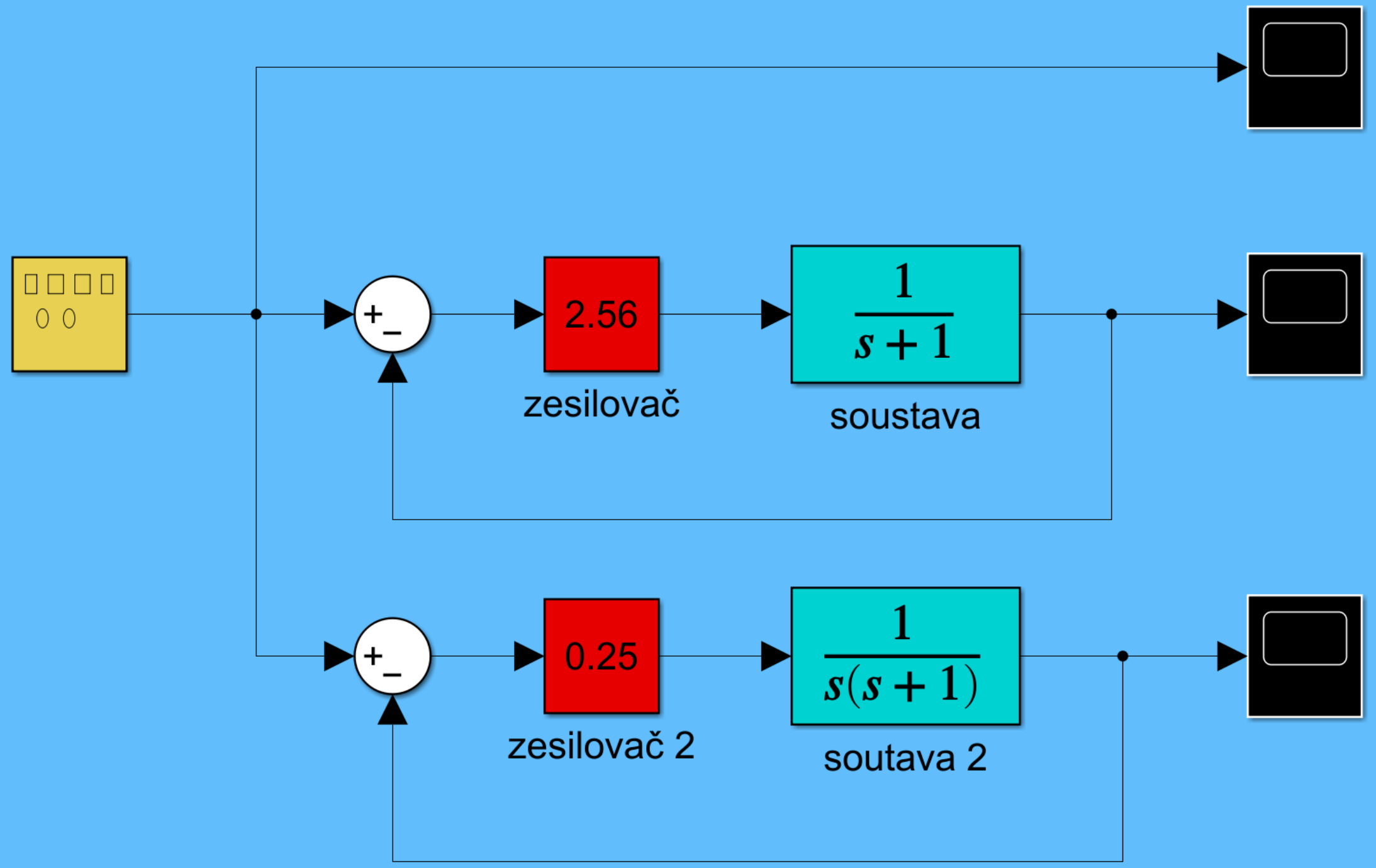
Vazba zpětná

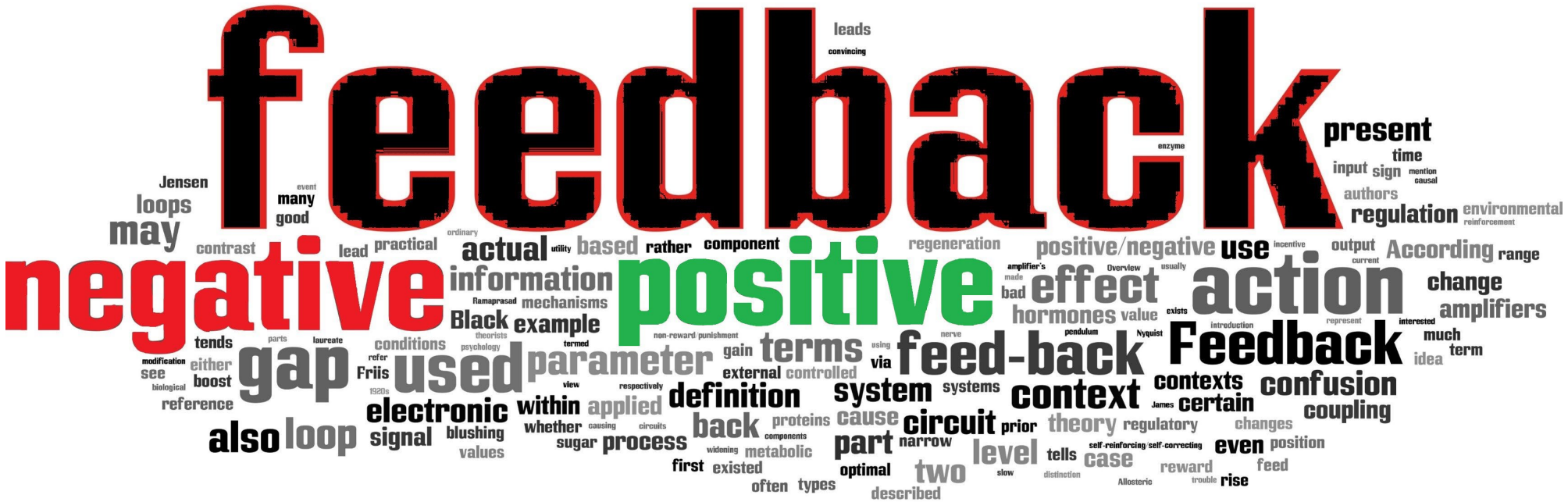
navíc využívá informace o výstupu, o skutečném reakci systému na řízení
výstupy systému vrací zpět na vstupy (řídicího systému), vznikne uzavřená smyčka

> *Jednoduché kauzální uvažování o zpětnovazebním systému je obtížné, protože první systém ovlivňuje druhý a druhý systém ovlivňuje první, což vede ke kruhové argumentaci. To činí uvažování založené na příčině a následku složitým a je nutné analyzovat systém jako celek.*

Přesněji:

> *Uzavřením smyčka vzniká úplně nový systém, který dříve neexistoval.*
> *Původní řízený systém „zmizel“, jako součást celku se chová úplně jinak.*
> *To platí, pokud je smyčka uzavřená.*


+
−
2.56
zesilovač
$\frac{1}{s+1}$
soustava
+
−
0.25
zesilovač 2
$\frac{1}{s(s+1)}$
soutava 2


feedback
leads
convincing
enzyme
present
time
input
sign
mention
causal
authors
regulation
environmental
reinforcement
Jensen
loops
may
event
many
good
contrast
lead
practical
ordinary
actual
utility
based
rather
component
regeneration
positive/negative
use
incentive
output
current
According
range
negative
information
positive
amplifier's
made
Overview
usually
effect
action
change
amplifiers
Ramaprasad
mechanisms
bad
hormones
value
exists
introduction
represent
interested
Black
example
theorists
non-reward/punishment
pendulum
Nyquist
much
tends
parts
laureate
conditions
psychology
termed
nerve
using
terms
feed-back
Feedback
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term
modification
either
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gain
via
gap
used
parameter
Friis
external
controlled
biological
boost
1920s
view
respectively
system
systems
context
contexts
confusion
reference
electronic
within
applied
definition
James
certain
coupling
whether
causing
circuits
back
proteins
cause
circuit
prior
theory
regulatory
changes
also
loop
signal
blushing
sugar
process
components
widening
metabolic
part
narrow
level
tells
self-reinforcing/self-correcting
even
position
values
first
existed
optimal
two
slow
distinction
case
reward
feed
often
types
Allosteric
trouble
rise
described

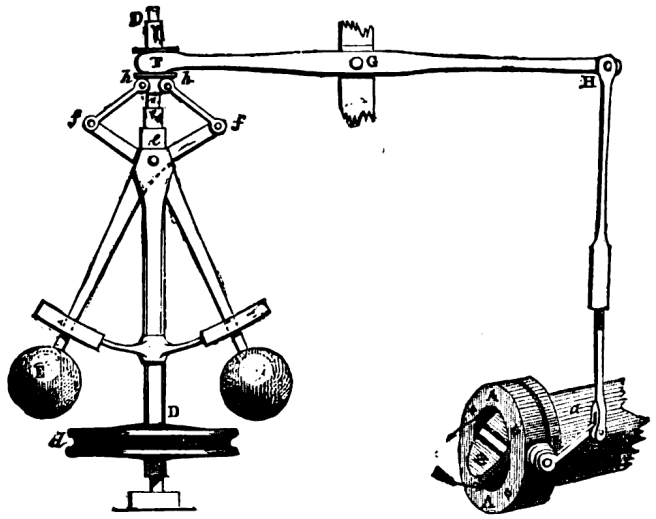
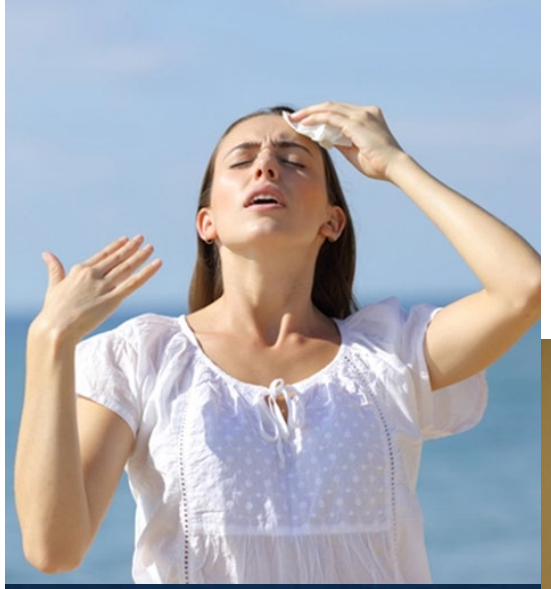
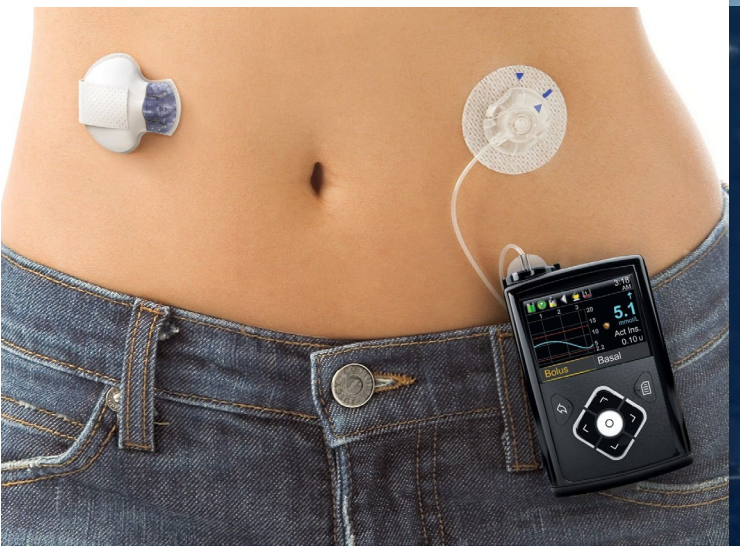


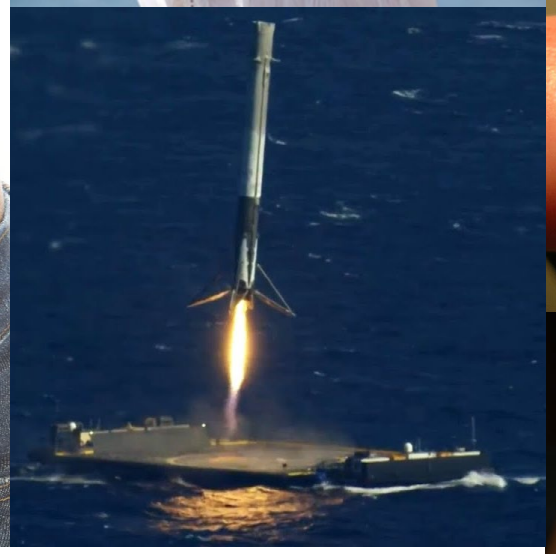
FIG. 4.—*Governor and Throttle-Valve.*



kladná zpětná vazba

působí pro změnu, zesiluje ji





záporná zpětná vazba

působí proti změně, zeslabuje ji

Feedforward

napájení,
přítok vody,
…

kvalita vody,
…

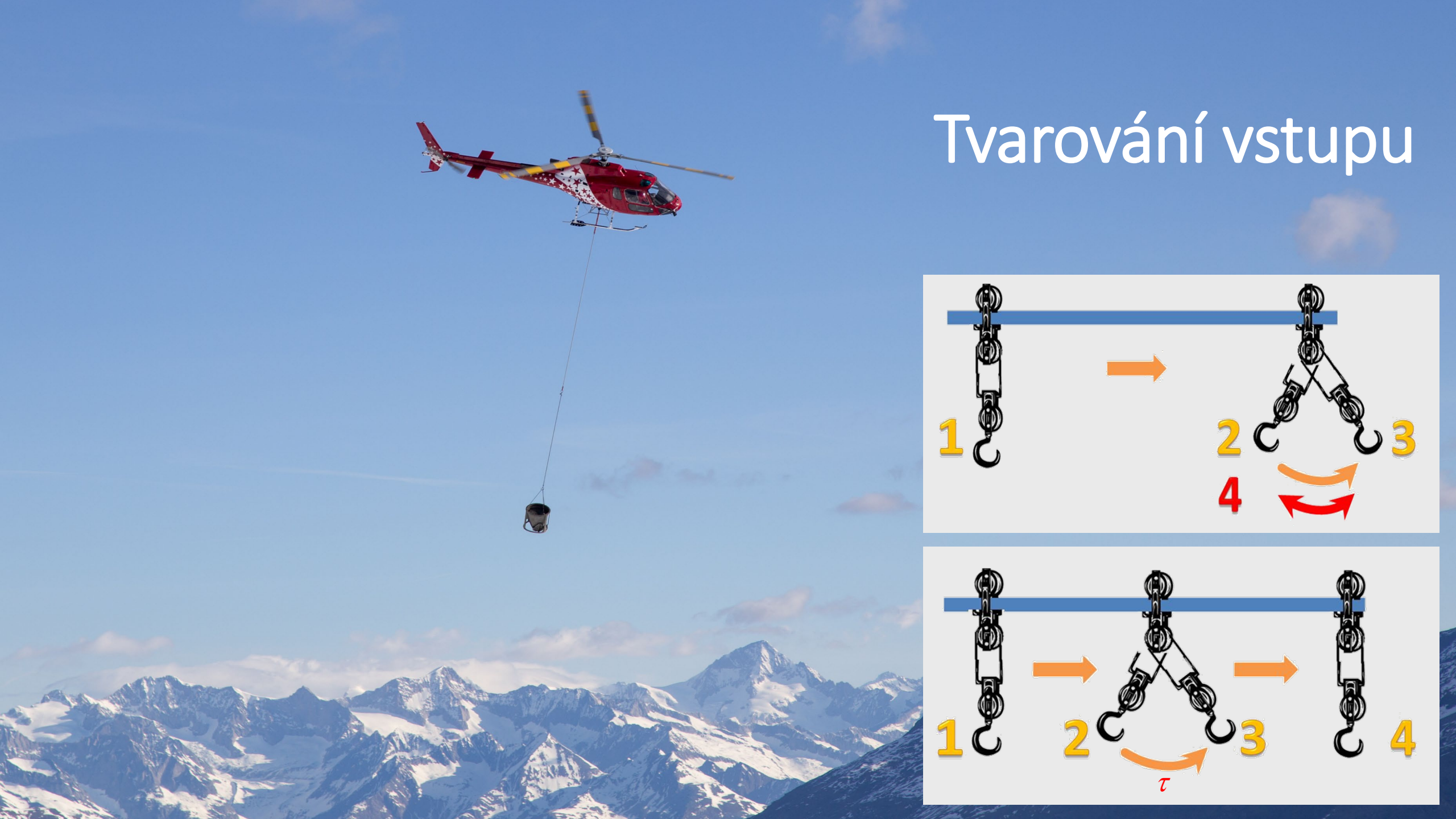
doba praní,
teplota,
…

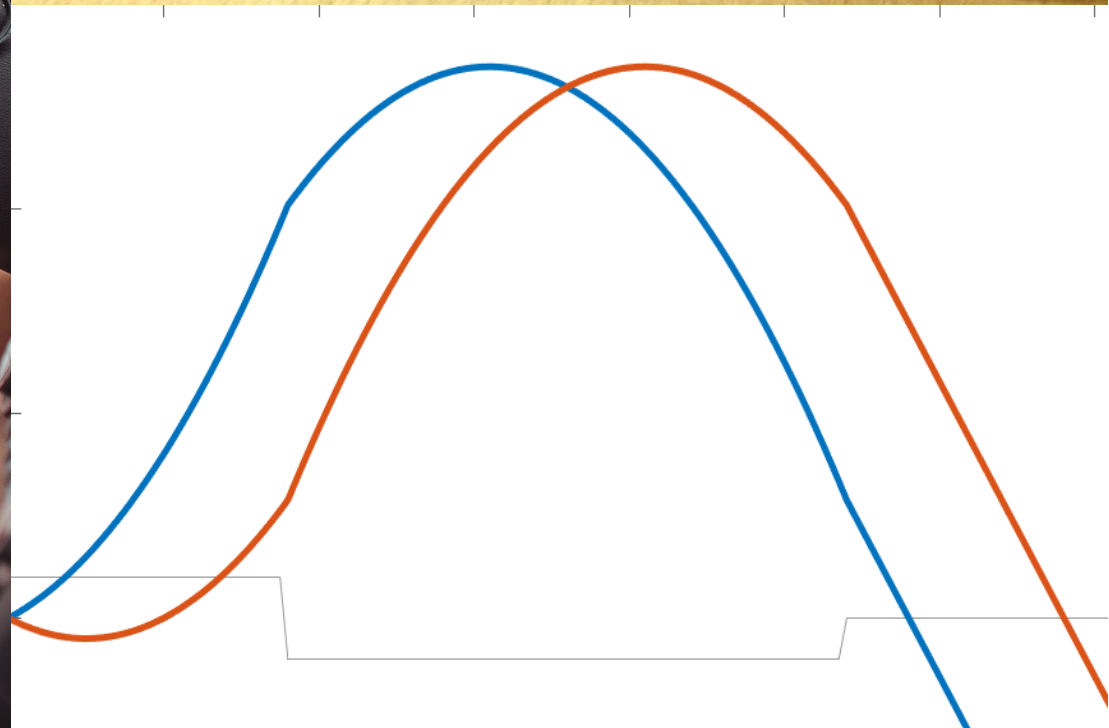
řídicí systém

pračka

zašpinění prádla,
množství prádla,
…

Tvarování vstupu





7AB 2024
r [m]
t [s]
x [m]
t [s]

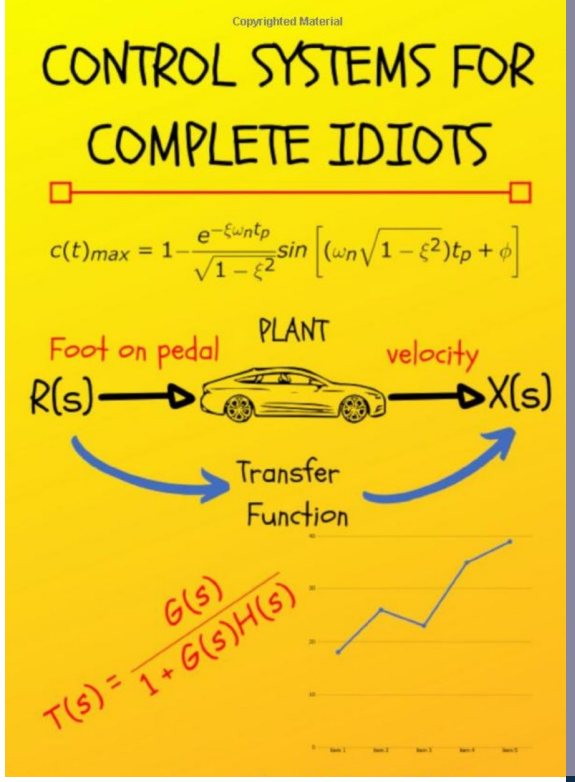
Automaton - IEEE Spectrum
Boston Dynamics

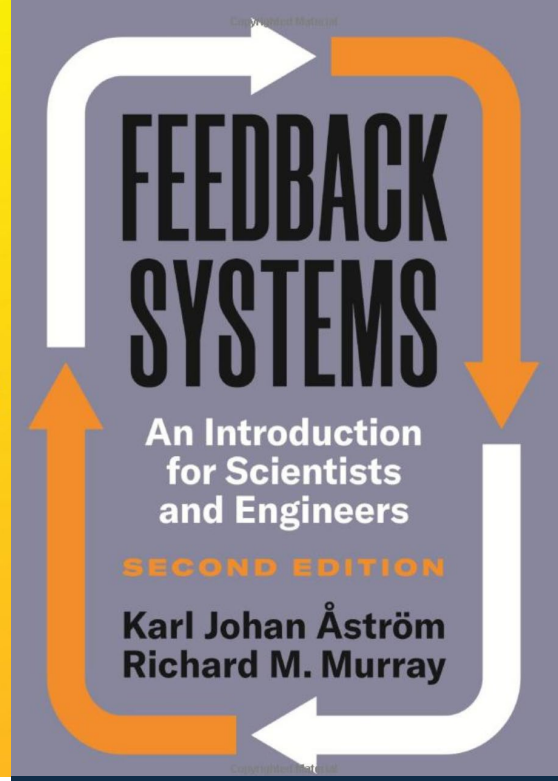
David Smith: Control Systems for Complete Idiots.
Independently published (July, 2019)
ISBN-10: 1079384545, ISBN-13: 978-1079384543

Karl Johan Åström Richard M. Murray:
Feedback Systems: An Introduction for Scientists and Engineers, 2nd Ed. Princeton University Press, 2021.
ISBN-10: 0691193983, ISBN-13: 978-0691193984

Bakalářský kurz FEL ČVUT Automatické řízení programu Kybernetika a robotika
Katedra řídicí techniky FEL ČVUT, YouTube kanál
Studijní program Kybernetika a robotika na FEL ČVUT: web a prezentace
Videa studentů: Kryštof Pučejdl , Loi Do

Kiddle - Kids encyclopedia facts, Control system facts for kids, Control engineering facts for kids, Cybernetics facts for kids, Robot facts for kids





sítě, extrémy, labutě

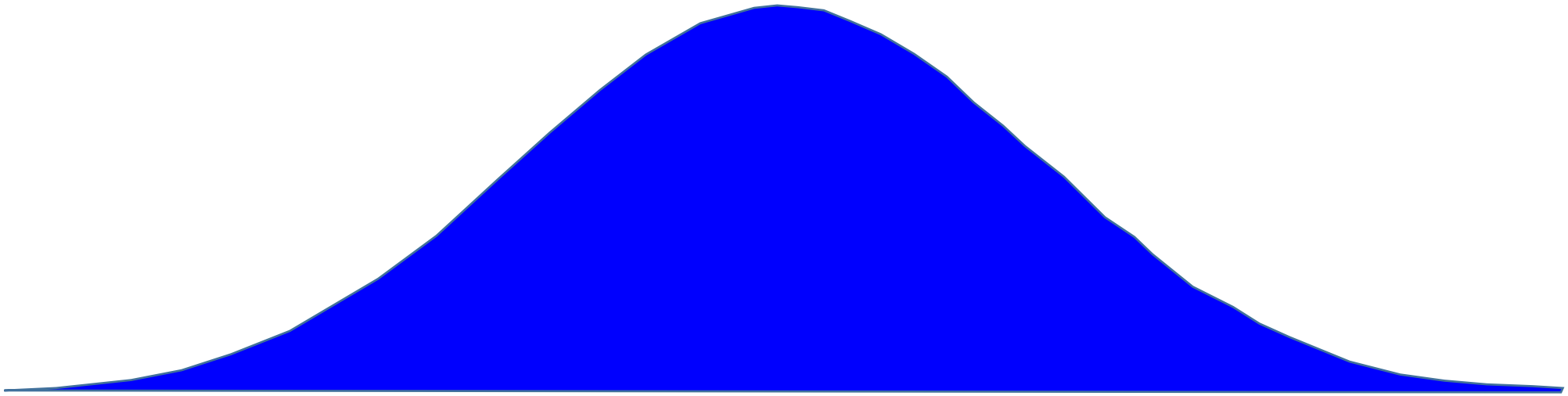
TESLA

populace

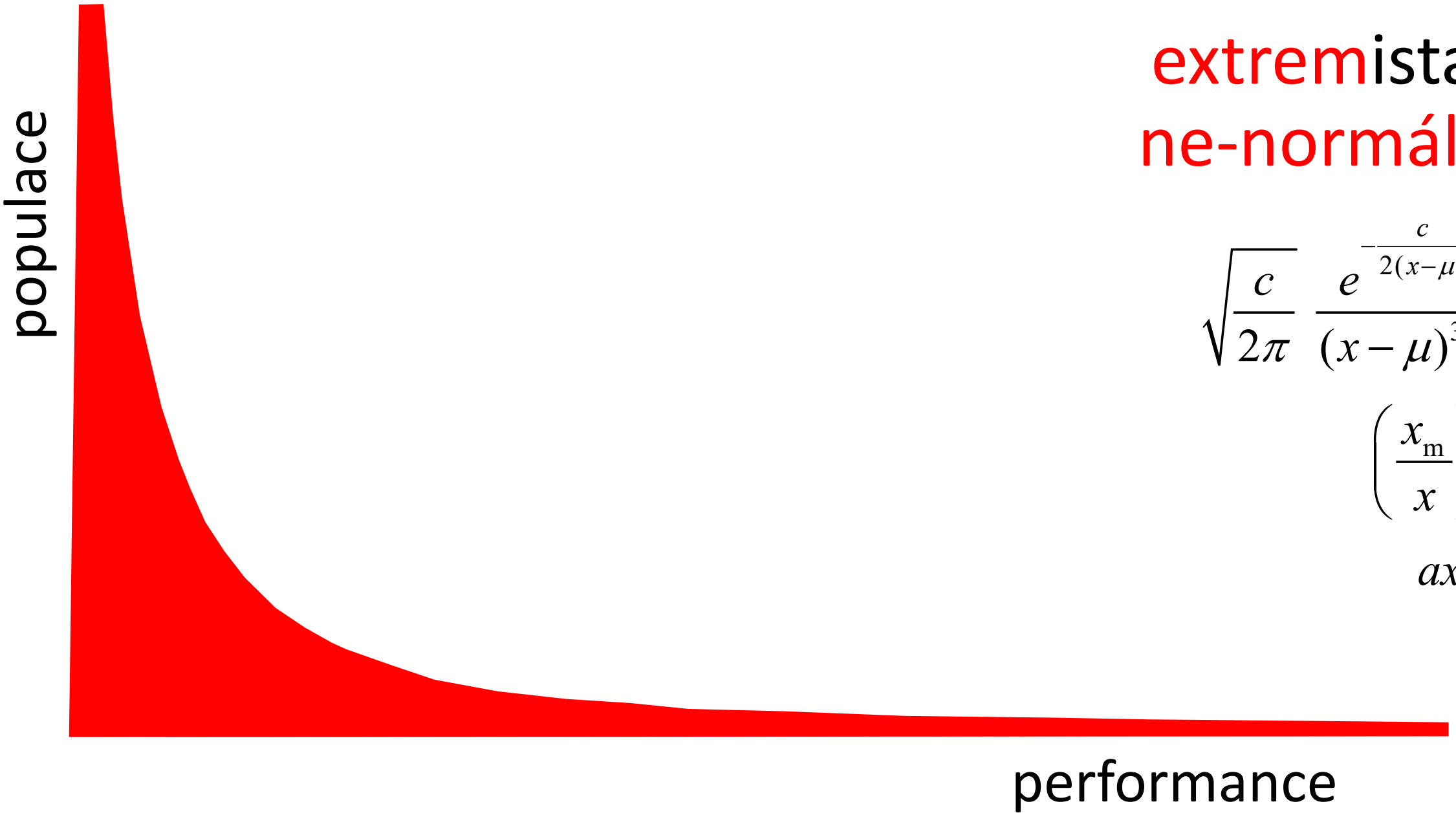
mediocristan

normální

$$\frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$



performance



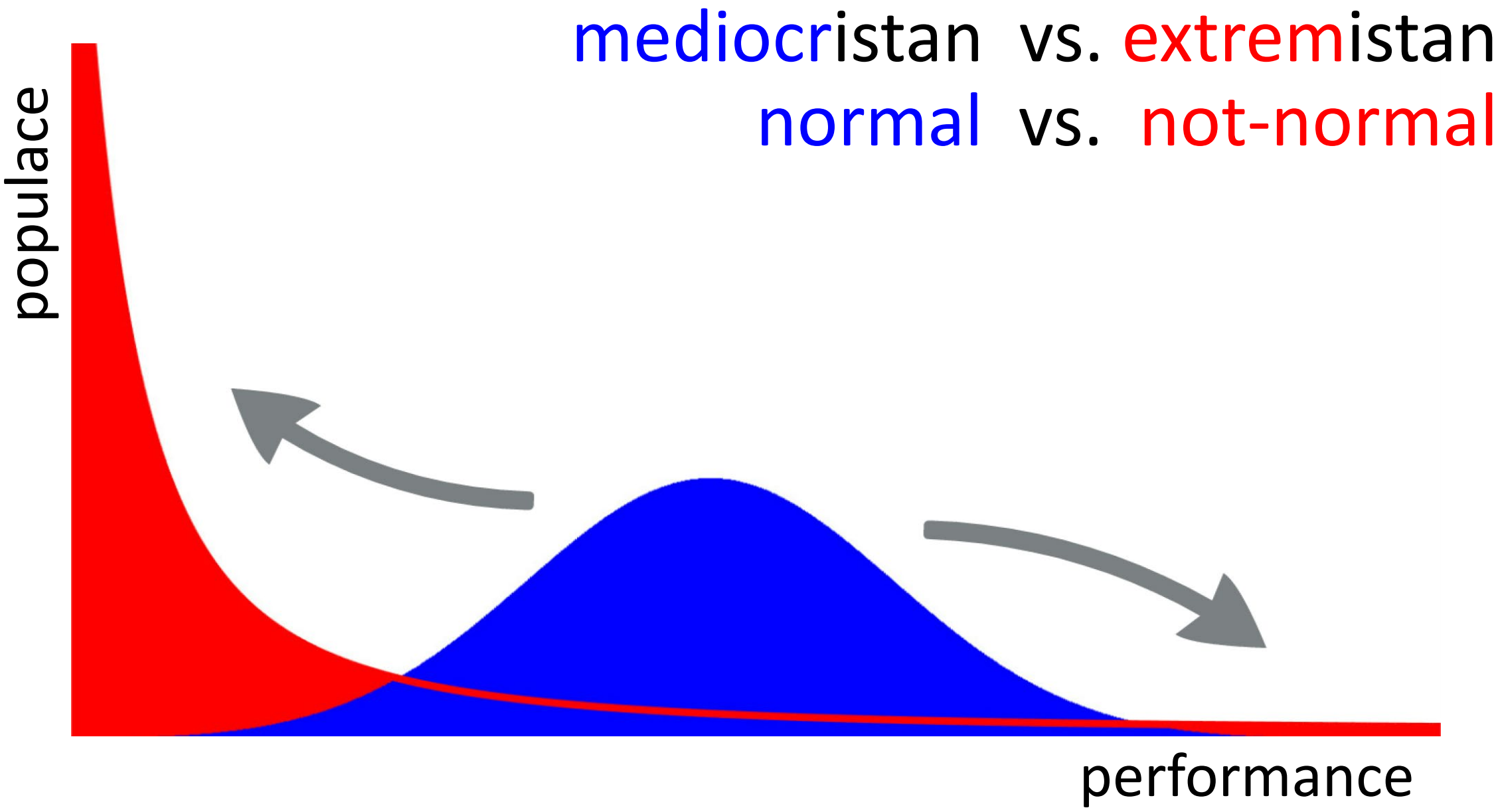
extremistan

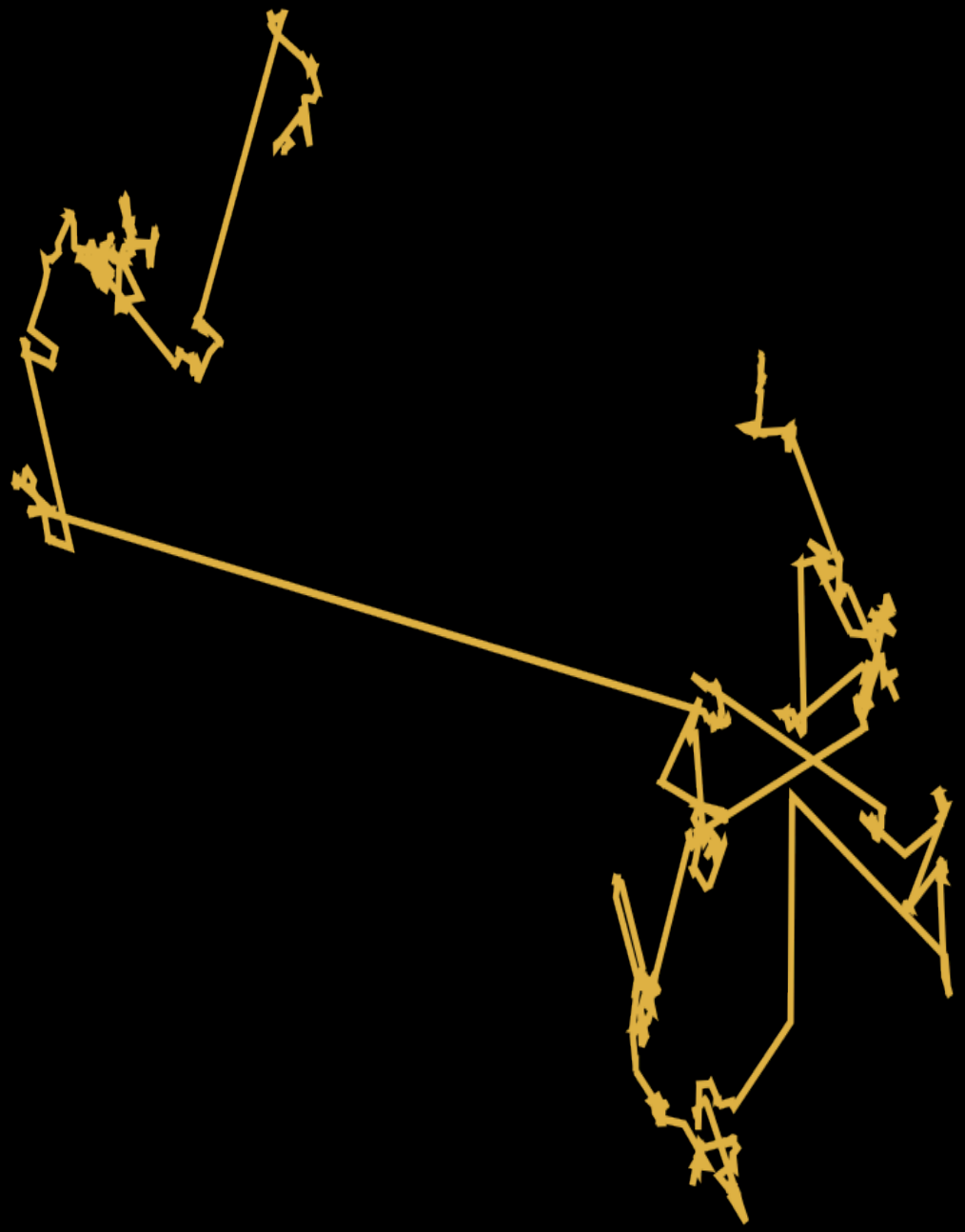
ne-normální

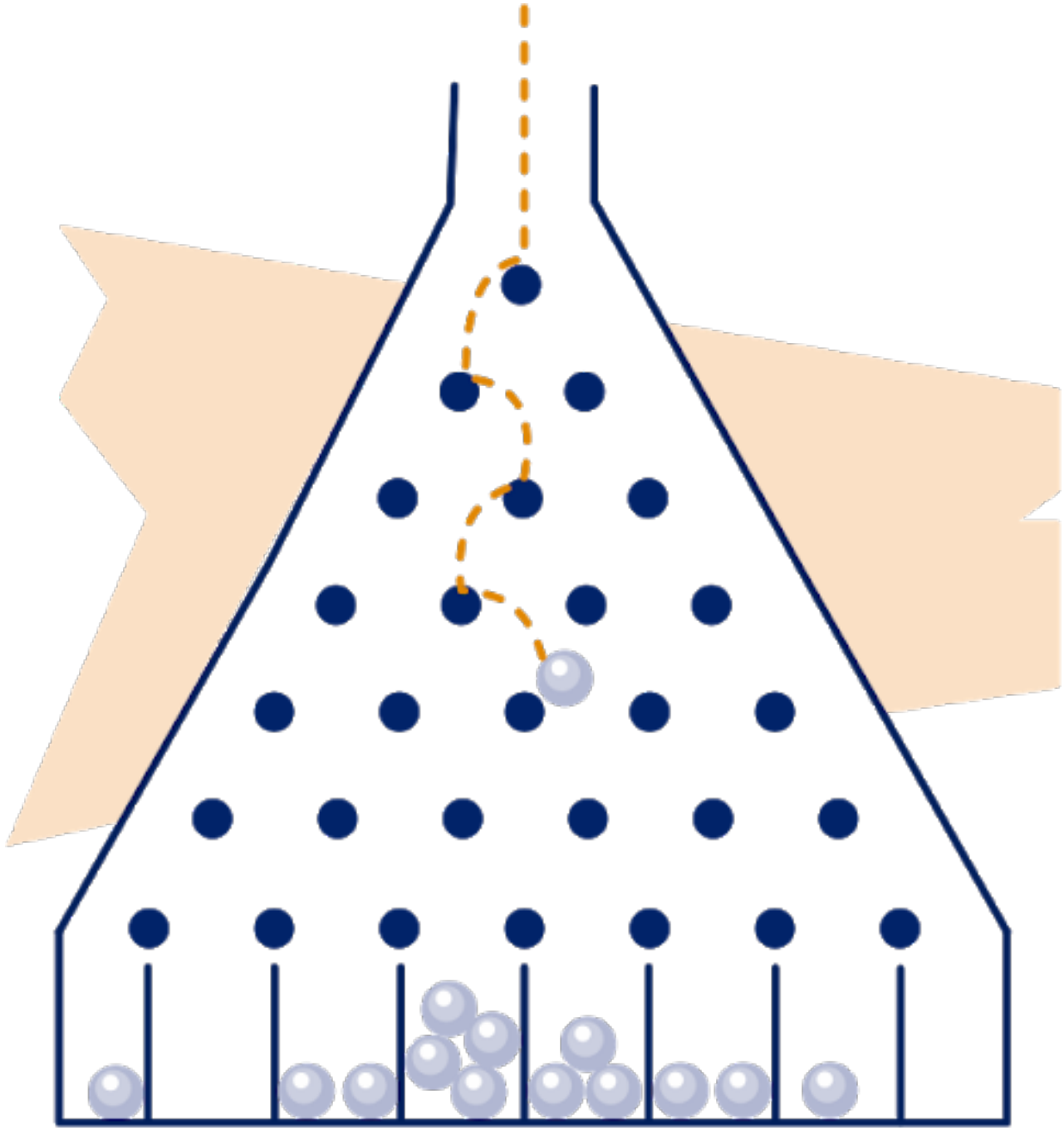
$$\sqrt{\frac{c}{2\pi}}\,\frac{e^{-\frac{c}{2(x-\mu)}}}{(x-\mu)^{3/2}}$$

$$\left(\frac{x_{\mathrm{m}}}{x}\right)^{\alpha}$$

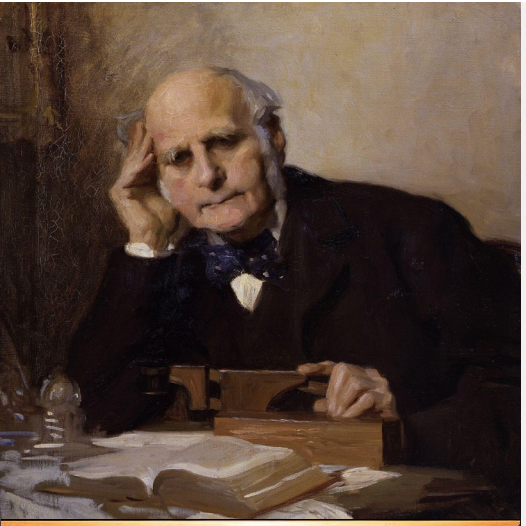
$$ax^{-k}$$

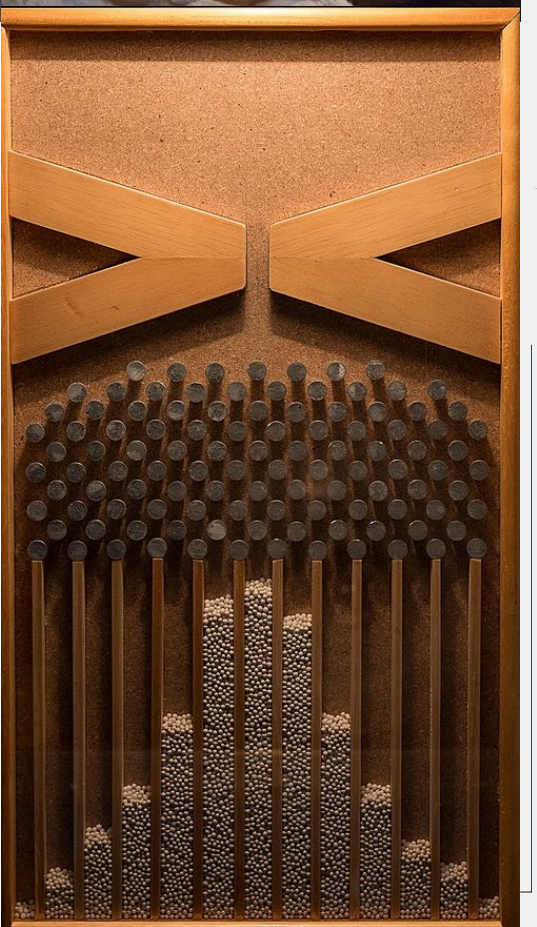

mediocristan vs. extremistan
normal vs. not-normal
populace
performance

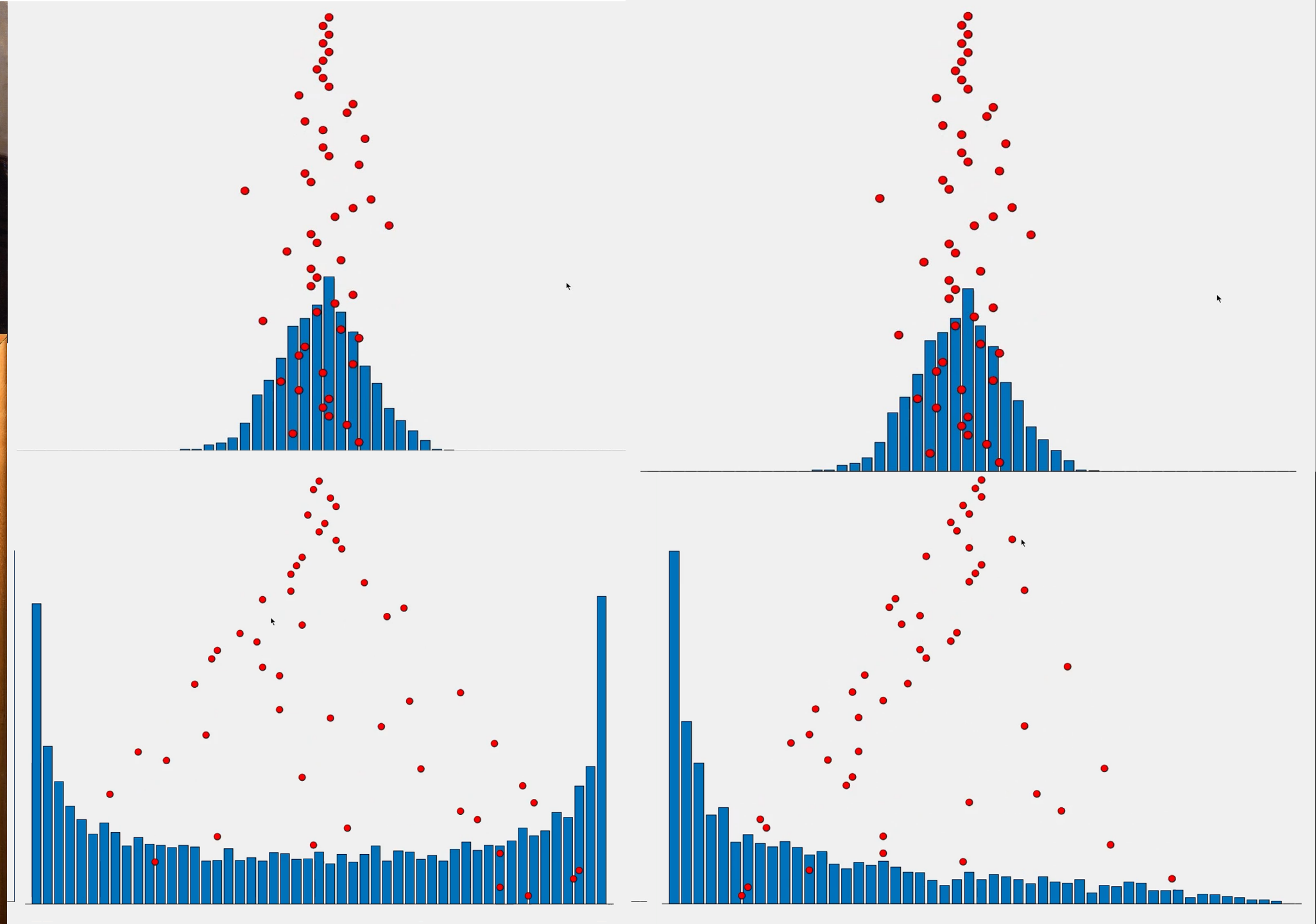




Galton Board bean machine



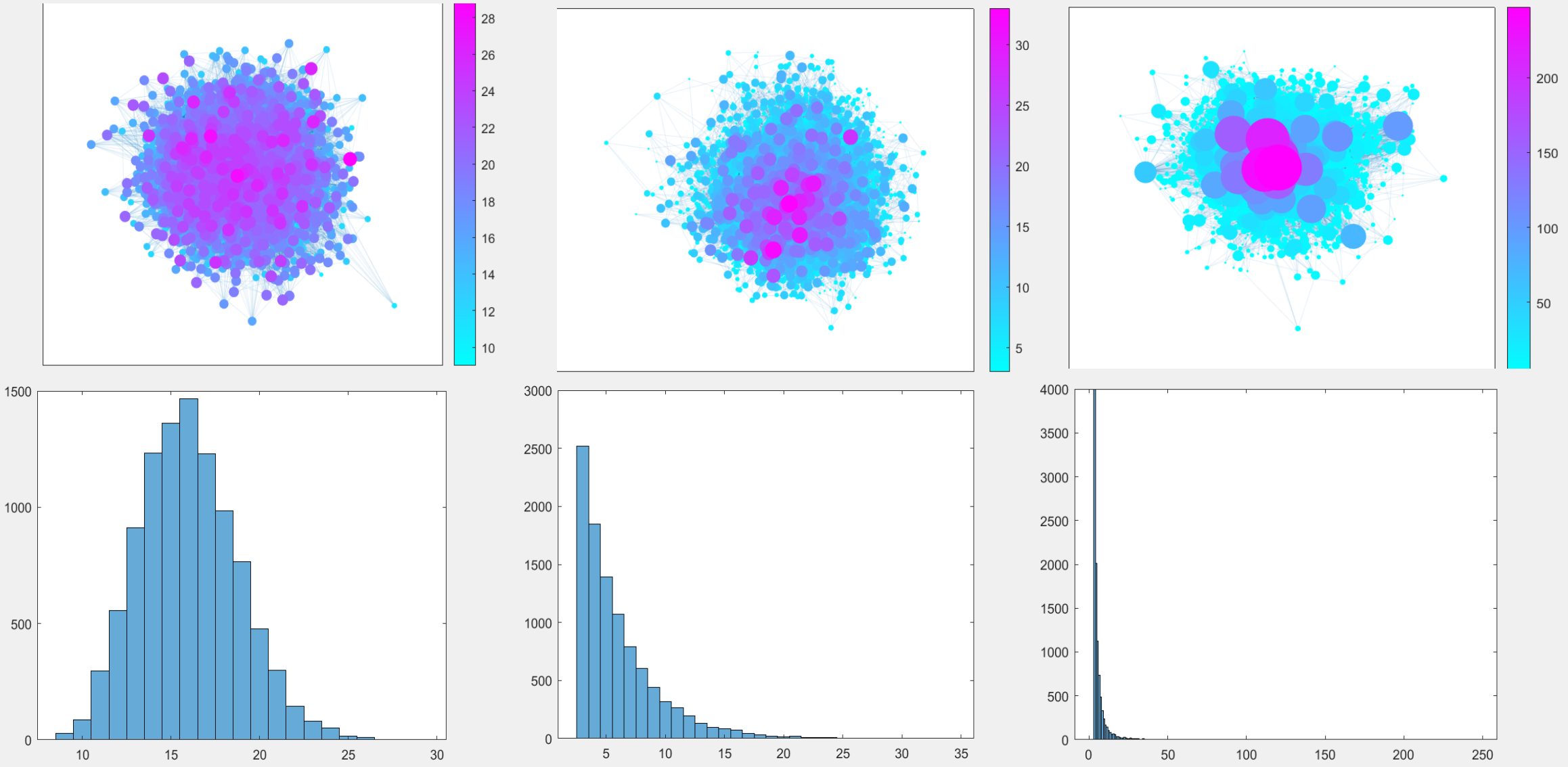


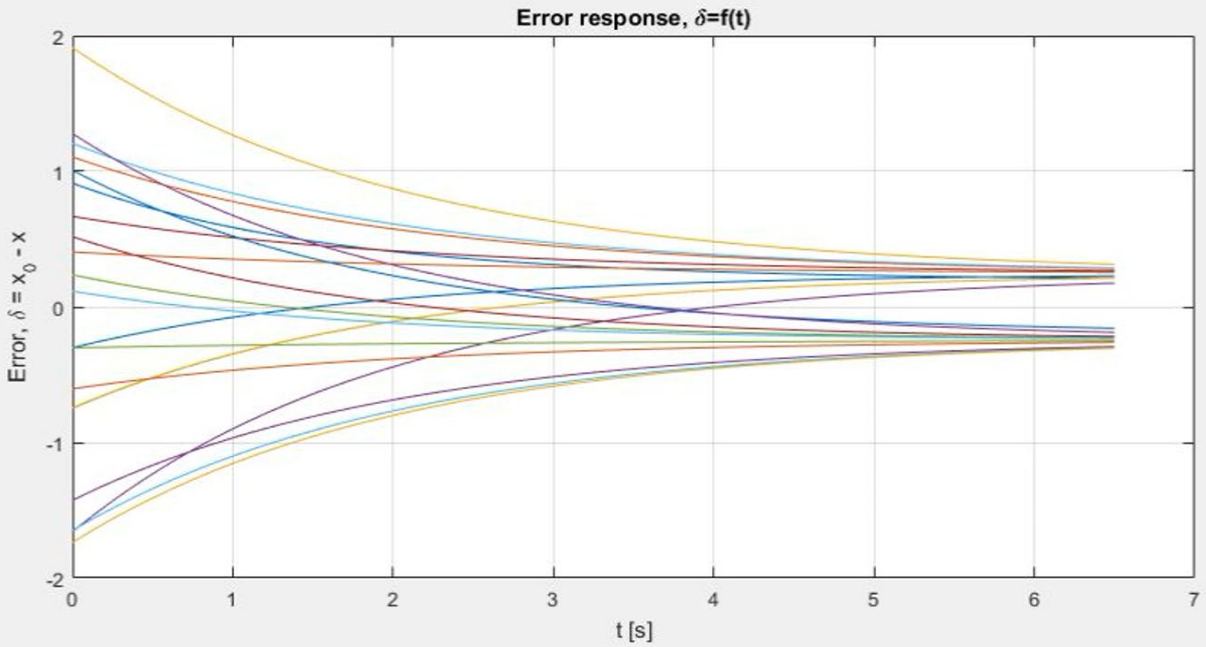


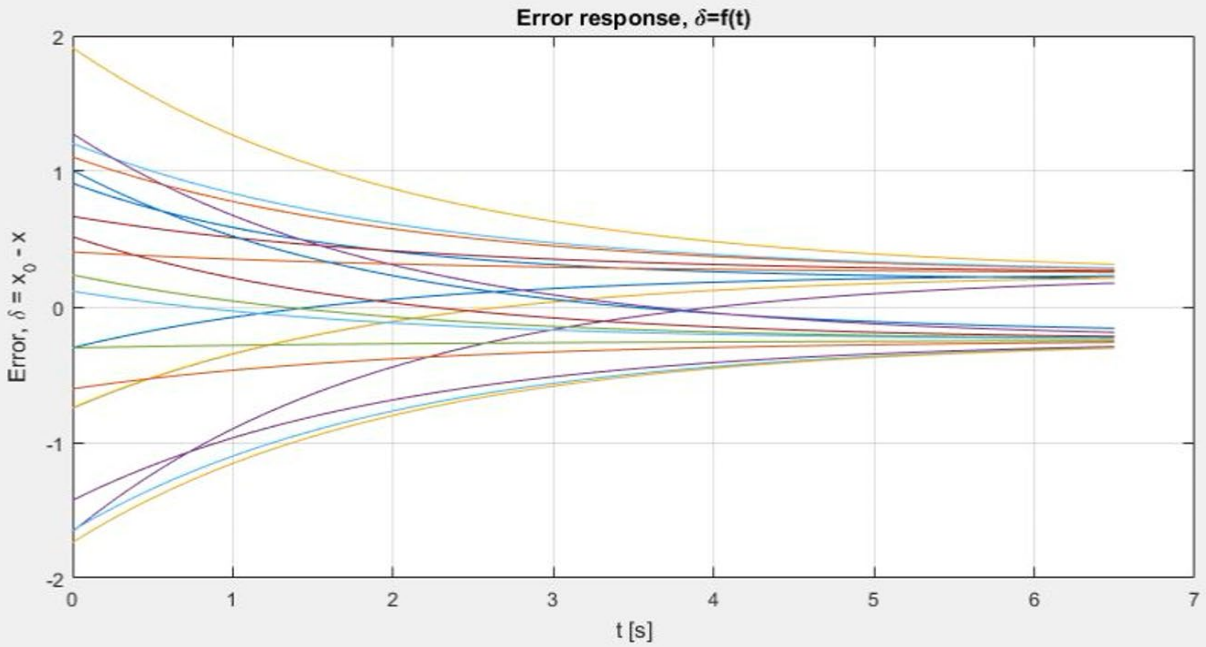
graf sítě

Preferential attachment

$$p_i = \frac{k_i}{\sum_j k_j},$$




Error response, δ=f(t)
Error, δ = x0 - x
t [s]
2
1
0
-1
-2
0
1
2
3
4
5
6
7


Error response, δ=f(t)
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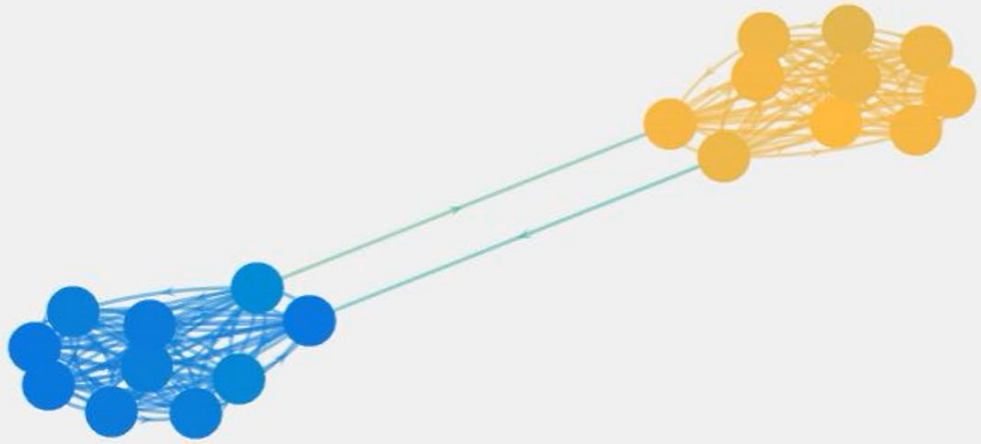
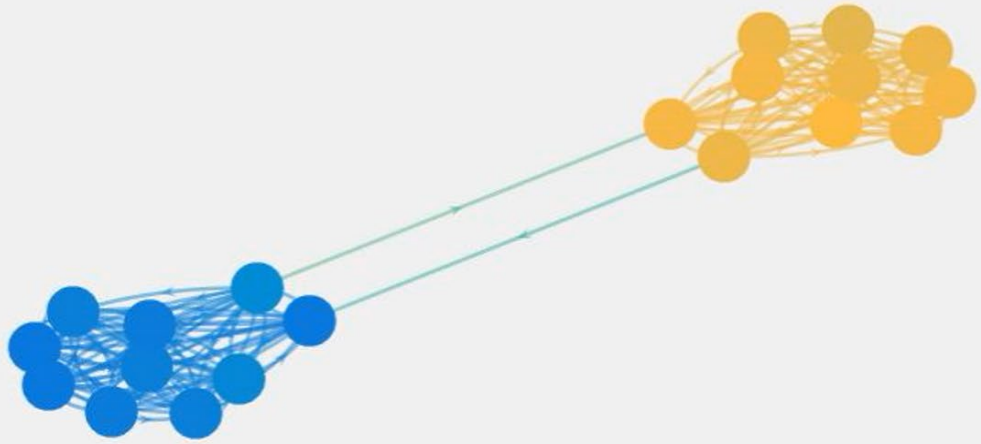
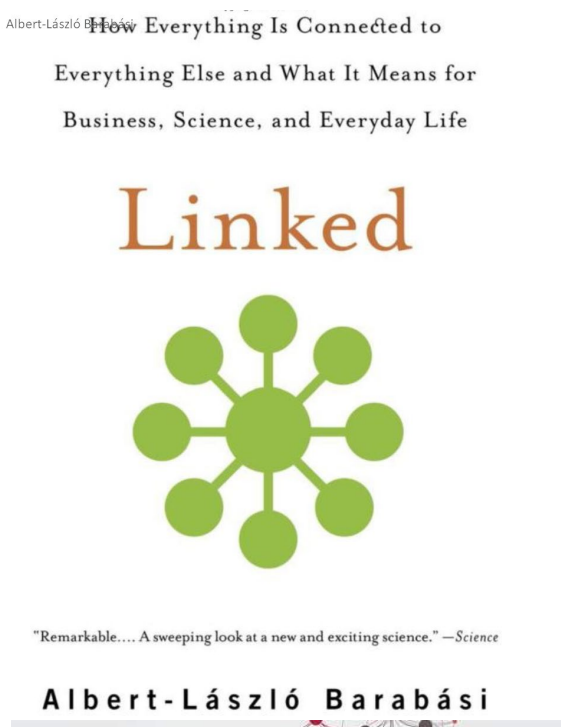


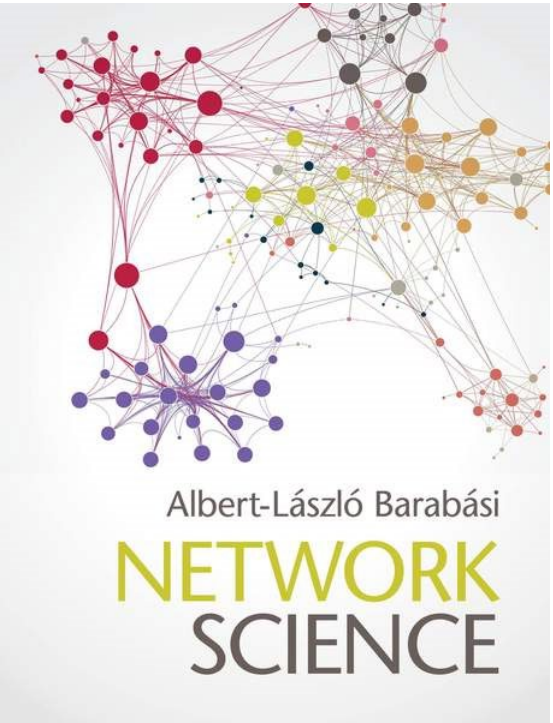


Albert-László Barabási: Linked: How Everything Is Connected to Everything Else and What It Means for Business, Science, and Everyday Life,
Basic Books, 2014.
ISBN-10: 0465085733, ISBN-13: 978-04650857362014

Albert-Laszlo Barabasi: Network Science.
Cambridge University Press, 2016.
ISBN-10: 1107076269, ISBN-13: 978-1107076266
Webová verze s animacemi.

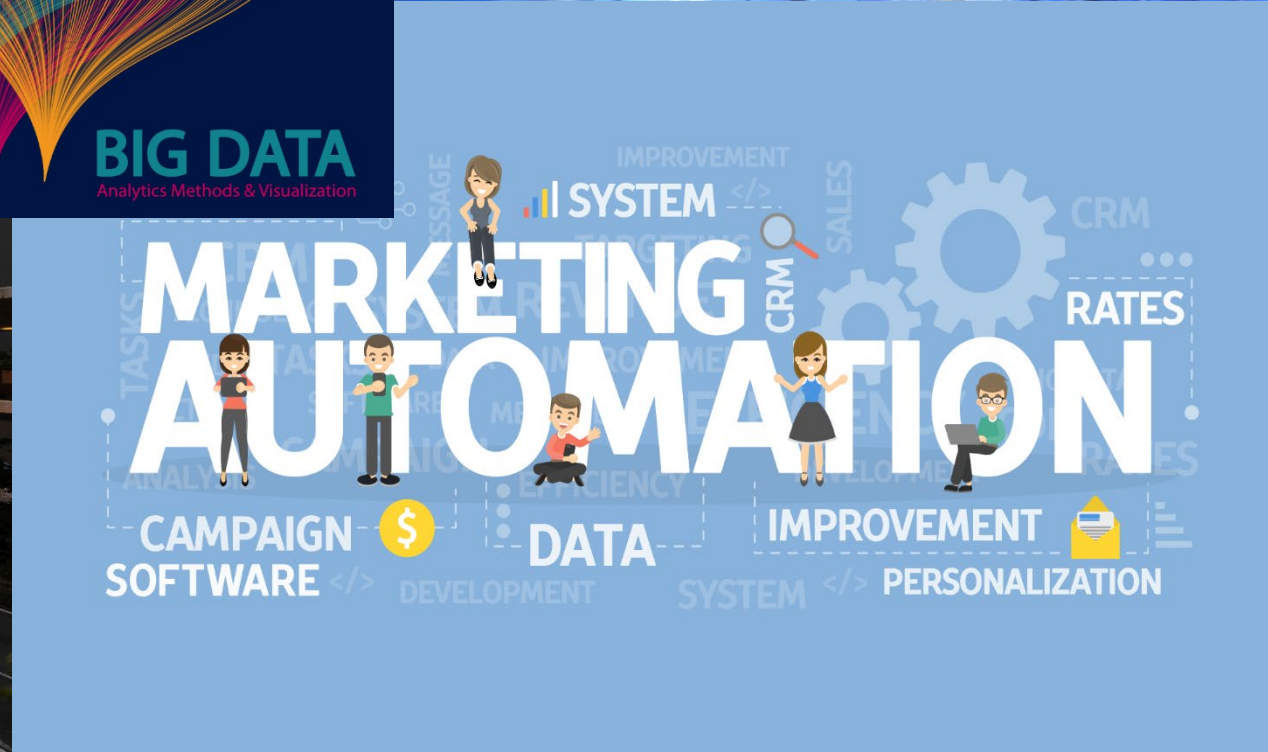
Videa
What is a Random Walk?, Graph Theory Overview
Introduction to Graph Theory: A Computer Science Perspective, Graph Theory Introduction
Exponentials & Power Laws

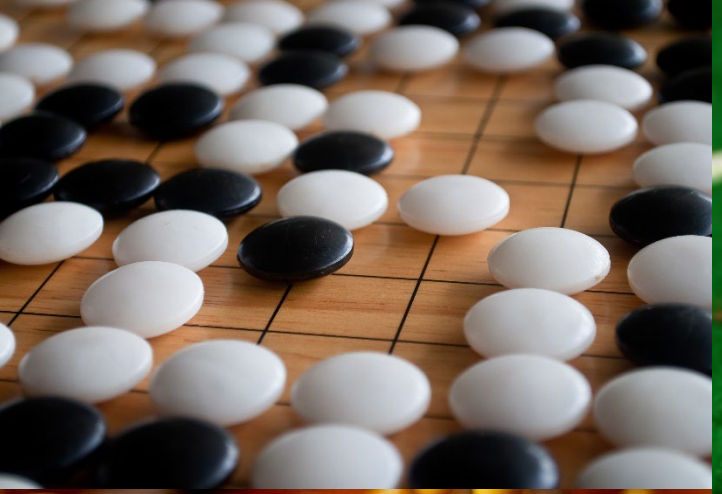




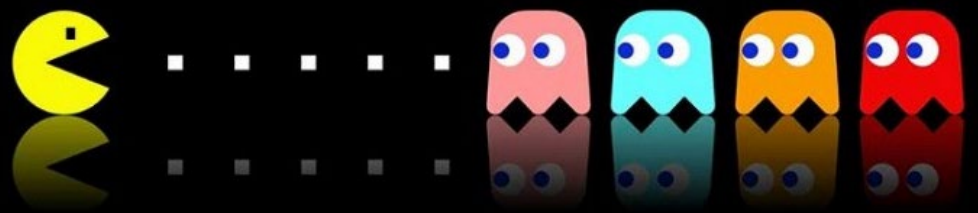
ARTIFICIAL
INTELLIGENCE

BIG DATA
Analytics Methods & Visualization


SYSTEM
MARKETING
AUTOMATION
CRM
RATES
CAMPAIGN
SOFTWARE
DATA
IMPROVEMENT
PERSONALIZATION

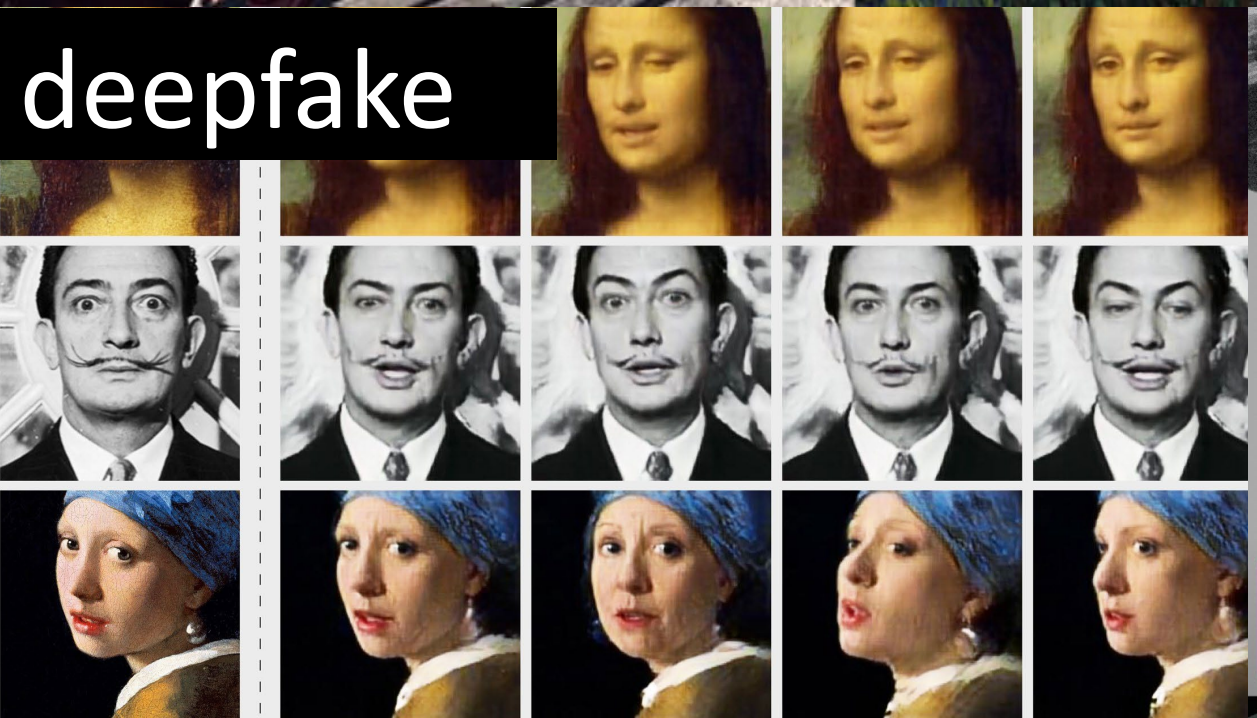


ALL SOLVED

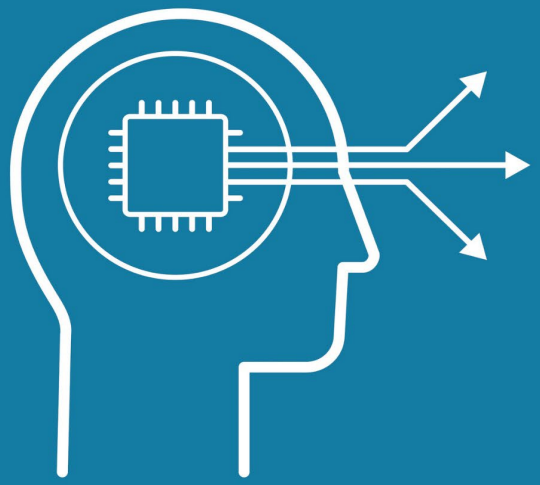


přenos stylu

deepfake



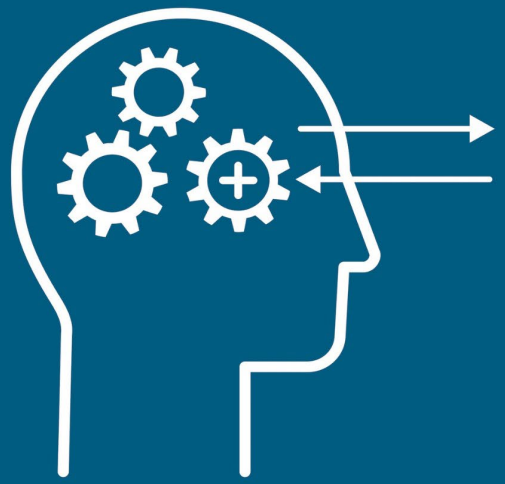
1950



ARTIFICIAL INTELLIGENCE

ENGINEERING OF MACHINES
THAT MIMIC COGNITIVE FUNCTIONS

1980



MACHINE LEARNING

ABILITY TO PERFORM TASKS
WITHOUT EXPLICIT INSTRUCTIONS
AND RELYING ON PATTERNS

2010

DEEP LEARNING

MACHINE LEARNING BASED
ON ARTIFICIAL NEURAL NETWORKS

rozpoznávání tváře

filtrování spamu

řeč na text

překlady

...

...

hodně dat

lepší hw a sw

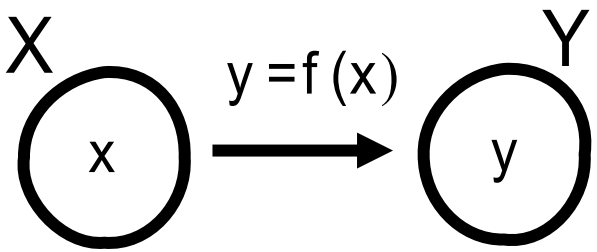
pokrok v matematice

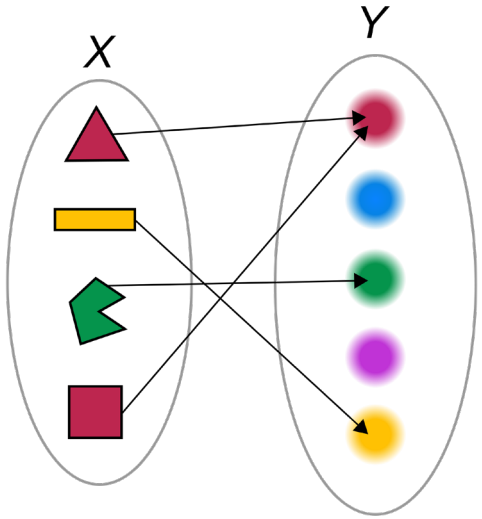
Funkce

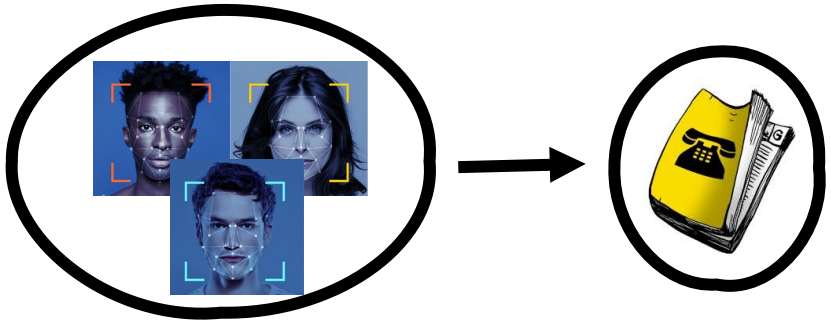
function, mapping, pattern,..

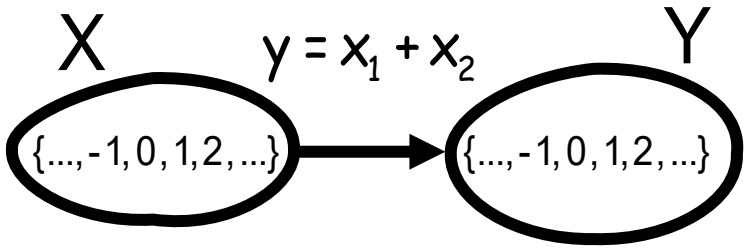
zobrazení z množiny výstupních hodnot na výstupní hodnoty

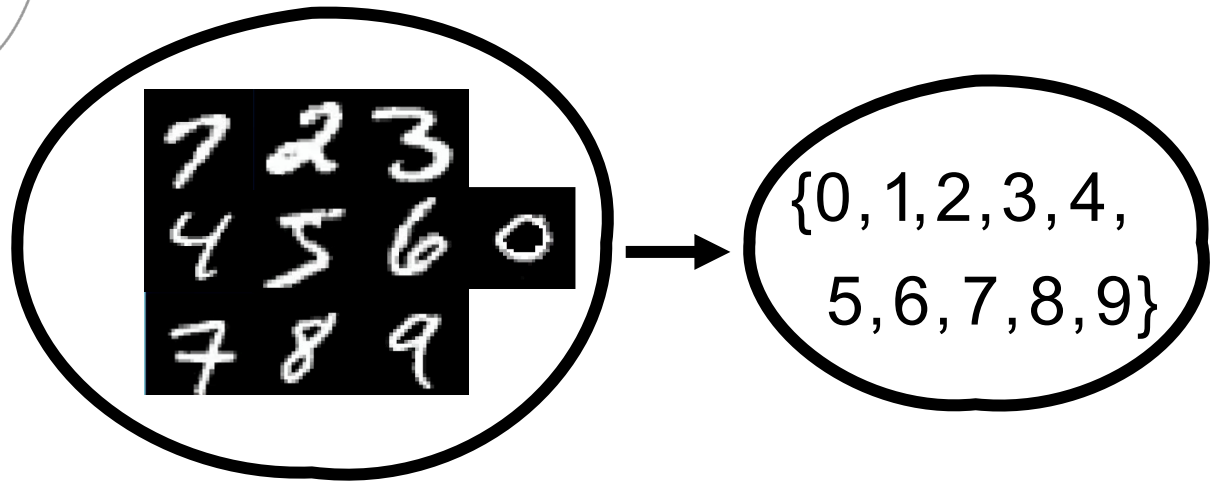
deterministická = pro stejné vstupy dá vždy stejné výstupy







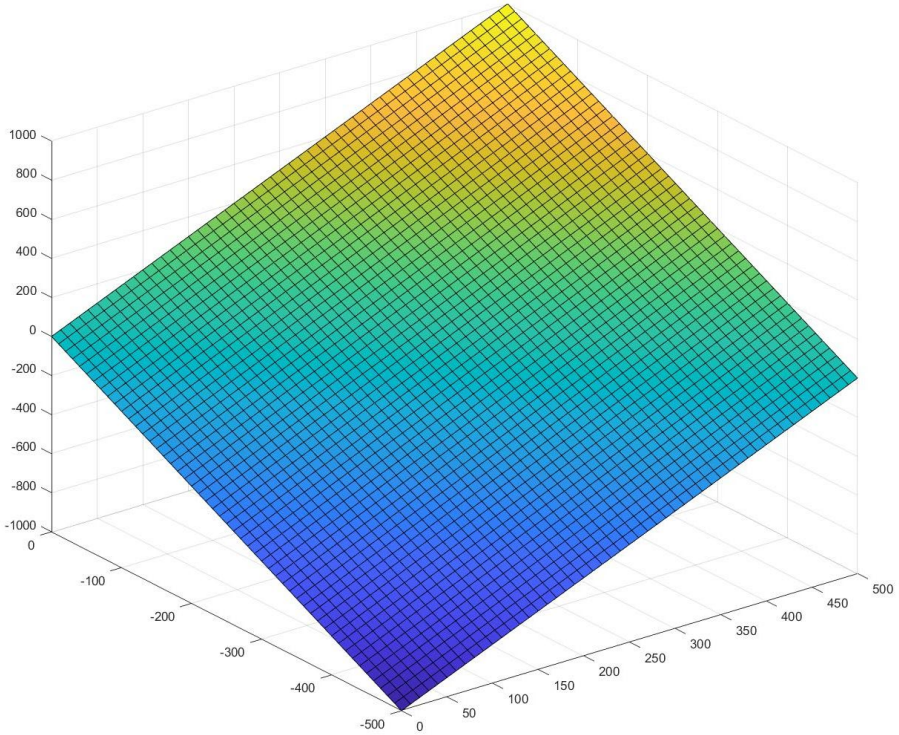




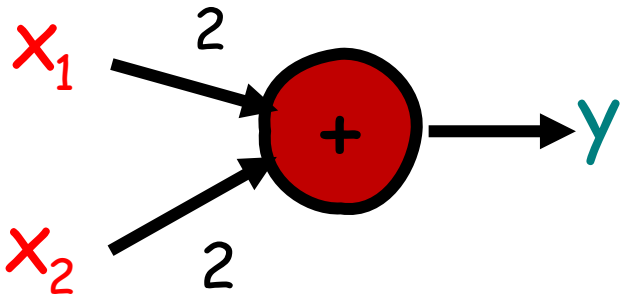
Modely funkcí

$$y = 2x_1 + 2x_2$$

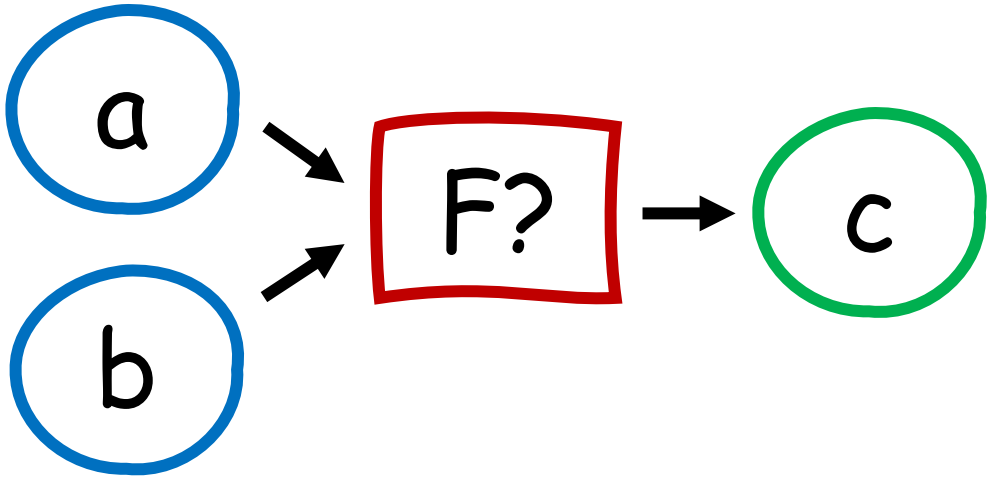
```
[X1,X2] = meshgrid(0:10:500,-500:10:0);
Y=2*X1+2*X2;
surf(X1,X2,Y)
```



ID	Annual Income	Current Debt	Credit Solvency
1	$150	-$100	100
2	$250	-$300	-50
3	$450	-$250	400
4	$200	-$350	-300



Hledáme F(a,b) = c



Co může být F?

+, -, x, /

Jak vhodná je F?

„tři správné ze tří"

Data:

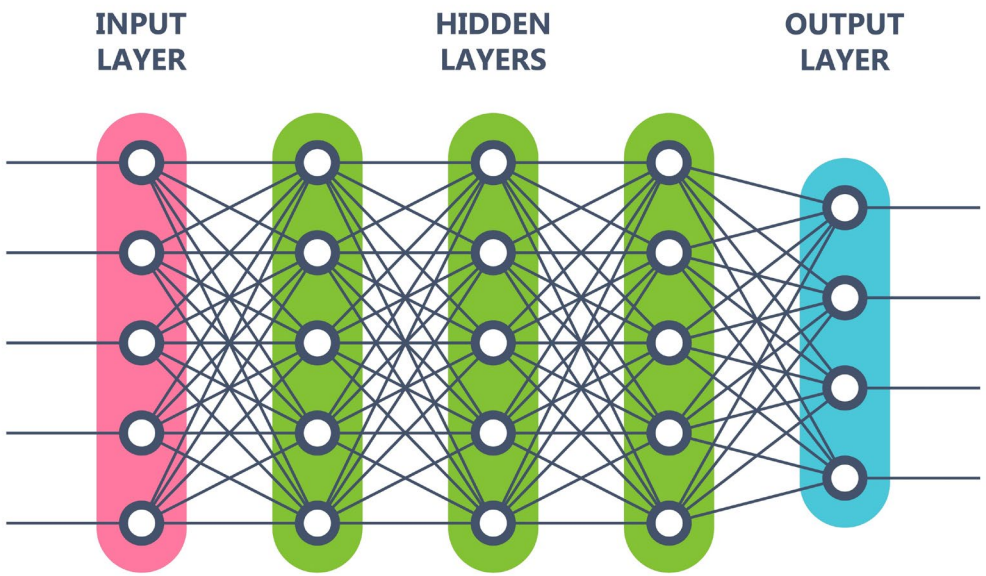
A	B	C
2	1	2
3	1	3
3	2	6

(4 1 4)

{3 2 5}

Strojové učení

umožňuje rozhodování založené na datech
z velkých souborů identifikuje a extrahuje dat funkce (vzory),
které mapují soubory složitých vstupů na správné výsledky
rozhodnutí.



Hluboké učení

funkce (vzory) získané z dat

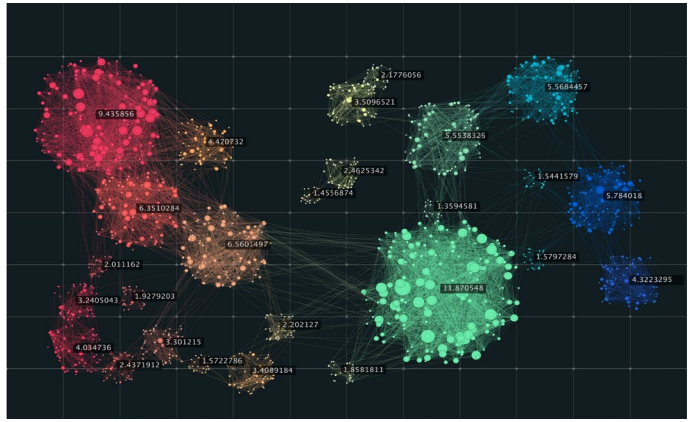
reprezentuje (modeluje)
neuronovými sítěmi

Klíčové složky strojového učení

data - soubor historických příkladů, instancí

soubor kandidátů funkcí - algoritmus prohledává, až najde nejlepší

míra vhodnosti (fitness) - vyhodnocuje, jak kandidáti vyhovují



Kategorie strojového učení

pod dohledem, supervised - příklady mají správné řešení

bez dohledu, unsupervised - nemají ho

s posilováním, reinforcement - data až online, vhodnost ex post

Příklad: Výpočet platební schopnosti žadatelů o půjčku

Table 2.1. A dataset of loan applications and known credit solvency rating of the applicant

ID	Annual income	Current debt	Credit solvency
1	$150	-$100	100
2	$250	-$300	-50
3	$450	-$250	400
4	$200	-$350	-300

model

$$z = x_1 \times w_1 + x_2 \times w_2$$

platební schopnost =
= (příjem × váha pro příjem)
+ (dluh × váha pro dluh)

učení

váhy náhodně zvolíme a dosadíme

$$z = x_1 \times 3 + x_2 \times 1$$

platební schopnost =
= (příjem × 3) + (dluh × 1)
= (150 × 3) + (-100 × 1) = 350

porovnáme 100 – 350 = -250, chyba je záporná,

upravíme váhy, aby hodnotu zvětšily 3 ↘ 2, 1 ↗ 2

platební schopnost =
= (příjem × 2) + (dluh × 2)
= (150 × 2) + (-100 × 2) = 100

porovnáme 100 – 100 = 0, hodnota je správná

$$z = x_1 \times 2 + x_2 \times 2$$

Příklad - pokračování

úkolem bankéře není vypočítat číslo (platební schopnost), ale rozhodnout o půjčce

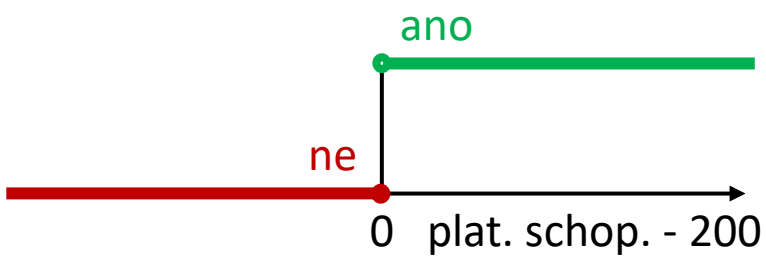
přidáme k modelu nějaké rozhodovací pravidlo. Například

„půjčka bude poskytnuta osobě, jejíž platební schopnost je vyšší než 200“

pravidlo je také modelem: mapuje vstupní proměnnou (platební schopnost) na výstupní (rozhodnutí o úvěru)

rozhodnutí o půjčce platební schopnost =
= rozhodovací pravidlo (platební schopnost = příjem × 2) + (dluh × 2) - práh)
= „If > 0“ (platební schopnost = 150 × 2) + (-100 × 2) - 200)
= odmítnout

$$z = \sigma(x_1 \times w_1 + x_2 \times w_2 + b)$$



Příklad – geometrická interpretace

$$x_1 \times w_1 + x_2 \times w_2 - b = 0$$

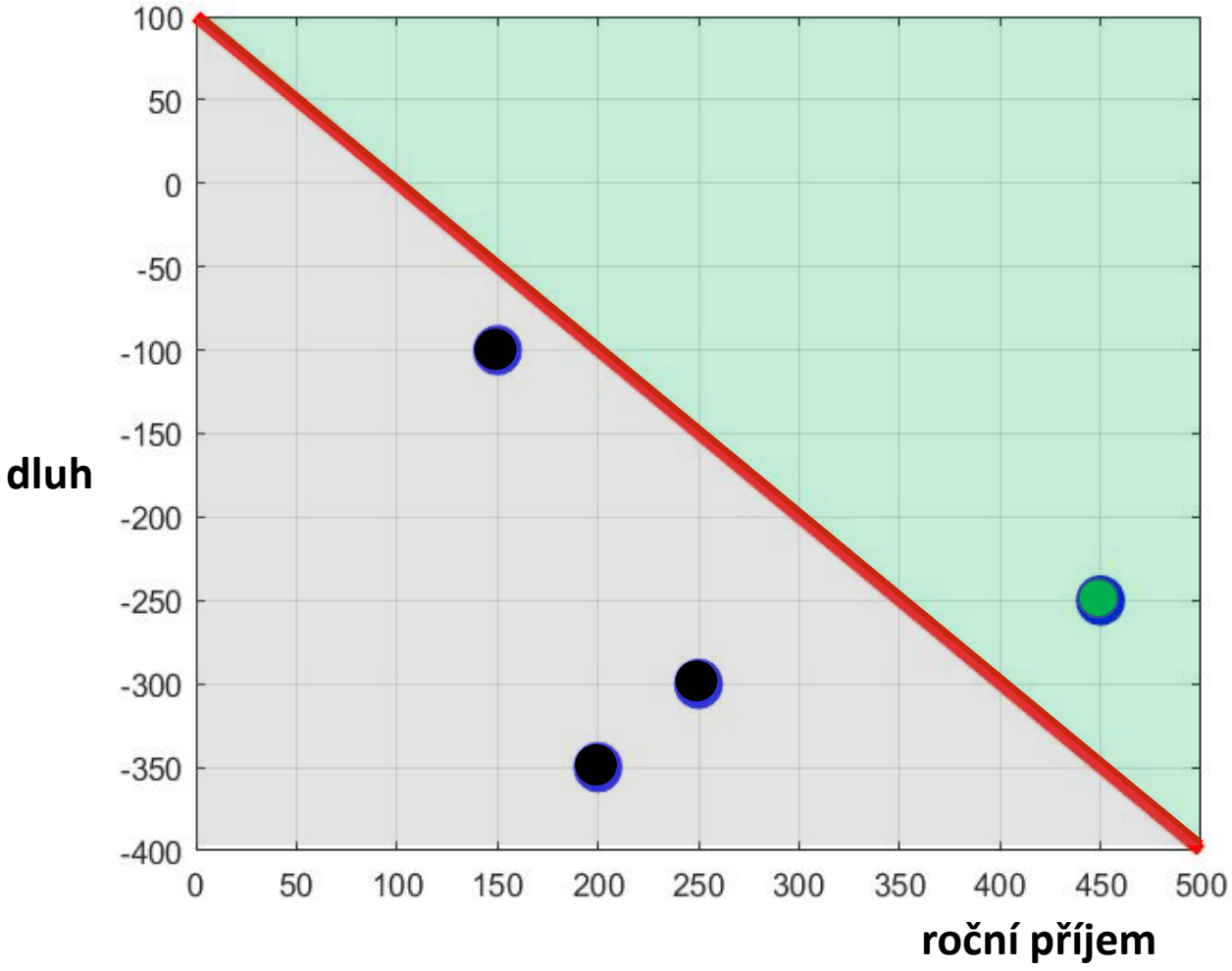
$$x_2 = \left(\left(-\frac{w_1}{w_2}\right) \right) x_1 + \left(\left(-\frac{b}{w_2}\right) \right)$$

$$y = Ax + B$$

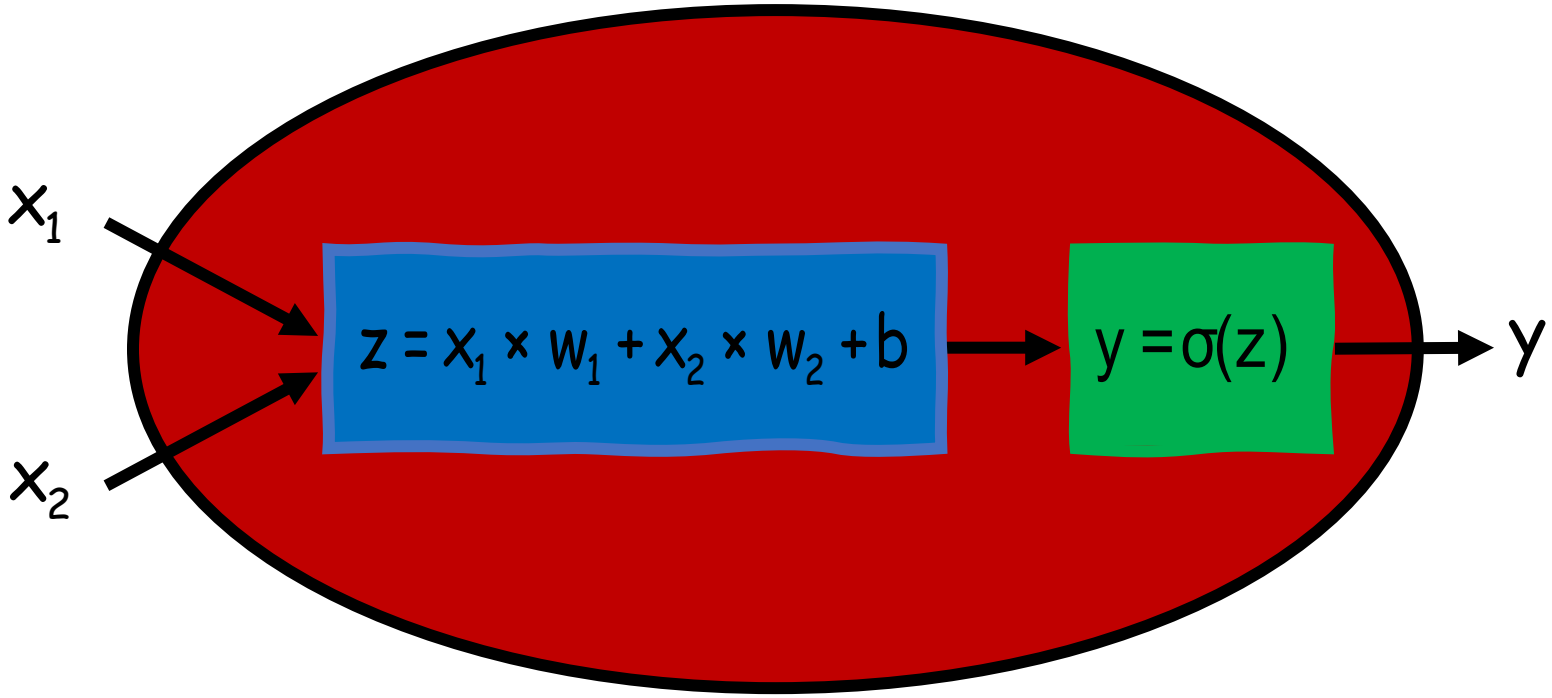
$$2x_1 + 2x_2 - 200 = 0$$

$$x_2 = -x_1 + 100$$

$$y = -x + 100$$

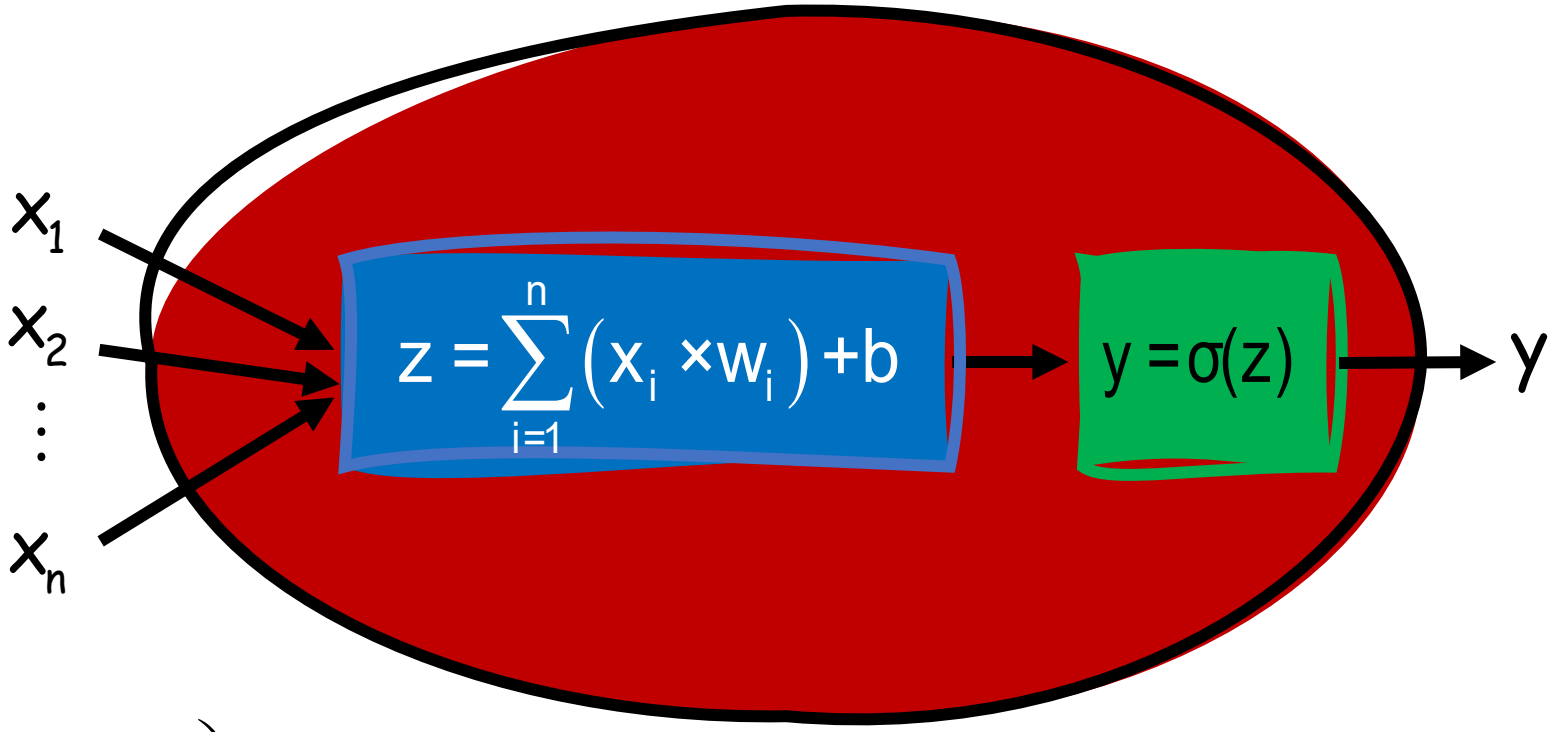


Neuron



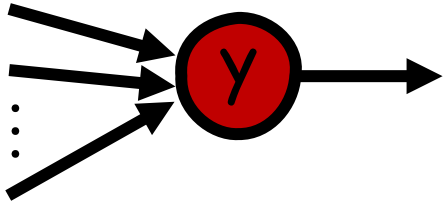
počítačový program

Neuron

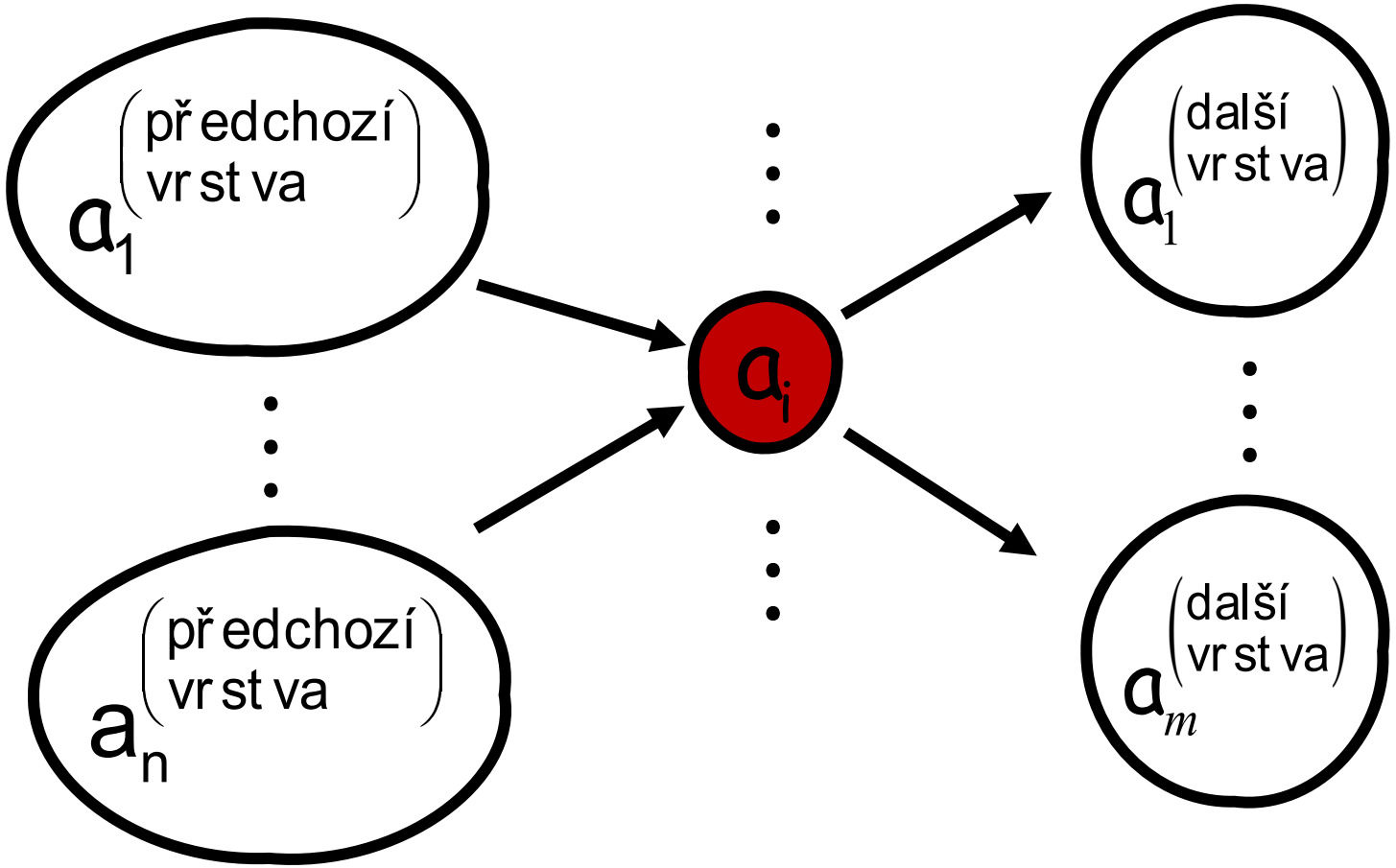


$$y = \sigma\left(\sum_{i=1}^{n} (x_i \times w_i) + b\right)$$

$$a_{vrstva} = \sigma\left(\sum_{i=1}^{n} \left(a_{\text{předchozí vrstva},i} \times w_i\right) + b\right)$$

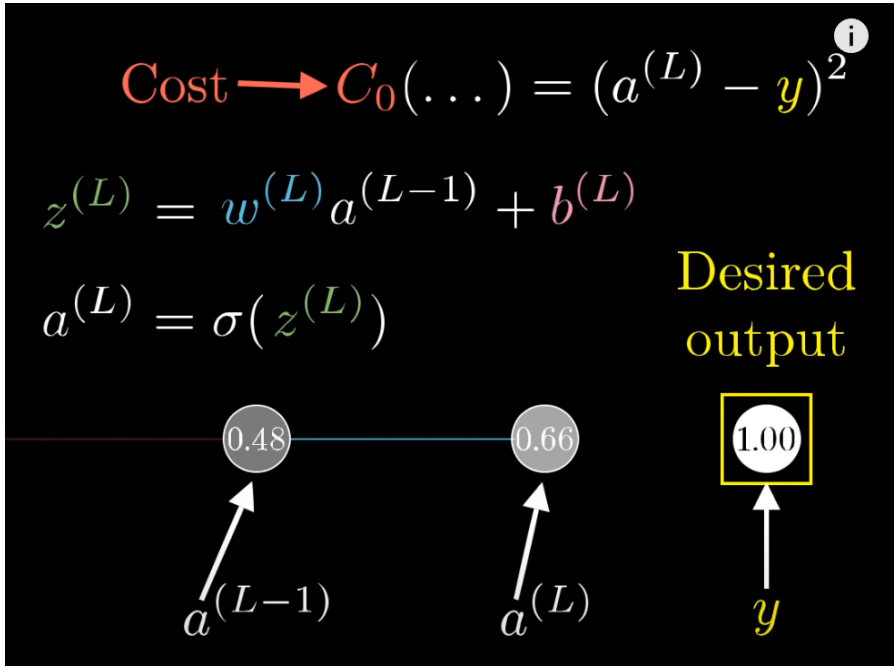


Neuronová síť



$$a_k^{(\text{tato vrstva})} = \sigma\left(\sum_{i=1}^{n}\left(a_i^{(\text{předchozí vrstva})} \times w_{k,i}\right) + b_k\right)$$

a = aktivace = výstup neuronu



Trénování

iterací přes příklady v datové sadě postupně vybíráme funkce

pokaždé síti předložíme vstupní hodnoty a síť vrátí výstupní

ty porovnáme se správným výstupem uvedeným v datové sadě

rozdíl užijeme k aktualizaci parametrů sítě, aby lépe odpovídala

jakmile je model dostatečně přesný, učení se ukončí

a algoritmus vrátí konečný model

Inference, odvozování

hotový model aplikujeme na nové příklady, u kterých

neznáme správnou výstupní hodnotu

model (síť) pro nás generuje odhady této hodnoty

Data

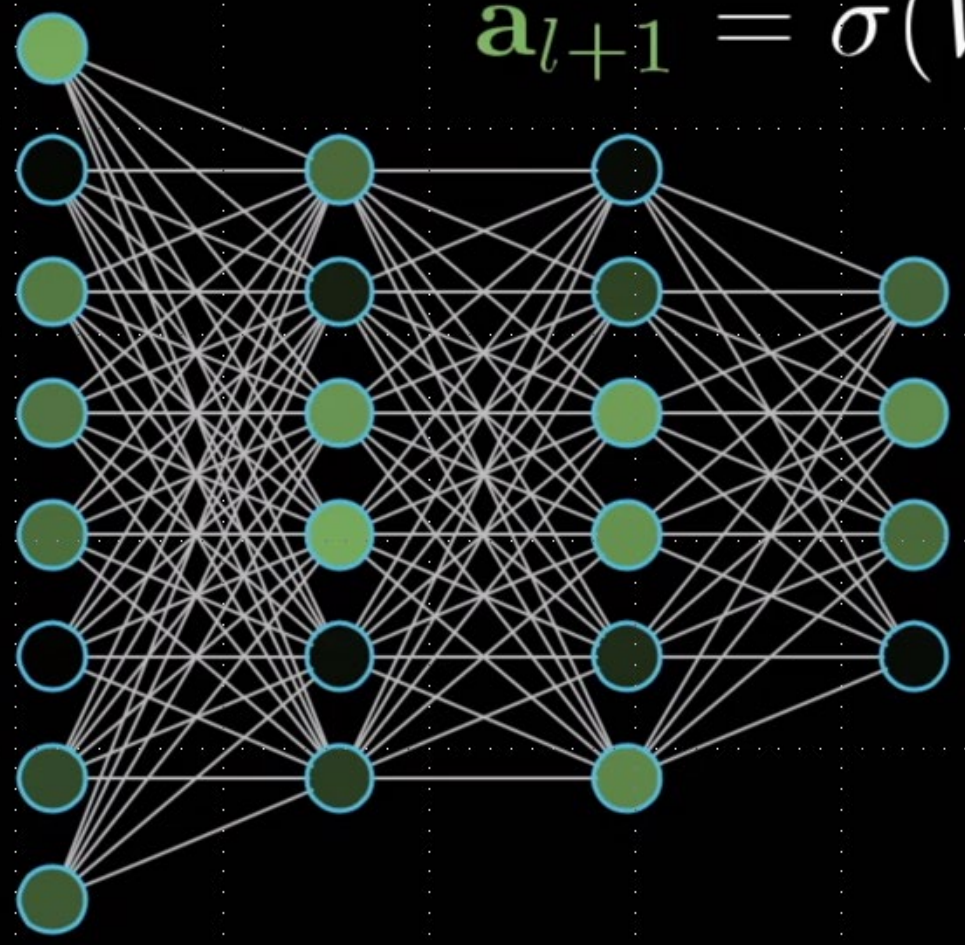
multidimenzionální

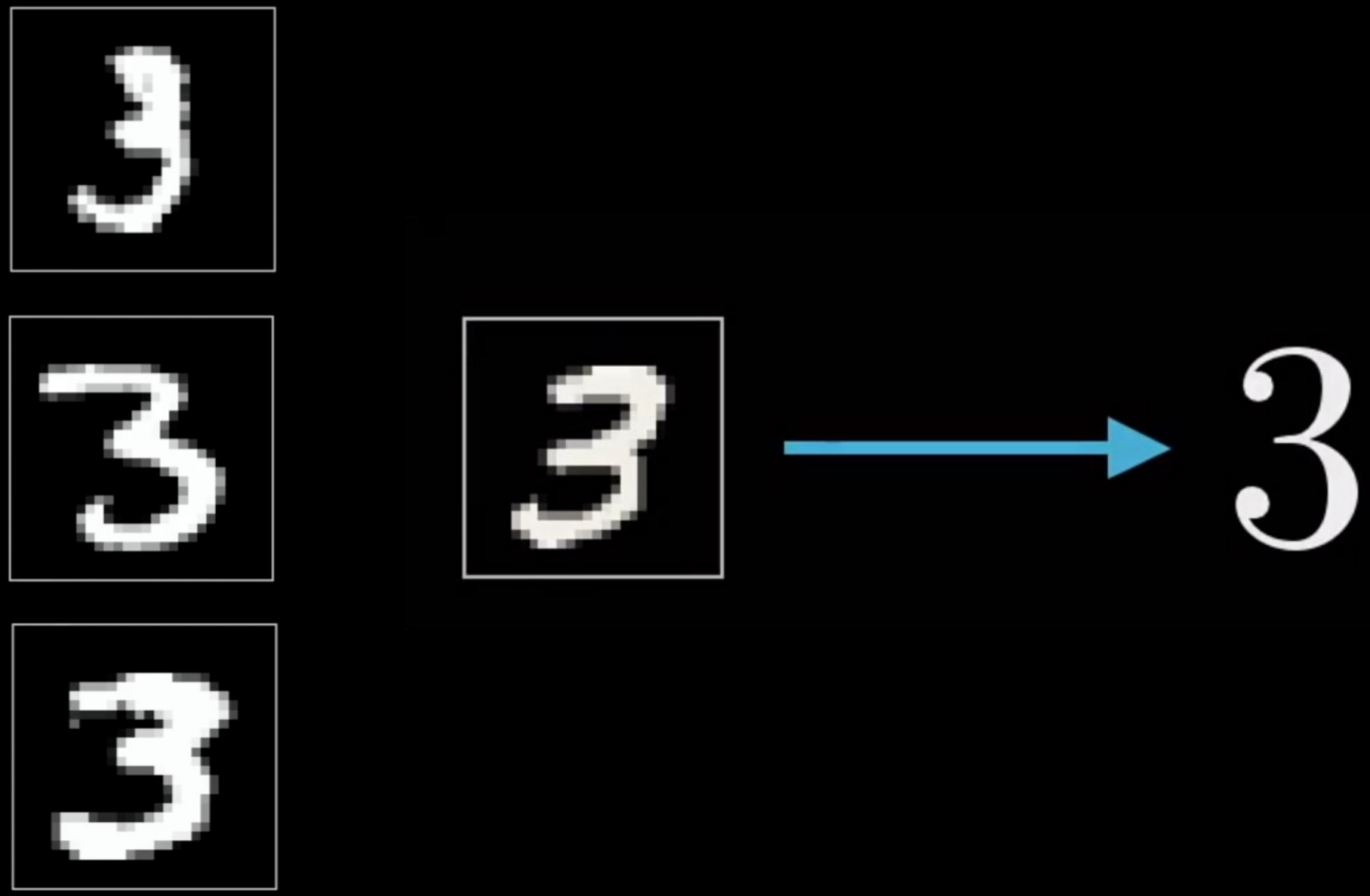
big, small, synthetic

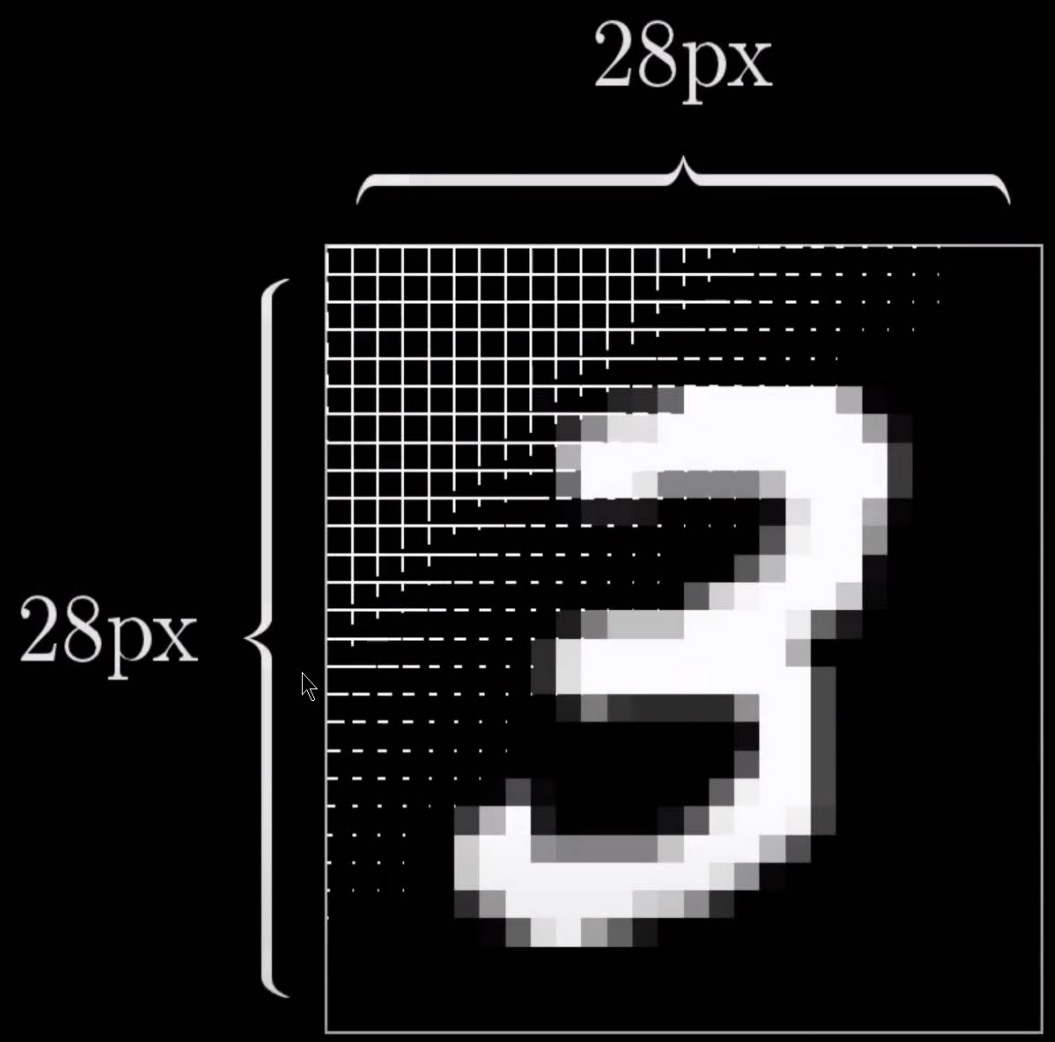
surová vs. předzpracovaná

data a šum (over-, uderfitting)

$$\mathbf{a}_{l+1} = \sigma(W_l \mathbf{a}_l + b_l)$$




3


28px
28px

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.1 0.2 0.4 1.0 1.0 1.0 1.0 1.0 1.0 0.7 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.2 0.5 0.9 0.9 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 0.1 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.7 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.2 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.4 1.0 1.0 0.9 0.5 0.5 0.5 0.5 0.7 1.0 1.0 1.0 1.0 0.2 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.1 0.1 0.1 0.0 0.0 0.0 0.0 0.1 0.9 1.0 1.0 0.7 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.3 0.9 1.0 1.0 0.6 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.3 0.7 1.0 1.0 1.0 0.1 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.4 0.8 1.0 1.0 1.0 1.0 0.8 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.1 0.5 0.8 0.8 0.8 1.0 1.0 1.0 1.0 0.9 0.4 0.1 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.2 0.9 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.7 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
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0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.1 0.5 0.2 0.2 0.2 0.2 0.2 0.6 1.0 1.0 0.3 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
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0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.3 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.4 0.9 1.0 1.0 0.3 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.2 0.7 1.0 0.1 0.0 0.0 0.0 0.0 0.1 0.4 0.9 1.0 1.0 0.9 0.3 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.8 1.0 1.0 0.6 0.5 0.5 0.5 0.5 0.8 1.0 1.0 1.0 0.7 0.3 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.9 0.6 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.2 0.6 1.0 1.0 1.0 1.0 1.0 0.8 0.8 0.6 0.2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.4 0.9 1.0 0.7 0.4 0.1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
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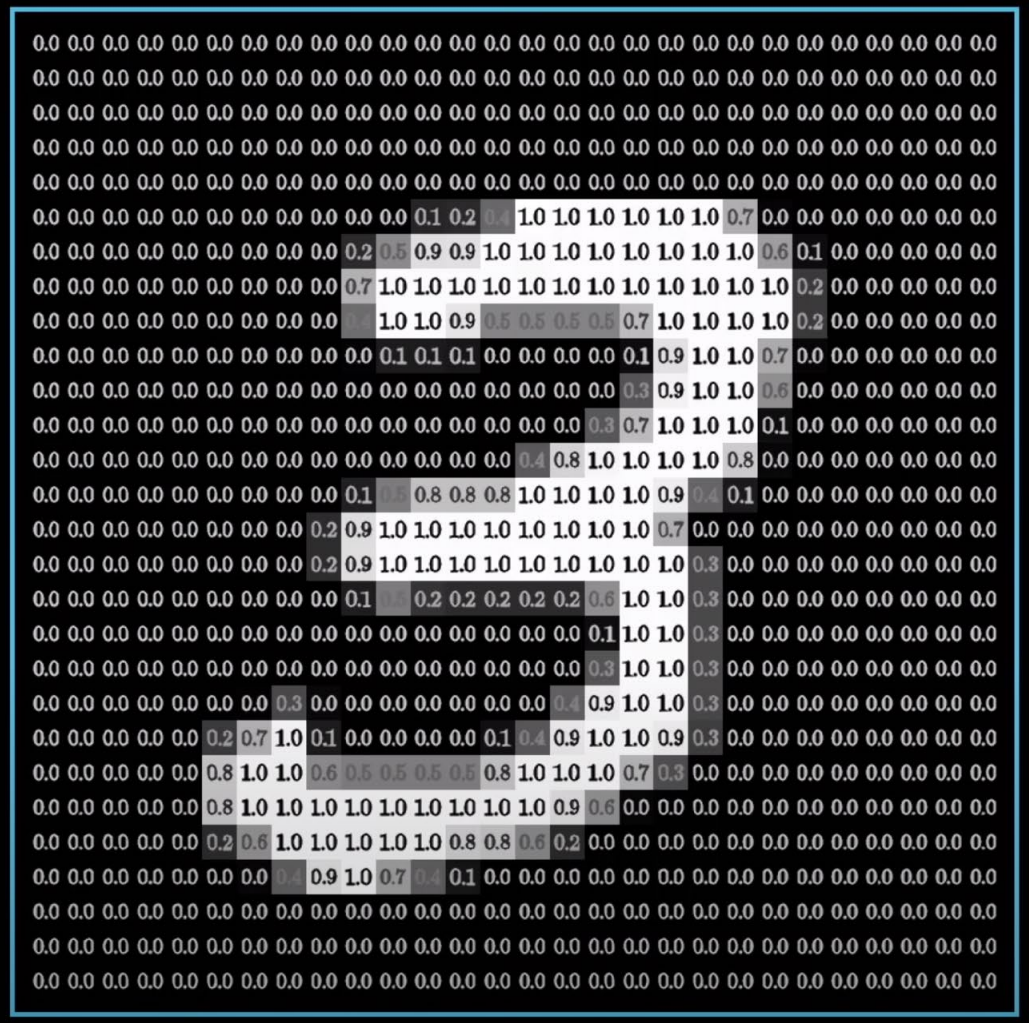
0.7 0.0 0.0
1.0 0.6 0.1
1.0 1.0 0.2

Co vlastně je neuronová síť? | Hluboké učení, část 1



3

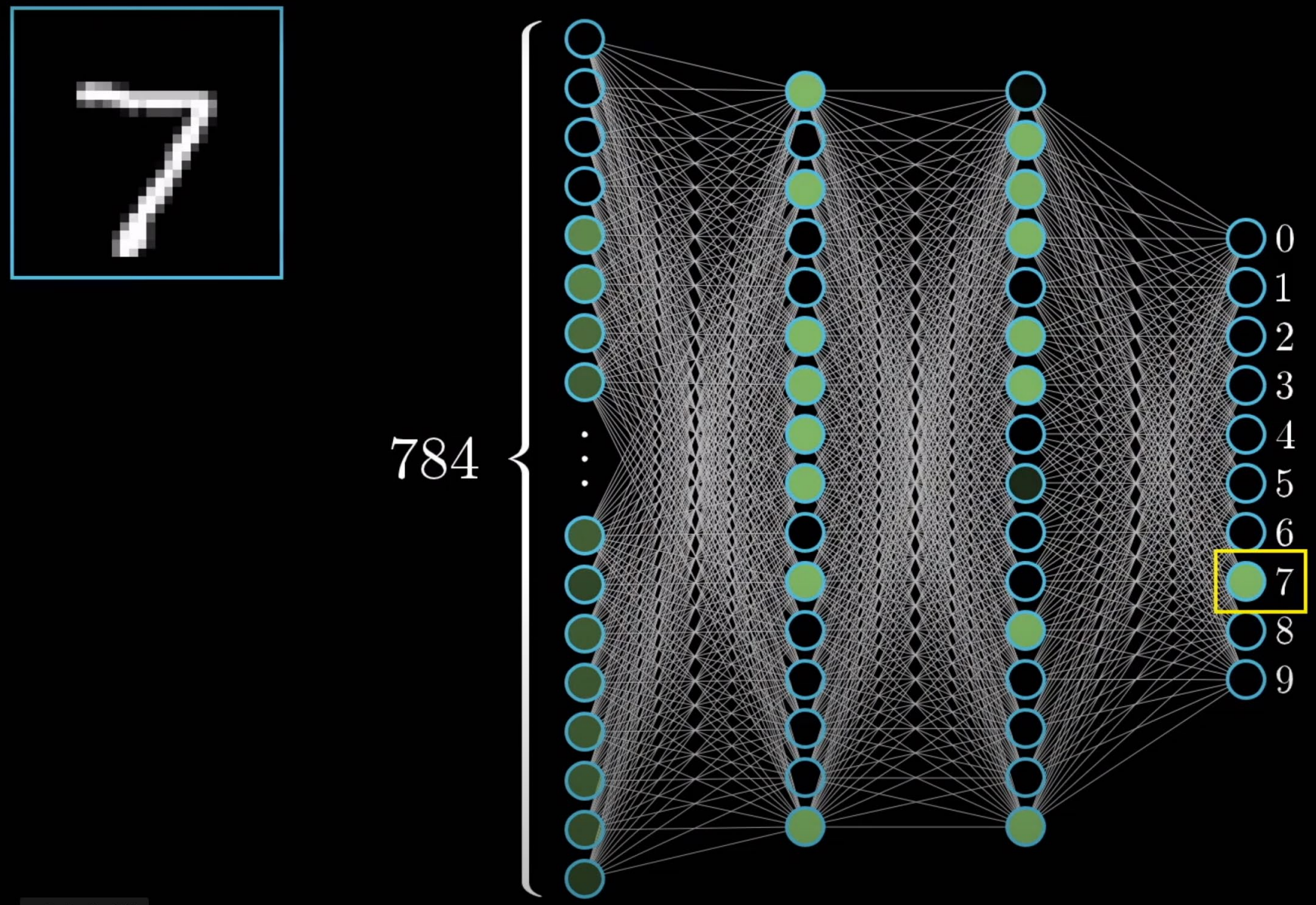
Unless you've been living under a rock

Přehrát (k)

1:07 / 19:13 • Series preview ›

Posunutím zobrazíte více

Co vlastně je neuronová síť? | Hluboké učení, část 1

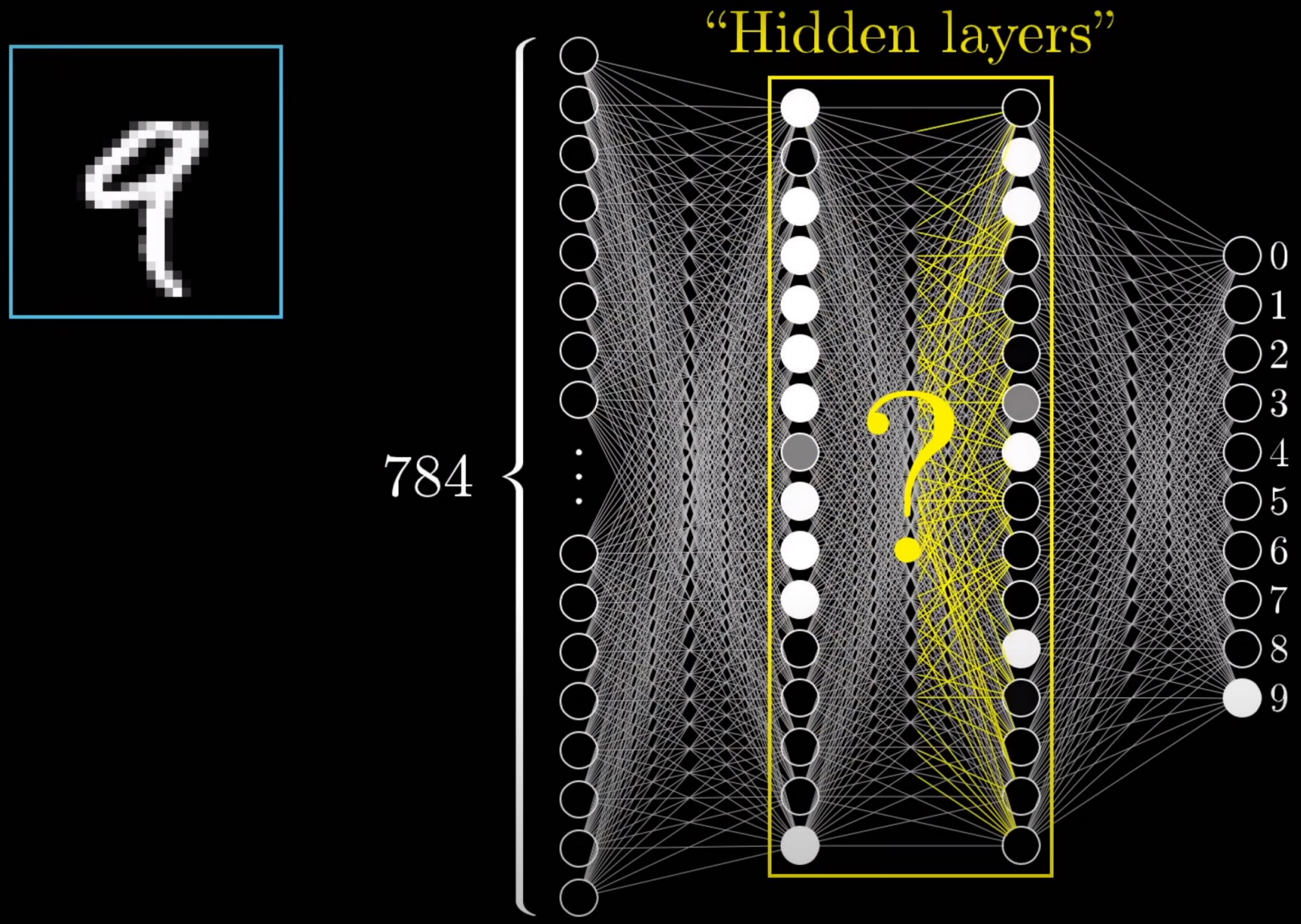


Přehrát (k)

1:48 / 19:13 • Series preview ›

Posunutím zobrazíte více

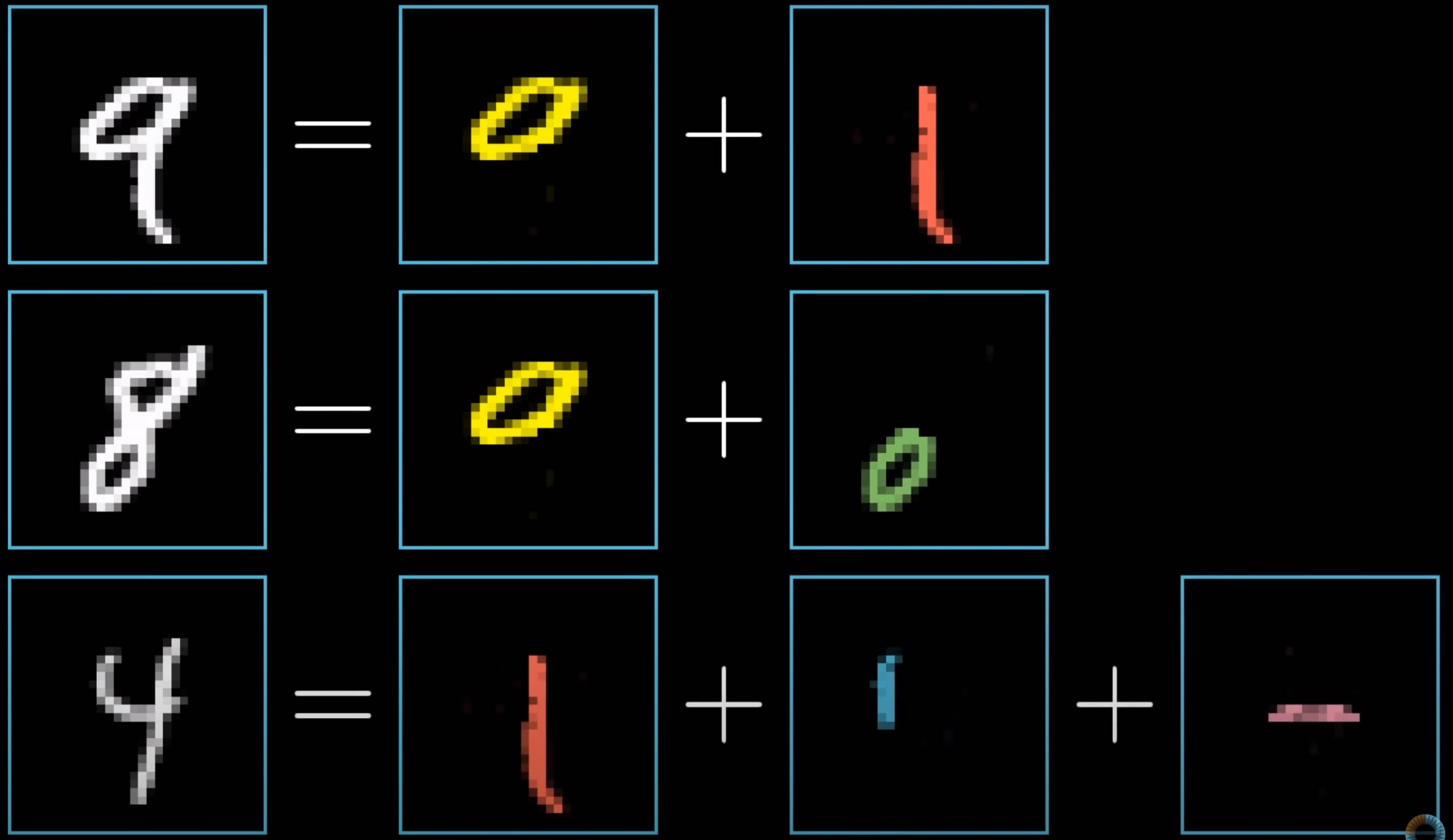
Co vlastně je neuronová síť? | Hluboké učení, část 1



4:39 / 19:13 • Introducing layers ›

Posunutím zobrazíte více

Co vlastně je neuronová síť? | Hluboké učení, část 1

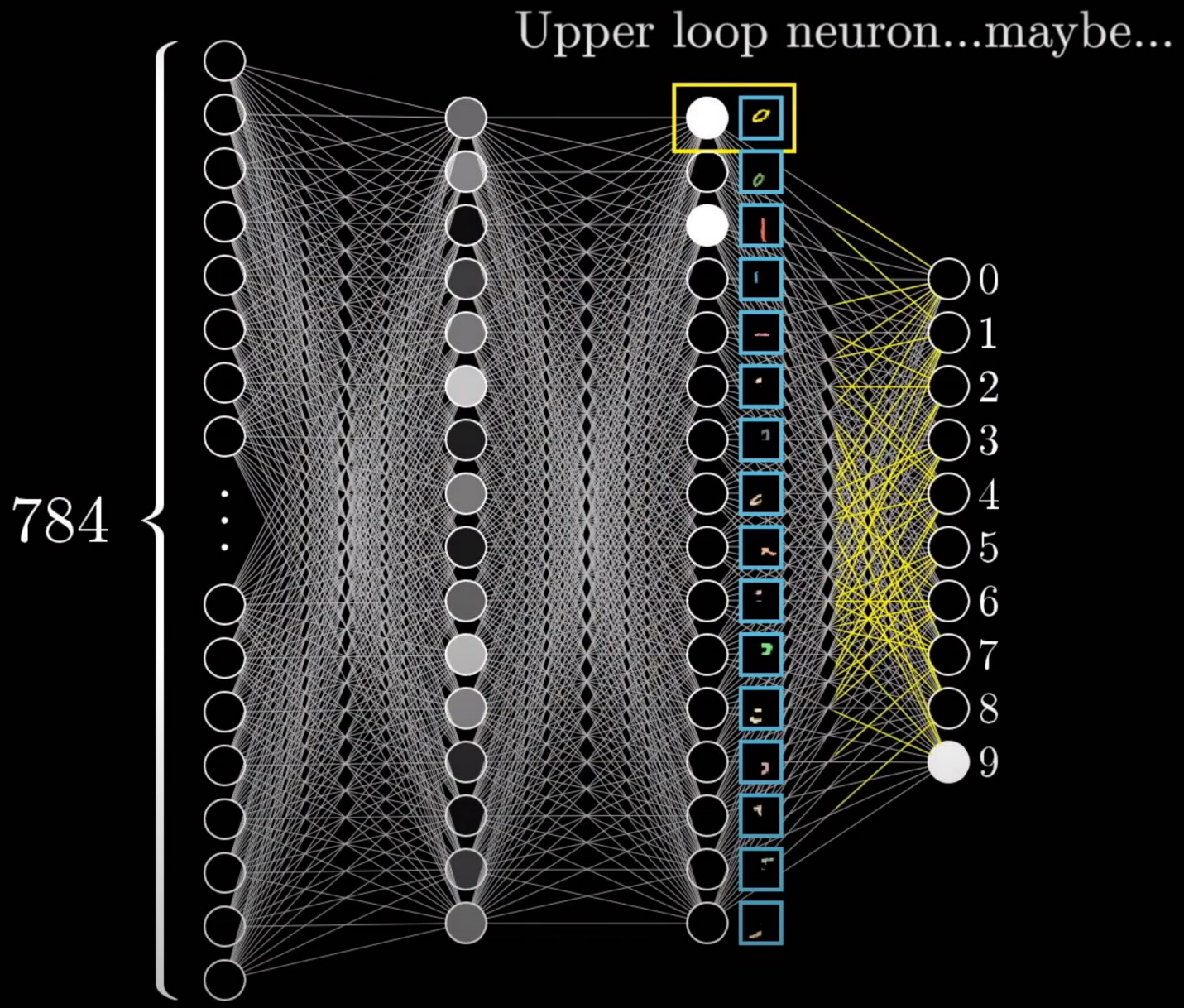


Přehrát (k)

6:06 / 19:13 • Why layers? ›

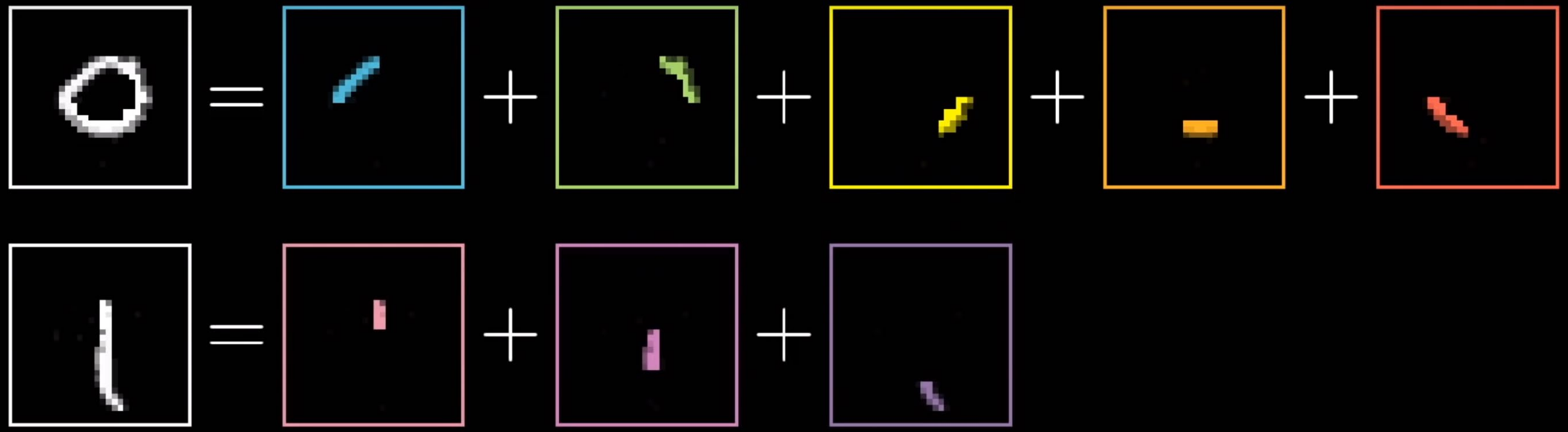
Posunutím zobrazíte více

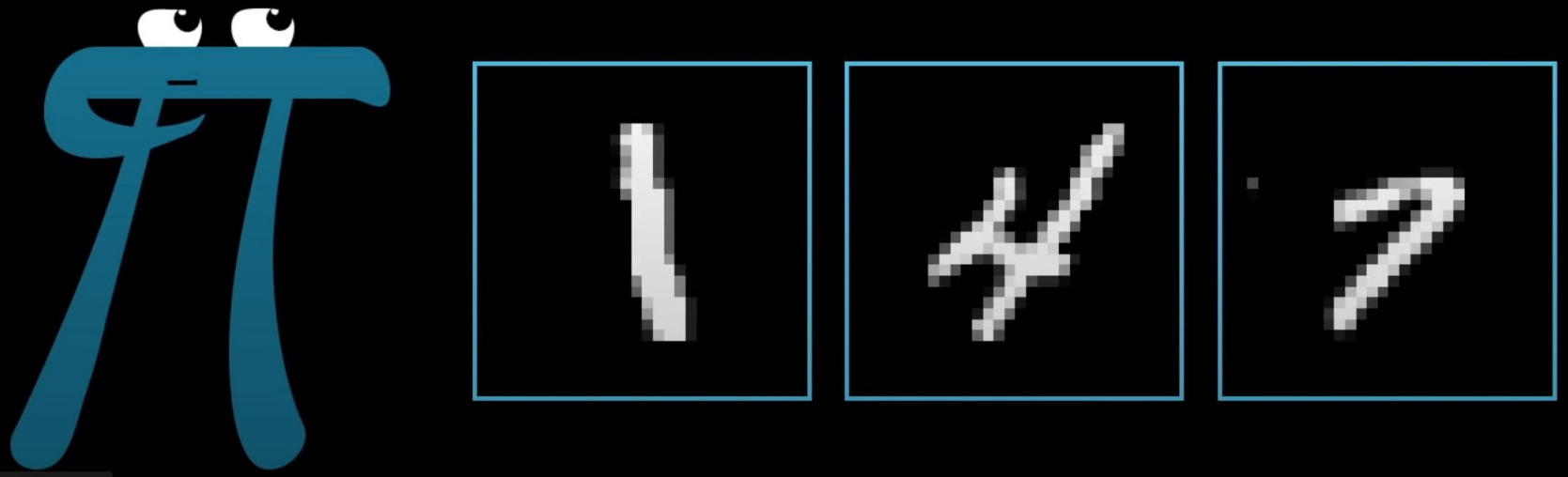
Co vlastně je neuronová síť? | Hluboké učení, část 1



6:27 / 19:13 • Why layers? ›
Posunutím zobrazíte více

Co vlastně je neuronová síť? | Hluboké učení, část 1



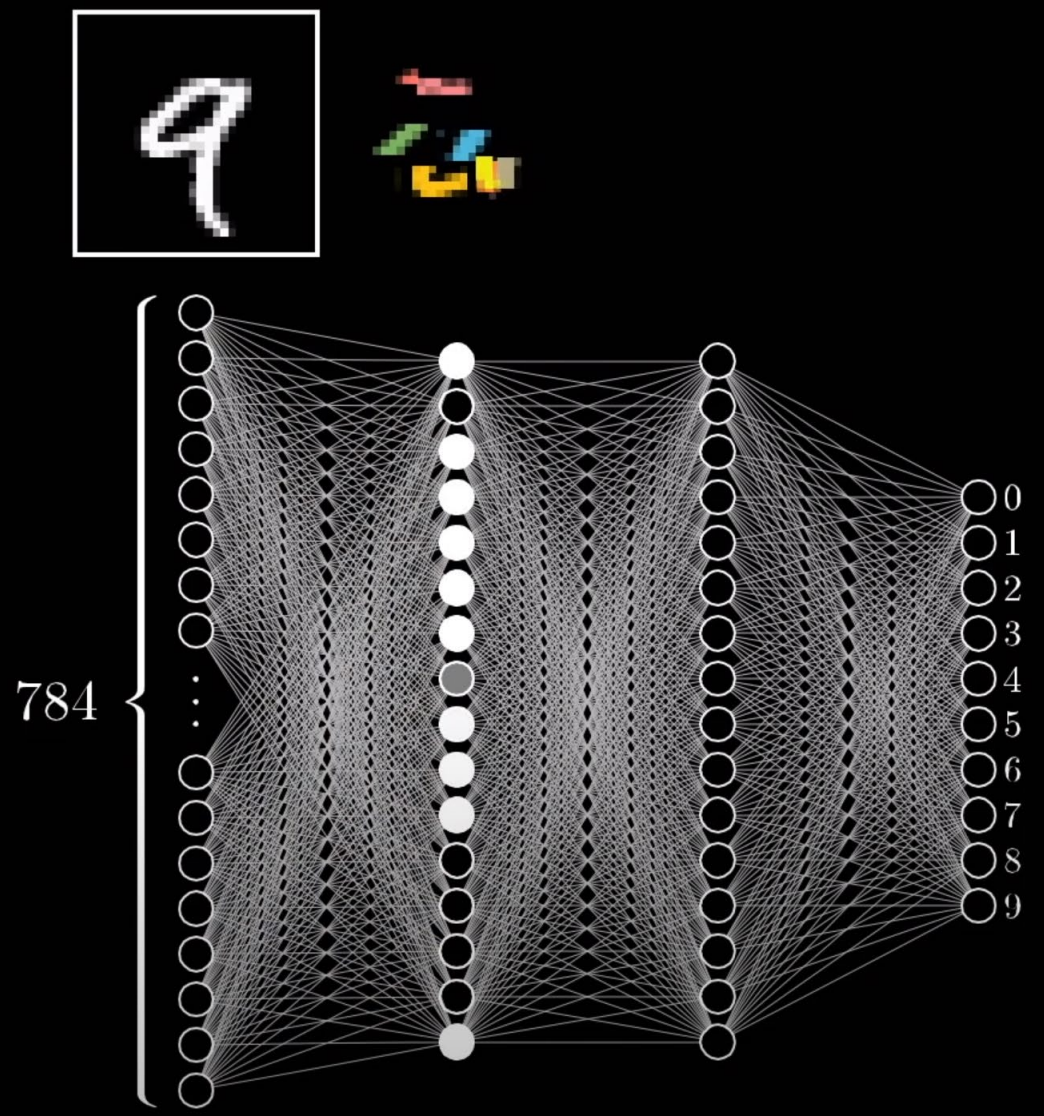


Přehrát (k)

7:13 / 19:13 • Why layers? ›

Posunutím zobrazíte více

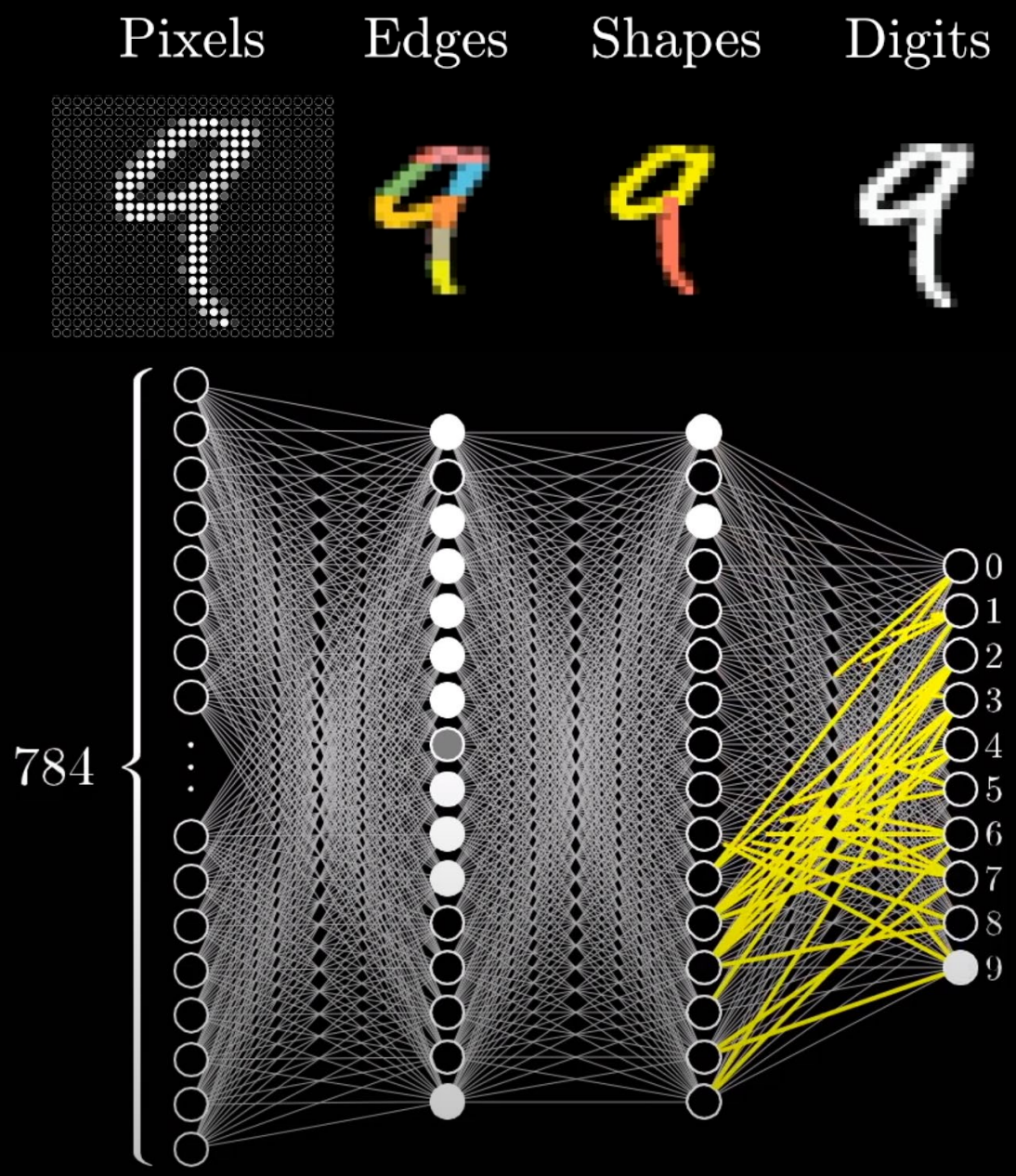
Co vlastně je neuronová síť? | Hluboké učení, část 1



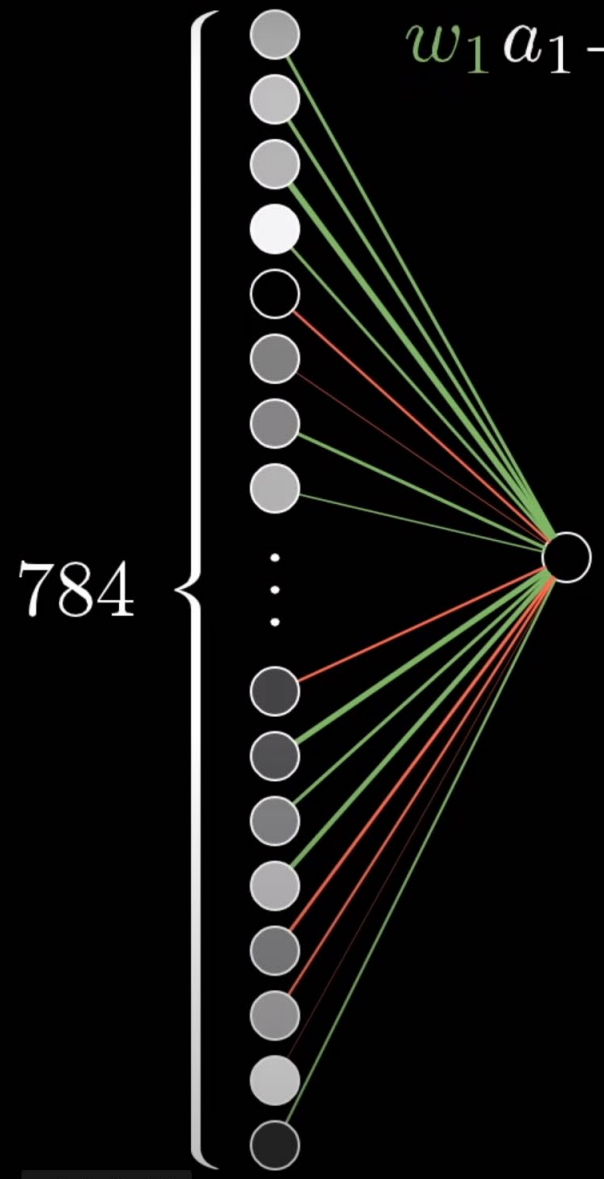
Přehrát (k)

7:31 / 19:13 • Why layers? ›

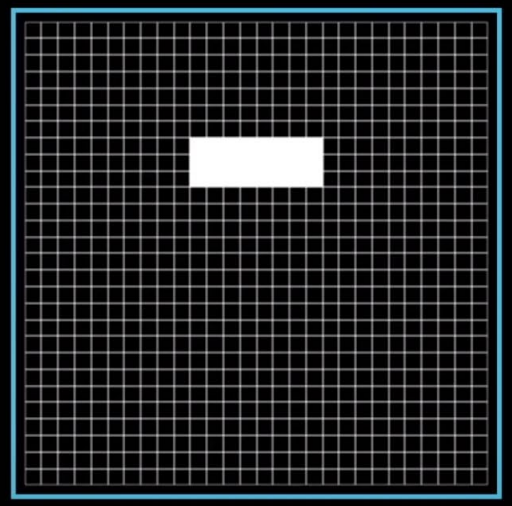
Posunutím zobrazíte více


Pixels
Edges
Shapes
Digits
784
0
1
2
3
4
5
6
7
8
9

$$w_1 a_1 + w_2 a_2 + w_3 a_3 + w_4 a_4 + \cdots + w_n a_n$$

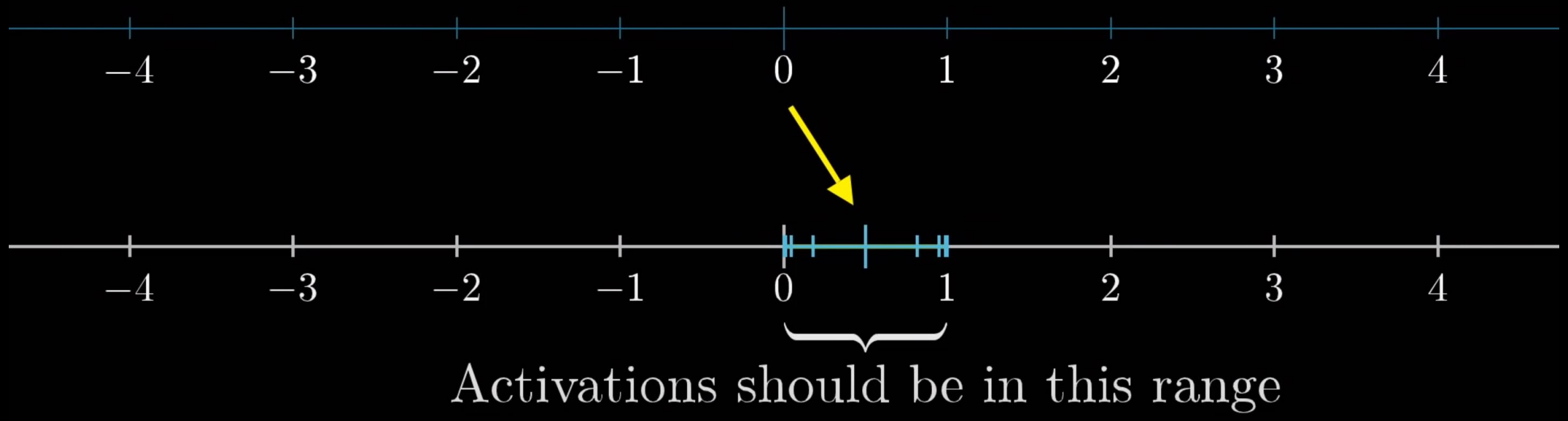


w_1: 2.07
w_2: 2.31
w_3: 3.64
w_4: 1.87
w_5: −1.51
w_6: −0.43
w_7: 2.01
w_8: 1.07
⋮



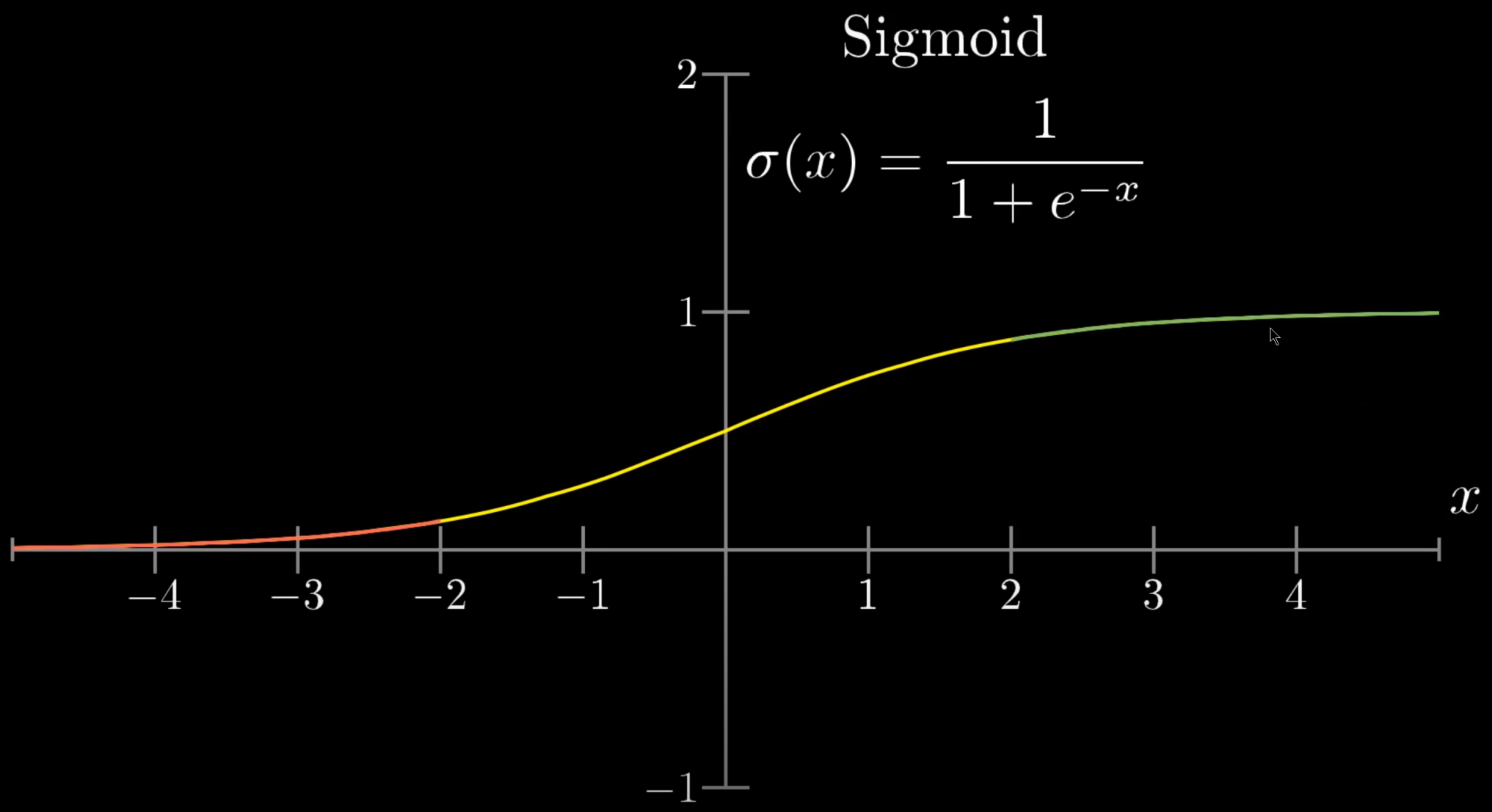
Přehrát (k)
9:27 / 19:13 • Edge detection example
Posunutím zobrazíte více
https://www.youtube.com/watch?list=PLucb_VkwnU8_oyUk5Cvr4HKdf_WA67JtI&v=O4-YJdKB0YI

$$w_1 a_1 + w_2 a_2 + w_3 a_3 + w_4 a_4 + \cdots + w_n a_n$$



10:29 / 19:13 • Edge detection example ›
Posunutím zobrazíte více

Co vlastně je neuronová síť? | Hluboké učení, část 1



10:44 / 19:13 • Edge detection example ›

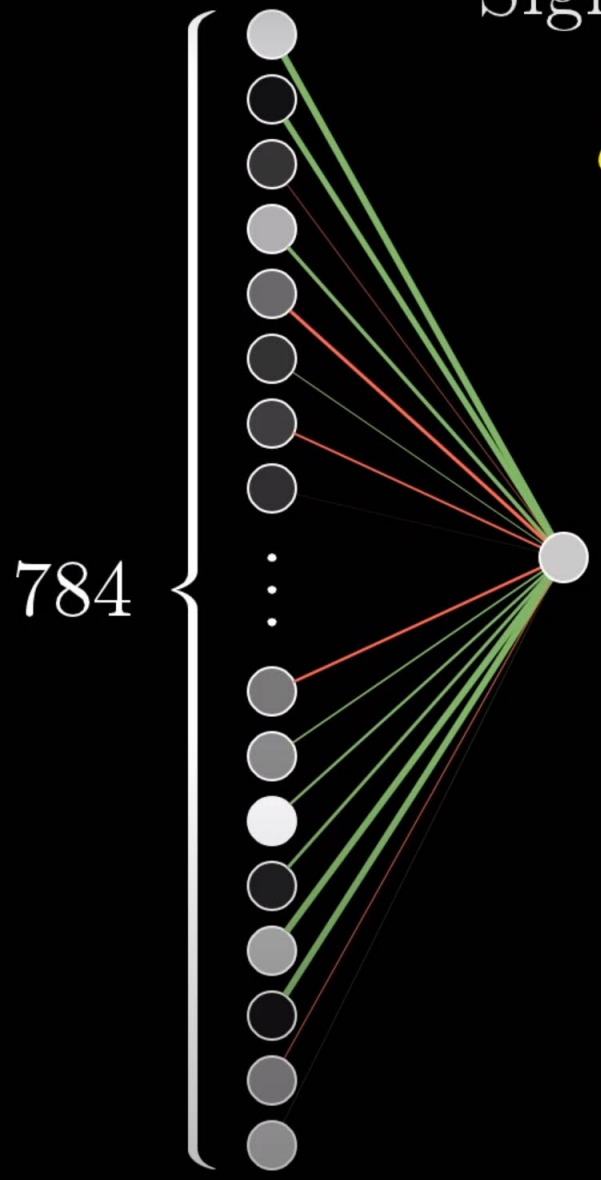
Posunutím zobrazíte více

Sigmoid

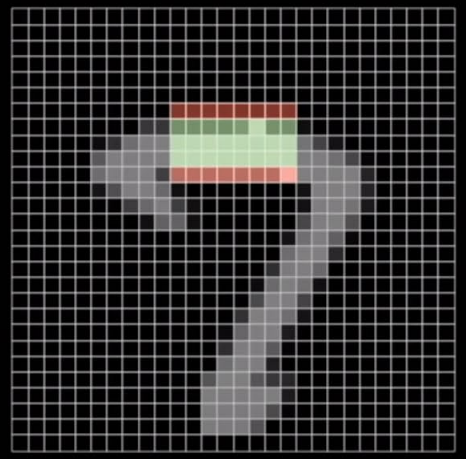
How positive is this?

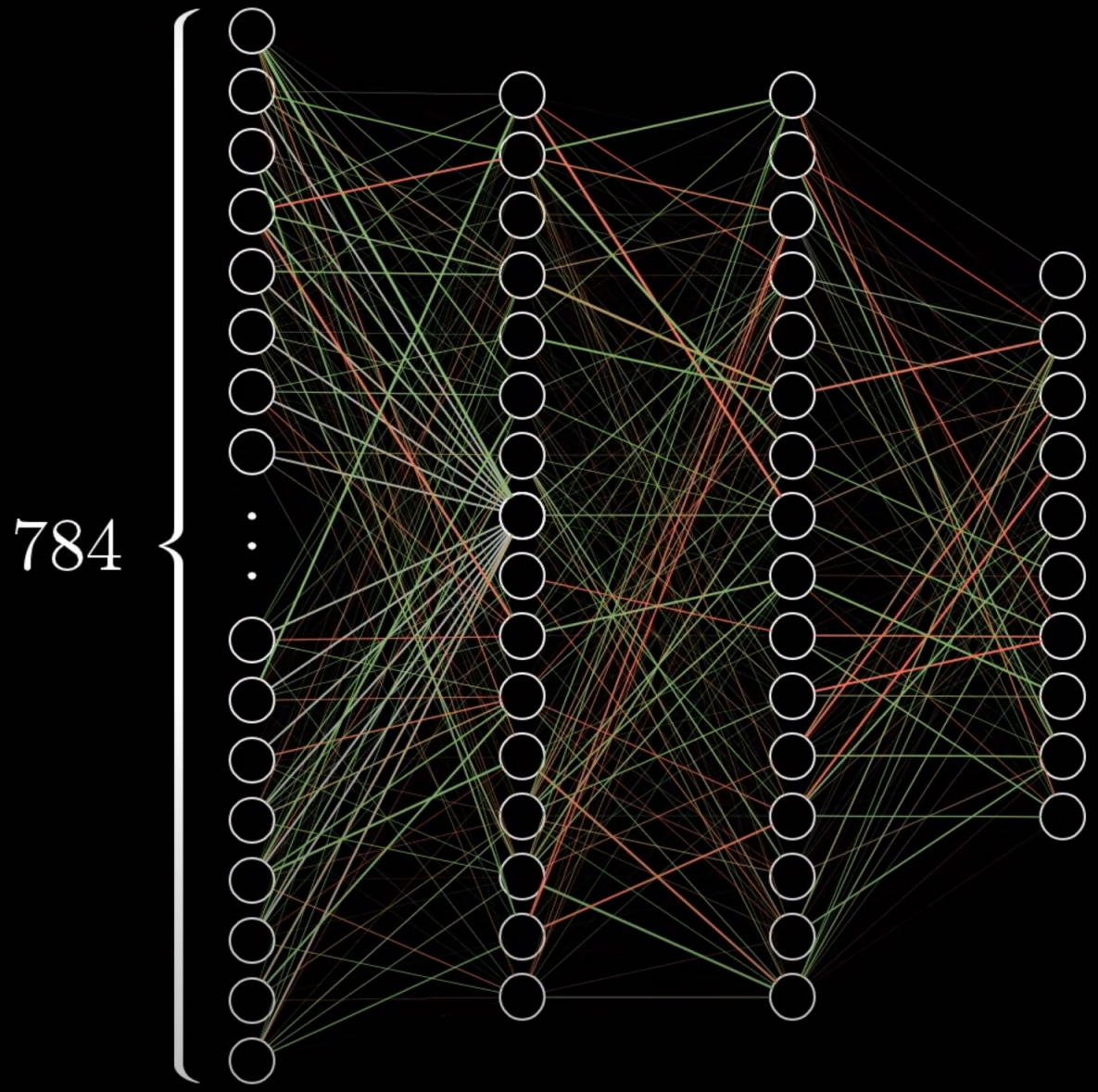
$$\sigma\left(w_1 a_1 + w_2 a_2 + w_3 a_3 + \cdots + w_n a_n \boxed{-10}\right)$$

"bias"



Only activate meaningfully when weighted sum > 10



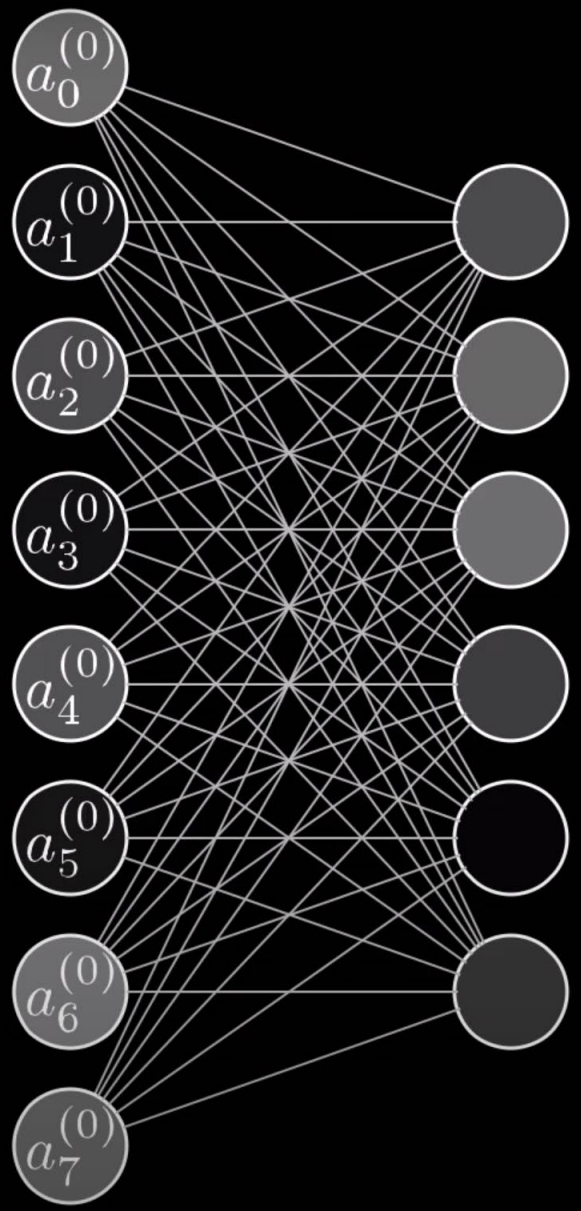


$$784 \times 16 + 16 \times 16 + 16 \times 10$$
weights

$$16 + 16 + 10$$
biases

$$13{,}002$$

12:27 / 19:13 • Counting weights and biases
Posunutím zobrazíte více



$$\mathbf{a}^{(1)} = \sigma\left(\mathbf{W}\mathbf{a}^{(0)} + \mathbf{b}\right)$$

$$\sigma\left(\begin{bmatrix} w_{0,0} & w_{0,1} & \cdots & w_{0,n} \\ w_{1,0} & w_{1,1} & \cdots & w_{1,n} \\ \vdots & \vdots & \ddots & \vdots \\ w_{k,0} & w_{k,1} & \cdots & w_{k,n} \end{bmatrix} \begin{bmatrix} a_0^{(0)} \\ a_1^{(0)} \\ \vdots \\ a_n^{(0)} \end{bmatrix} + \begin{bmatrix} b_0 \\ b_1 \\ \vdots \\ b_n \end{bmatrix}\right)$$

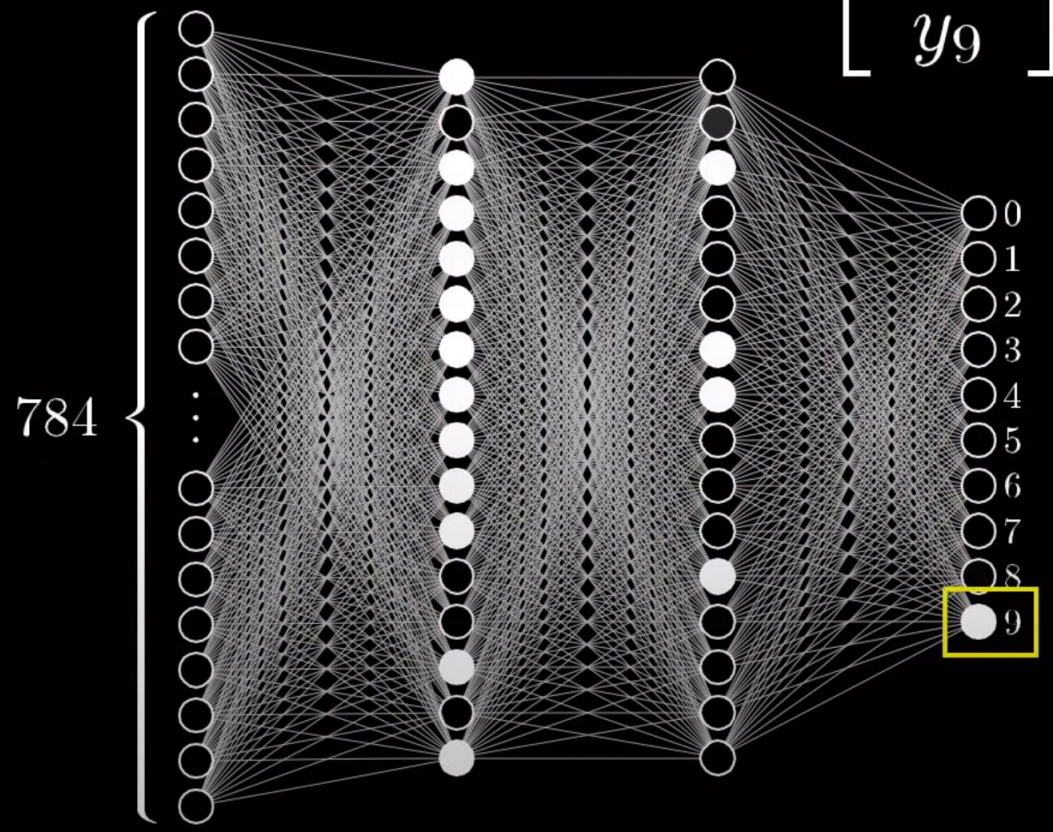
Ukončit režim celé obrazovky (f)
15:05 / 19:13 • Notation and linear algebra ›
Posunutím zobrazíte více

$$f(a_0, \ldots, a_{783}) = \begin{bmatrix} y_0 \\ \vdots \\ y_9 \end{bmatrix}$$

Network

↓

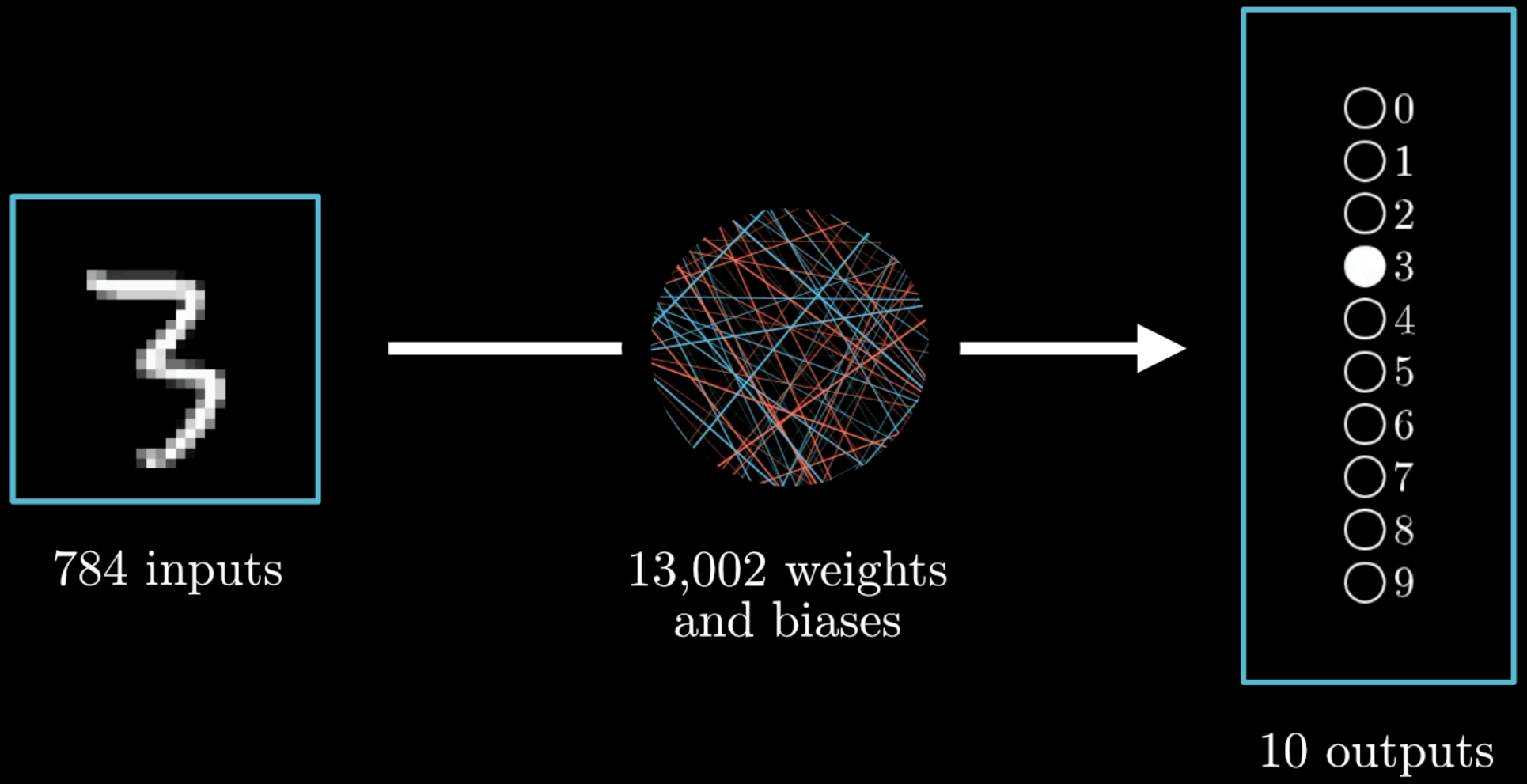
Function



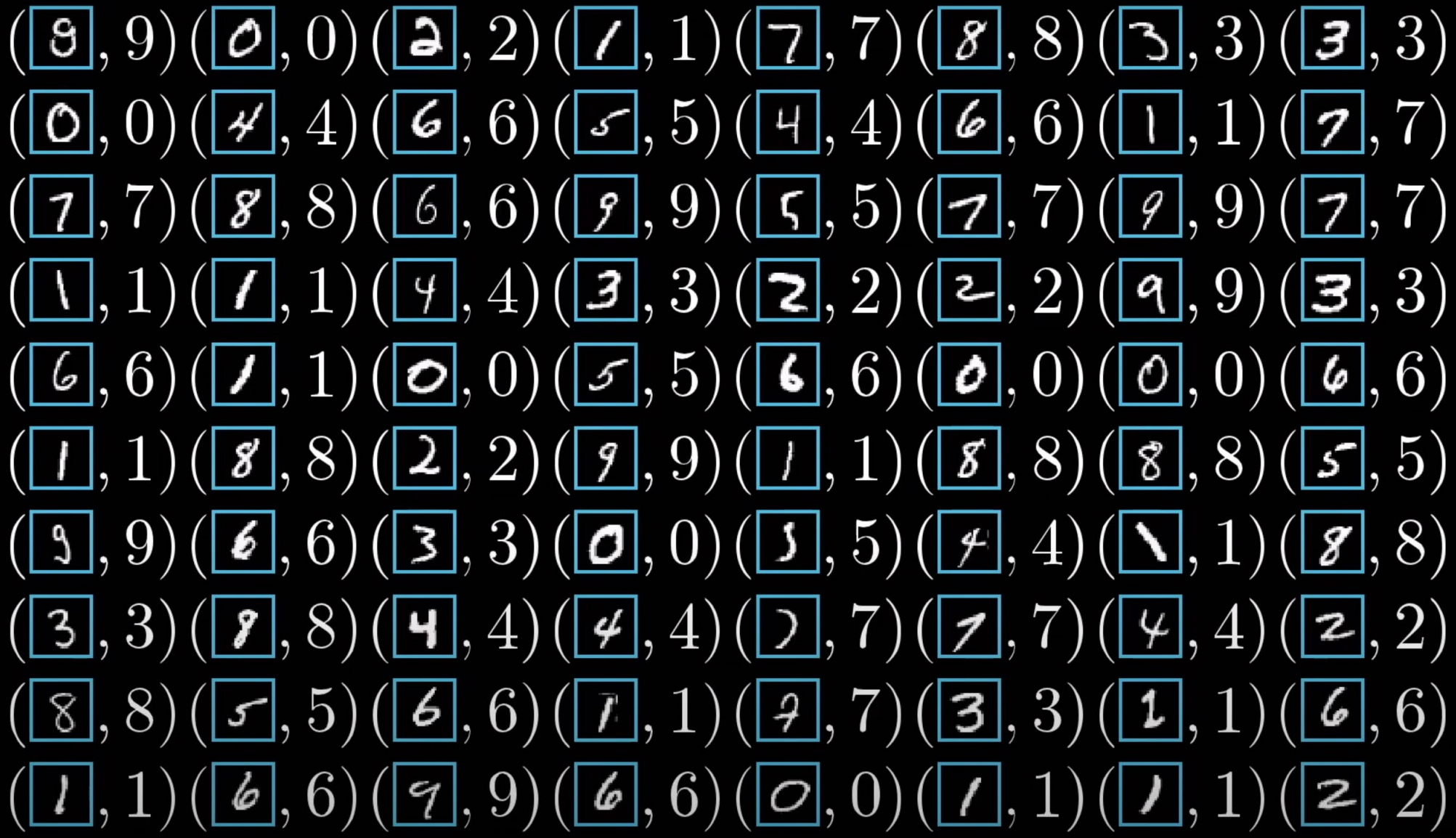
~~Thing that holds a number~~

Přehrát (k)
15:50 / 19:13 • Recap ›
Posunutím zobrazíte více

Neural network function



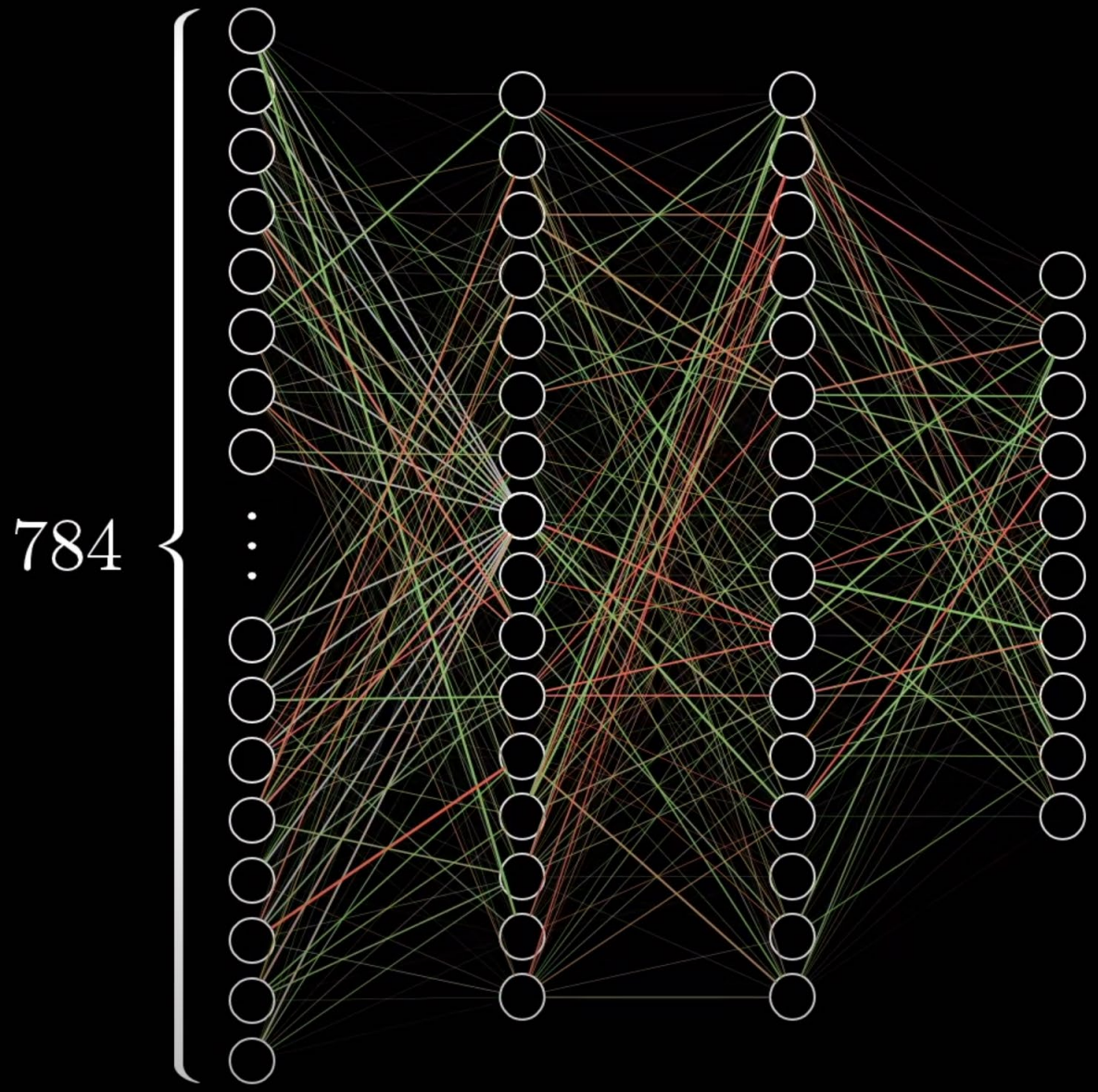
Gradient descent, how neural networks learn | Chapter 2, Deep learning



Přehrát (k)

2:42 / 21:00 • Using training data ›

Posunutím zobrazíte více



$$784 \times 16 + 16 \times 16 + 16 \times 10$$

weights

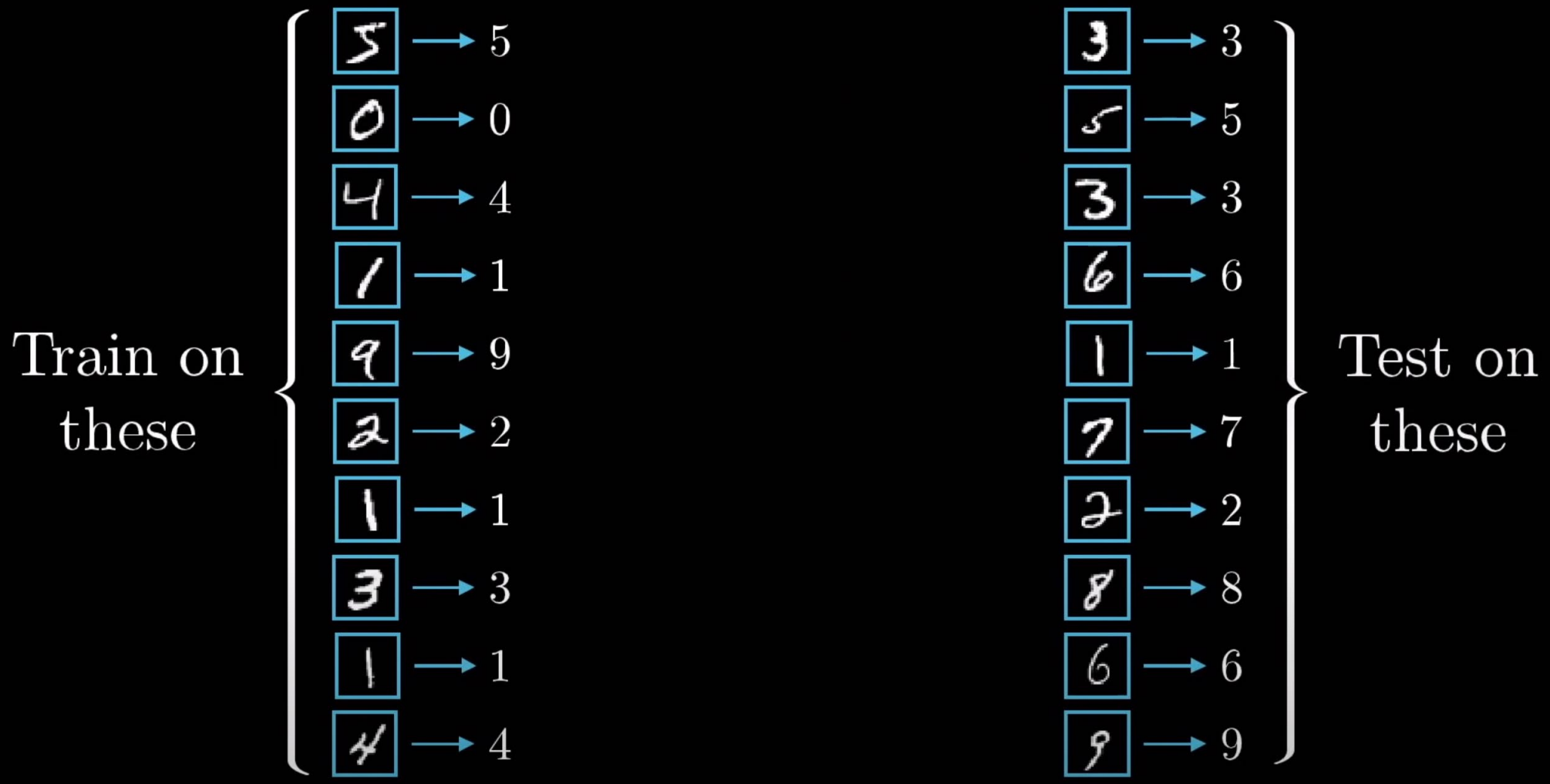
$$16 + 16 + 10$$

biases

$$13{,}002$$

Learning $\rightarrow$ Finding the right weights and biases

1:24 / 21:00 • Recap ›
Posunutím zobrazíte více

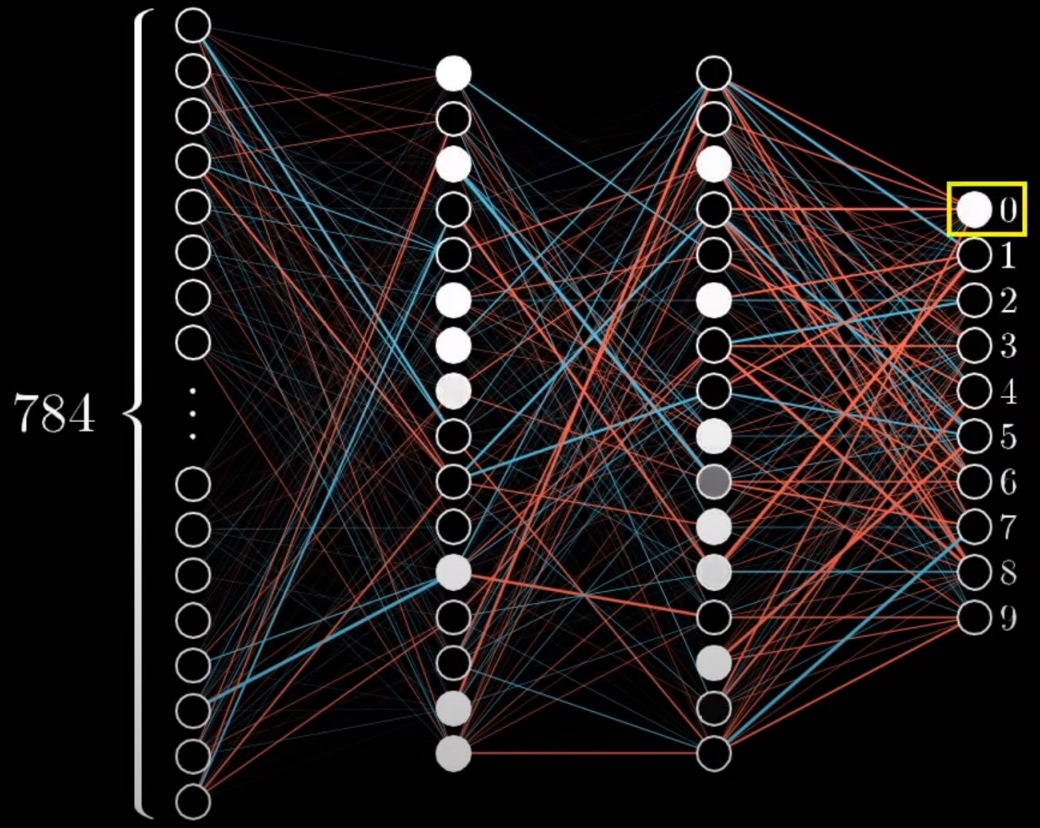


Přehrát (k)
2:21 / 21:00 • Using training data ›
Posunutím zobrazíte více

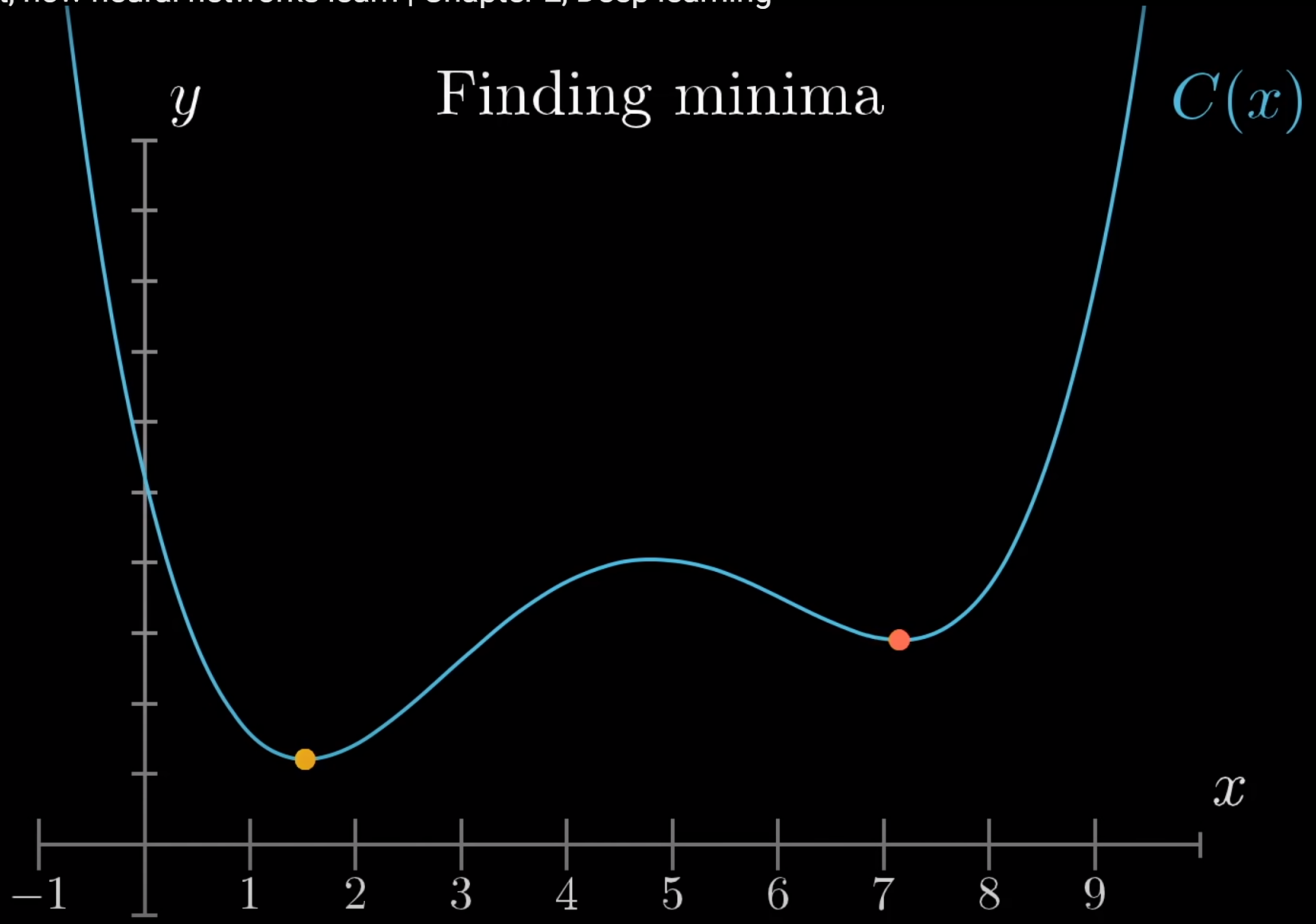
Testing data

Guess → 0

$$\frac{\text{Number correct}}{\text{total}} = \frac{55}{56} = 0.982$$



Gradient descent, how neural networks learn | Chapter 2, Deep learning

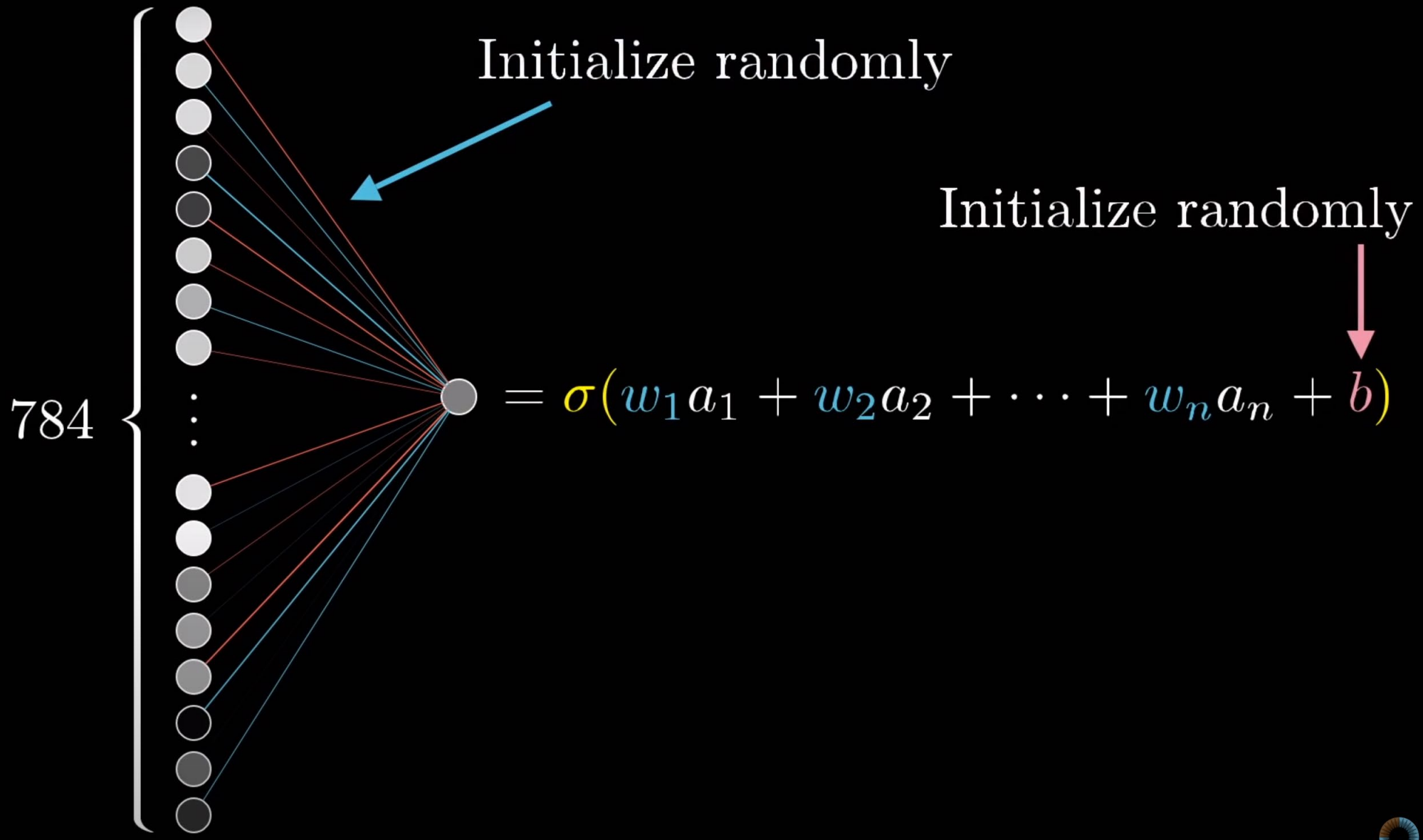


Přehrát (k)

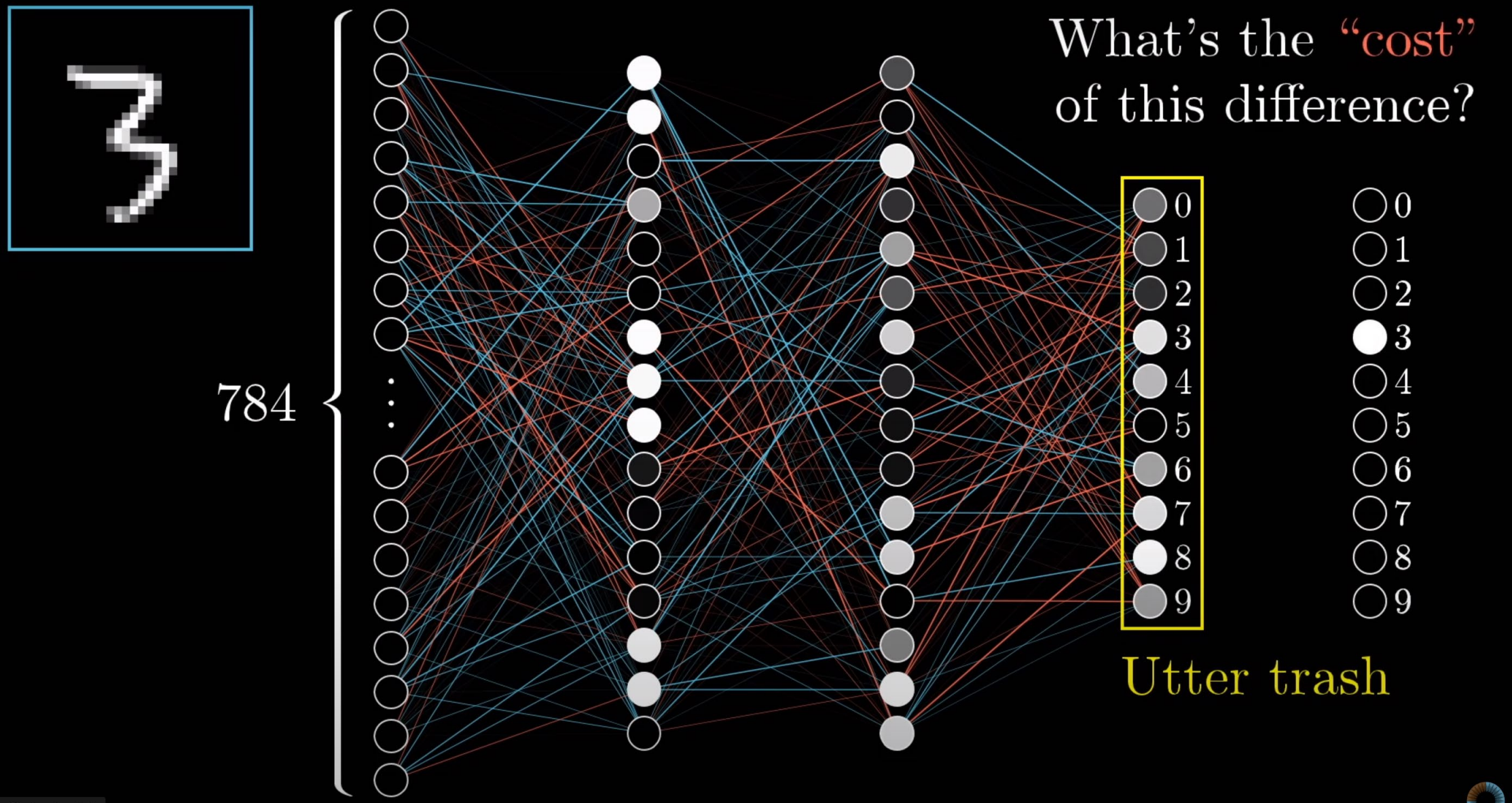
3:02 / 21:00 • Cost functions ›

Posunutím zobrazíte více

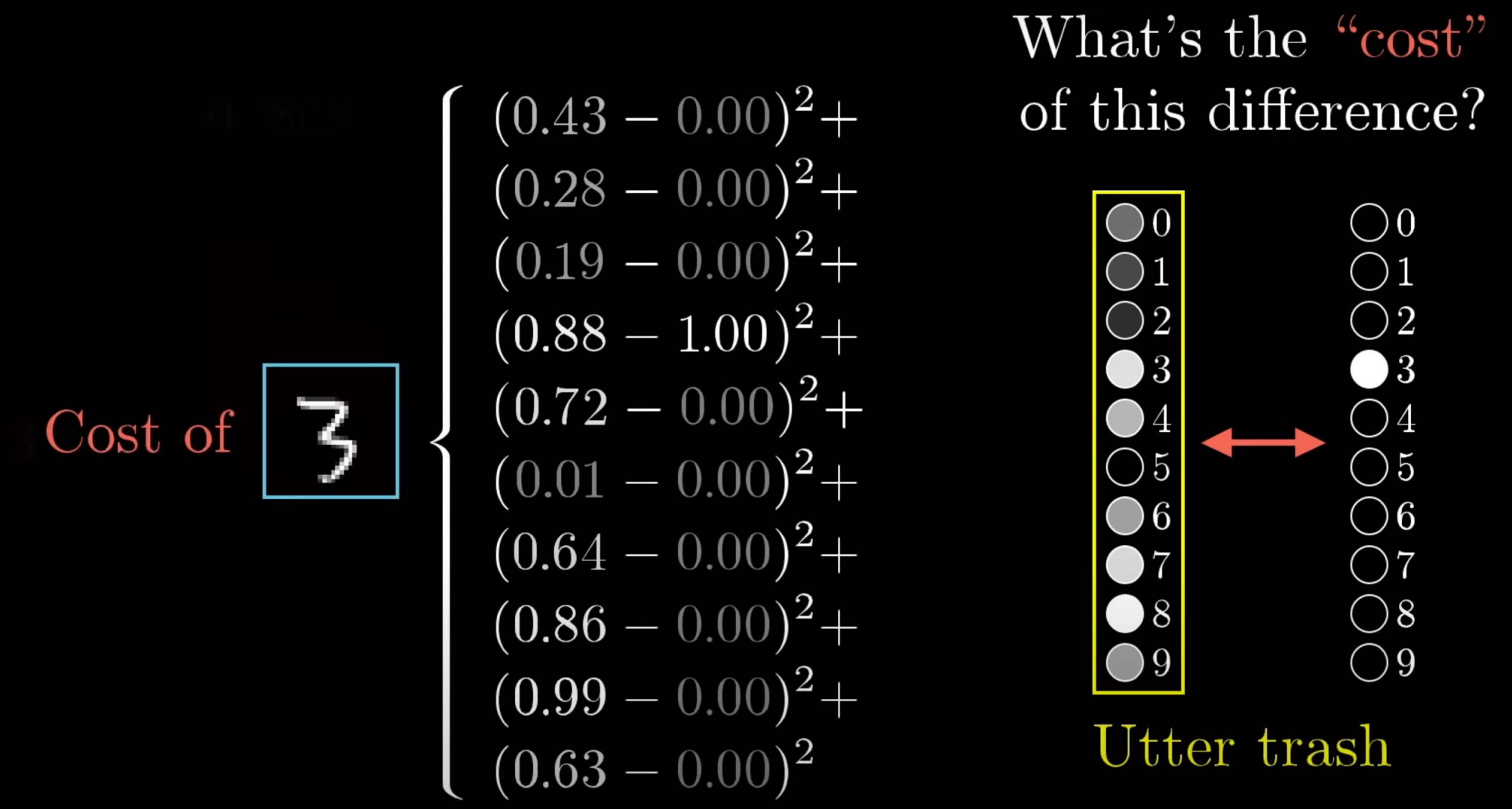
https://www.youtube.com/watch?v=Ilg3gGewQ5U



Přehrát (k)
3:23 / 21:00 • Cost functions ›
Posunutím zobrazíte více
https://www.youtube.com/watch?v=Ilg3gGewQ5U



Přehrát (k)
3:38 / 21:00 • Cost functions ›
Posunutím zobrazíte více

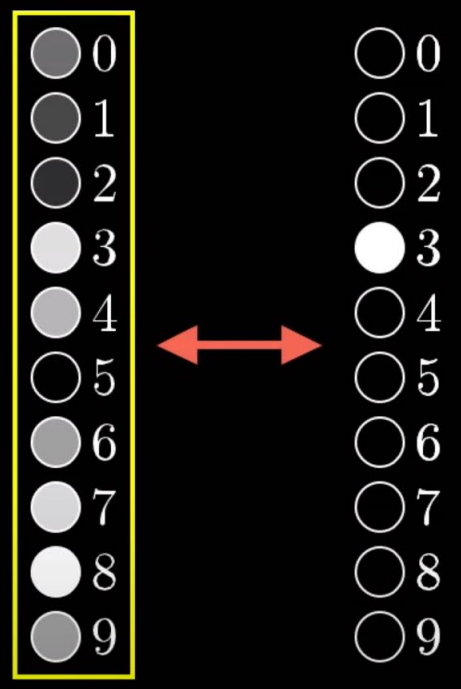


Přehrát (k)
4:01 / 21:00 • Cost functions ›
Posunutím zobrazíte více

Cost of 3

$$3.37 \left\{ \begin{array}{l} 0.1863 \leftarrow (0.43 - 0.00)^2 + \\ 0.0809 \leftarrow (0.28 - 0.00)^2 + \\ 0.0357 \leftarrow (0.19 - 0.00)^2 + \\ 0.0138 \leftarrow (0.88 - 1.00)^2 + \\ 0.5242 \leftarrow (0.72 - 0.00)^2 + \\ 0.0001 \leftarrow (0.01 - 0.00)^2 + \\ 0.4079 \leftarrow (0.64 - 0.00)^2 + \\ 0.7388 \leftarrow (0.86 - 0.00)^2 + \\ 0.9817 \leftarrow (0.99 - 0.00)^2 + \\ 0.3998 \leftarrow (0.63 - 0.00)^2 \end{array} \right.$$

What's the "cost" of this difference?



Utter trash

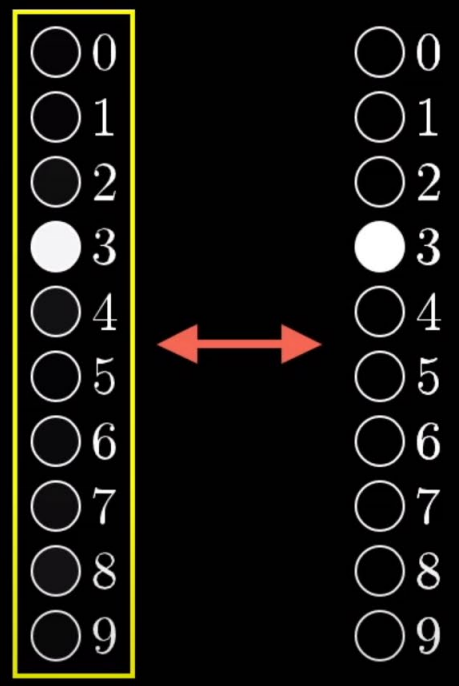
Cena jednoho příkladu !!!

Přehrát (k)
4:02 / 21:00 • Cost functions ›
Posunutím zobrazíte více

Cost of 3

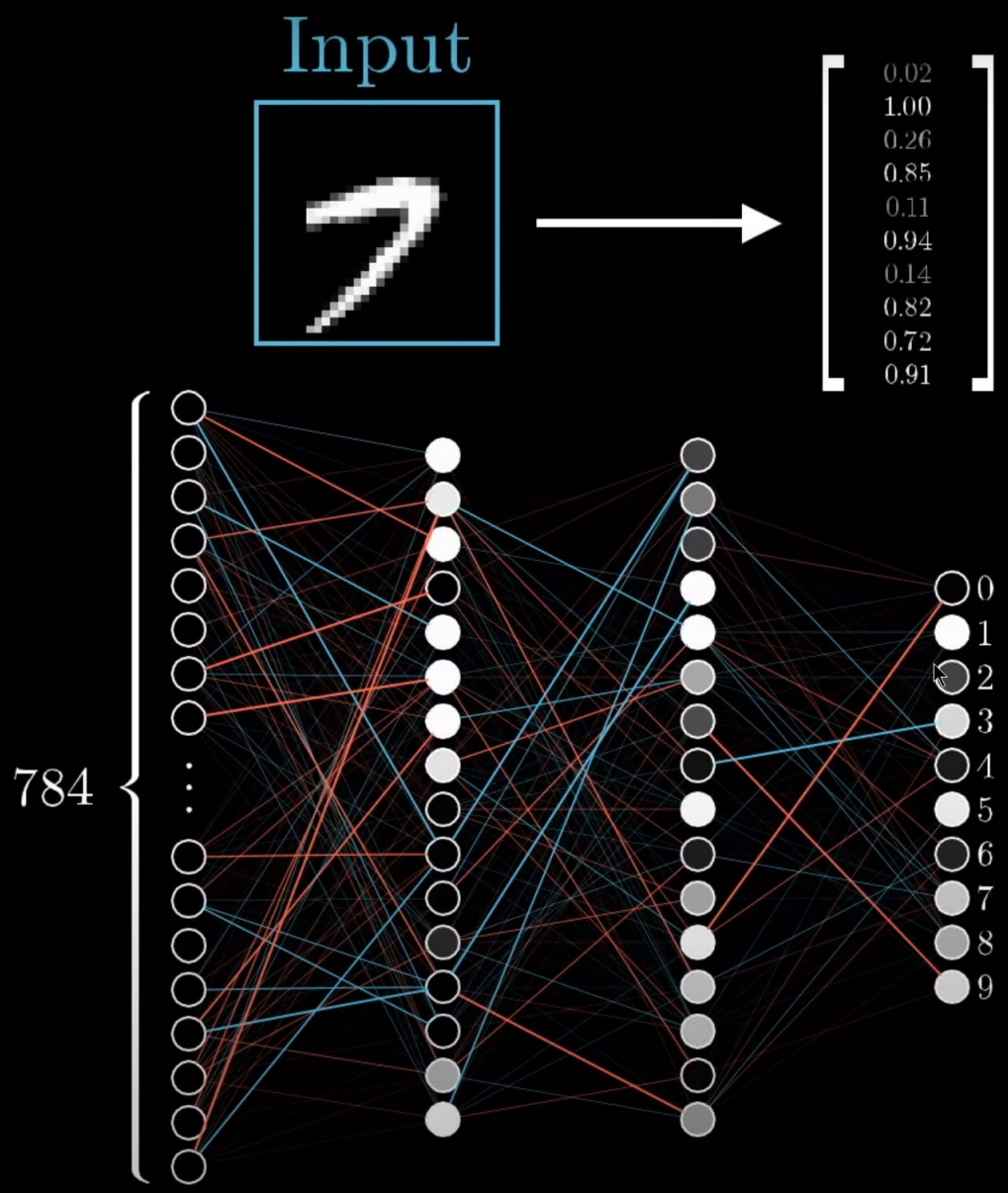
$$0.03 \left\{ \begin{array}{ll} 0.0006 \leftarrow & (0.02 - 0.00)^2 + \\ 0.0007 \leftarrow & (0.03 - 0.00)^2 + \\ 0.0039 \leftarrow & (0.06 - 0.00)^2 + \\ 0.0009 \leftarrow & (0.97 - 1.00)^2 + \\ 0.0055 \leftarrow & (0.07 - 0.00)^2 + \\ 0.0004 \leftarrow & (0.02 - 0.00)^2 + \\ 0.0022 \leftarrow & (0.05 - 0.00)^2 + \\ 0.0033 \leftarrow & (0.06 - 0.00)^2 + \\ 0.0072 \leftarrow & (0.08 - 0.00)^2 + \\ 0.0018 \leftarrow & (0.04 - 0.00)^2 \end{array} \right.$$

What's the "cost" of this difference?



Utter trash

Přehrát (k)
4:13 / 21:00 • Cost functions ›
Posunutím zobrazíte více



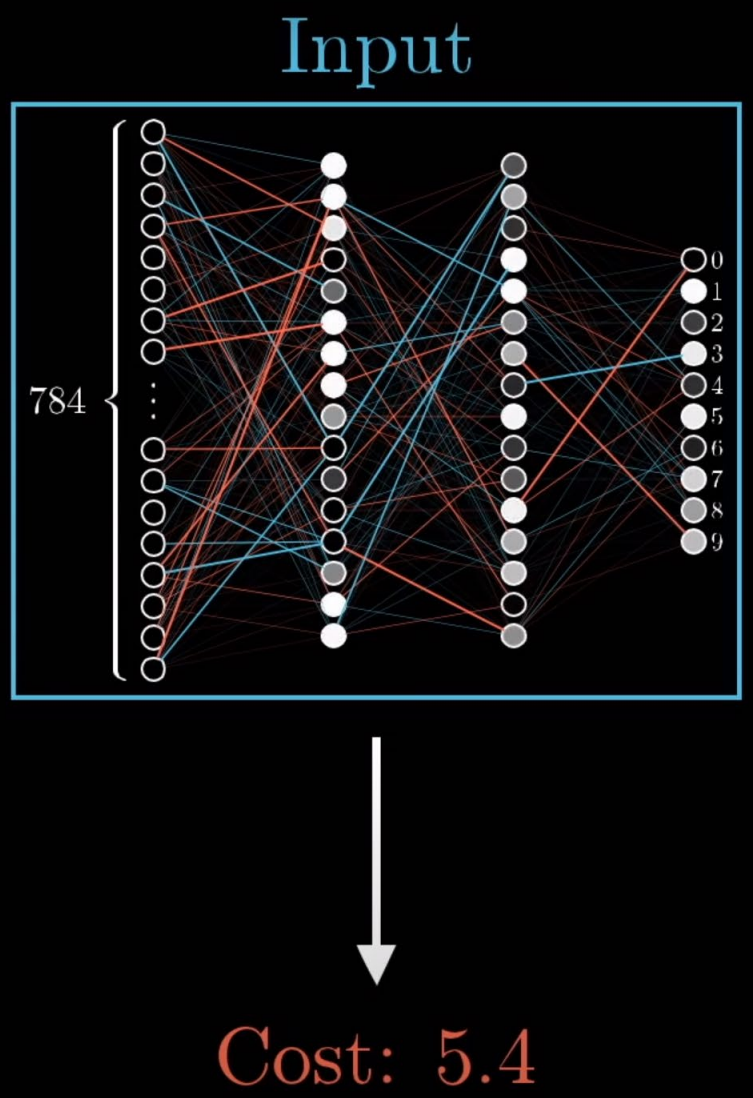
Neural network function

Input: 784 numbers (pixels)

Output: 10 numbers

Parameters: 13,002 weights/biases

4:50 / 21:00 • Cost functions ›
Posunutím zobrazíte více



Cost function

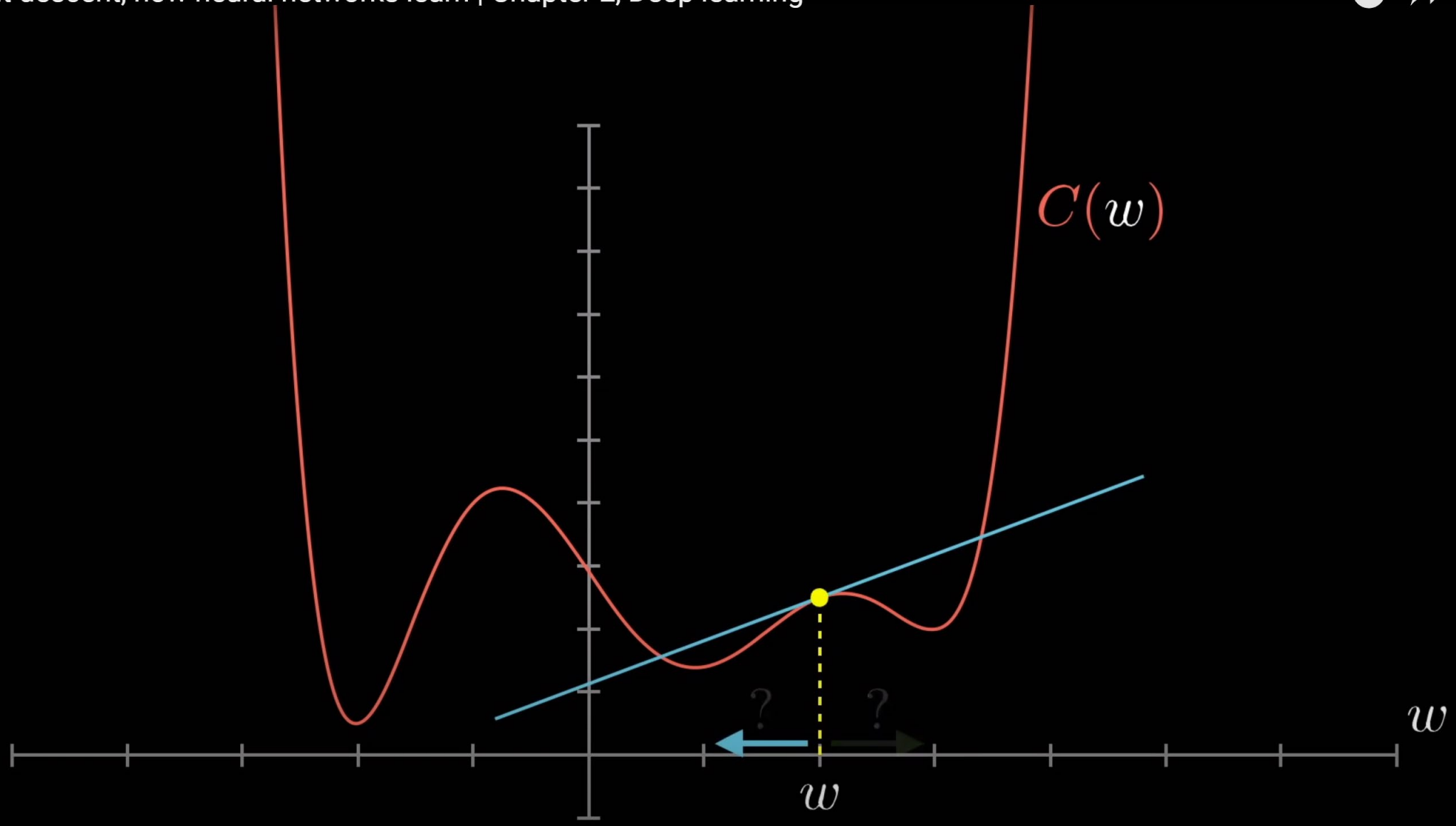
Input: 13,002 weights/biases

Output: 1 number (the cost)

Parameters: Many, many, many training examples

5:07 / 21:00 • Cost functions ›
Posunutím zobrazíte více

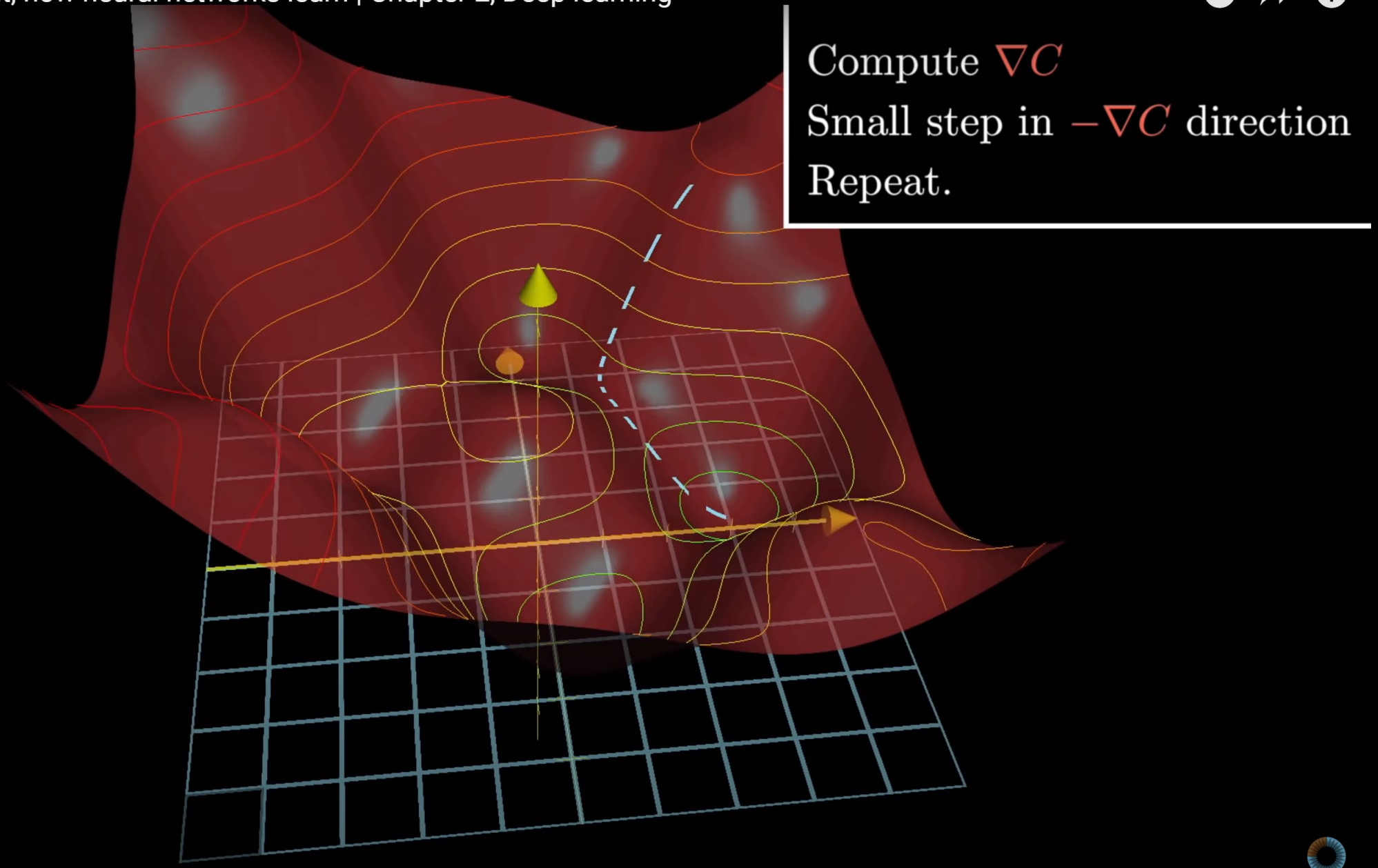
Gradient descent, how neural networks learn | Chapter 2, Deep learning



Přehrát (k)

6:04 / 21:00 • Cost functions ›

Posunutím zobrazíte více



Přehrát (k)
8:28 / 21:00 • Gradient descent ›
Posunutím zobrazíte více

13,002 weights and biases

How to nudge all weights and biases

$$\vec{\mathbf{W}} = \begin{bmatrix} 2.43 \\ -1.12 \\ 1.47 \\ \vdots \\ -0.96 \\ 3.82 \\ 1.21 \end{bmatrix} \qquad -\nabla C(\vec{\mathbf{W}}) = \begin{bmatrix} 0.18 \\ 0.45 \\ -0.51 \\ \vdots \\ 0.40 \\ -0.32 \\ 0.82 \end{bmatrix}$$

Přehrát (k)
8:49 / 21:00 • Gradient descent ›
Posunutím zobrazíte více

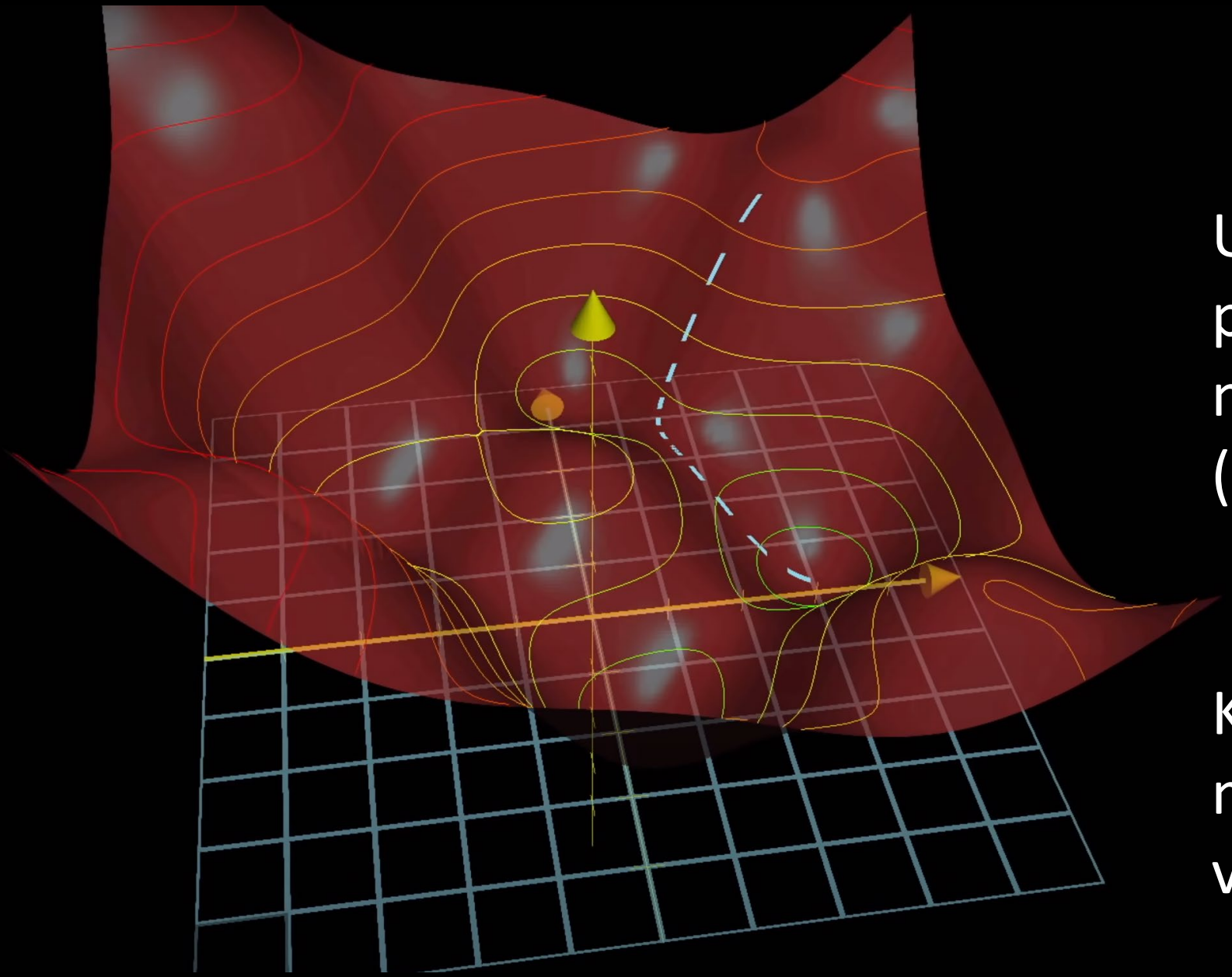
$$\vec{\mathbf{W}} = \begin{bmatrix} w_0 \\ w_1 \\ w_2 \\ \vdots \\ w_{13,000} \\ w_{13,001} \\ w_{13,002} \end{bmatrix}$$

$$-\nabla C(\vec{\mathbf{W}}) = \begin{bmatrix} 0.31 \\ 0.03 \\ -1.25 \\ \vdots \\ 0.78 \\ -0.37 \\ 0.16 \end{bmatrix}$$

w_0 should increase somewhat
w_1 should increase a little
w_2 should decrease a lot

$w_{13,000}$ should increase a lot
$w_{13,001}$ should decrease somewhat
$w_{13,002}$ should increase a little

Přehrát (k)
11:02 / 21:00 • Gradient descent ›
Posunutím zobrazíte více

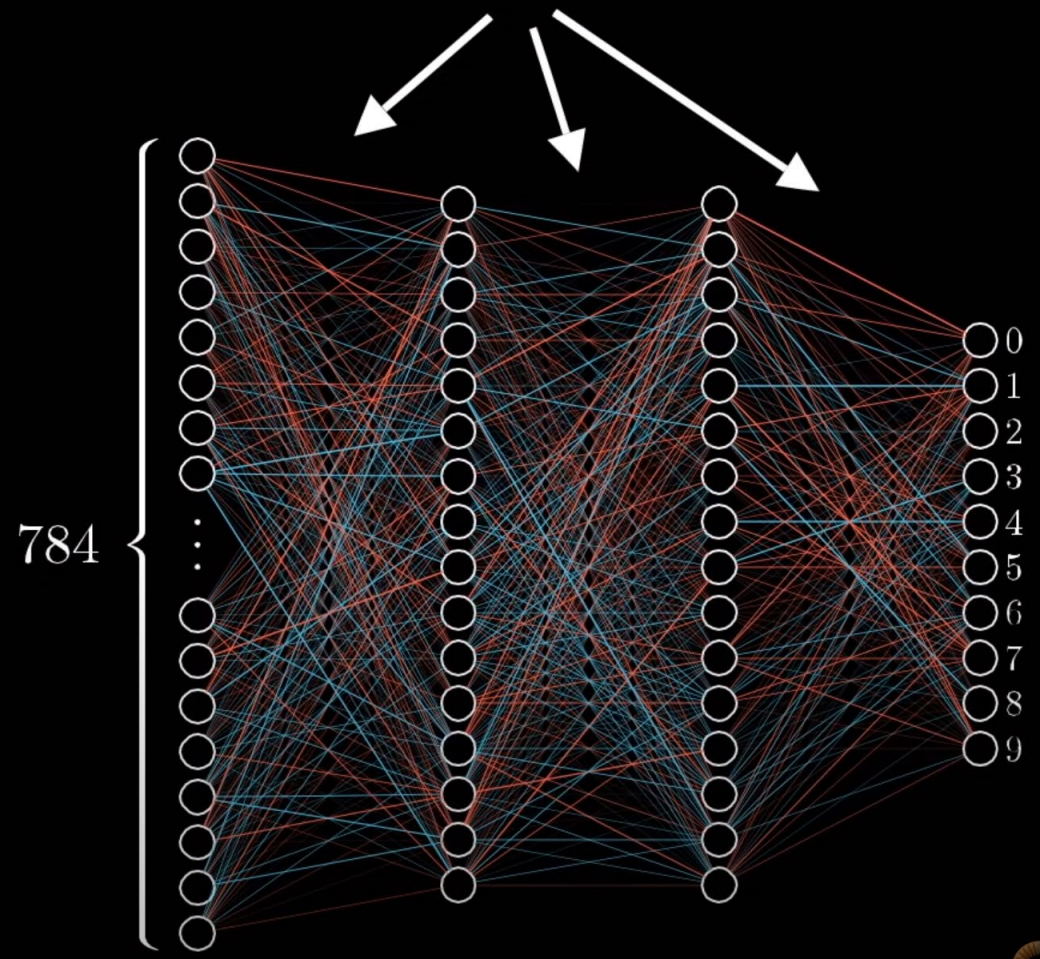


Učení
postupná minimalizace
nákladové funkce
(kritéria)

Každý krok
musí spočítat
všechny příklady

$$-\nabla C(\underbrace{\ldots}_{\text{All weights and biases}}) = \begin{bmatrix} -0.01 \\ 0.65 \\ -0.61 \\ 0.05 \\ \vdots \\ 1.52 \\ 1.53 \\ -1.42 \\ -1.15 \end{bmatrix}$$

Change by some small multiple of $-\nabla C(\ldots)$



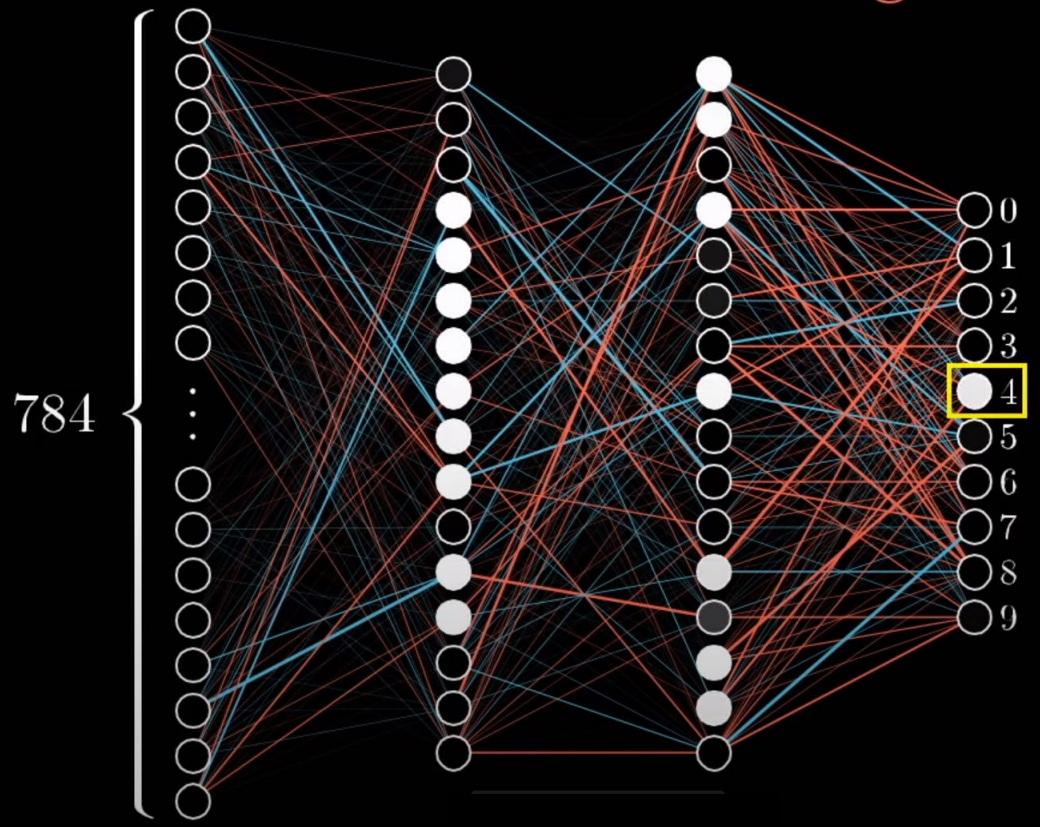
Přehrát (k)
13:00 / 21:00 • Gradient descent recap ›
Posunutím zobrazíte více

Testing data

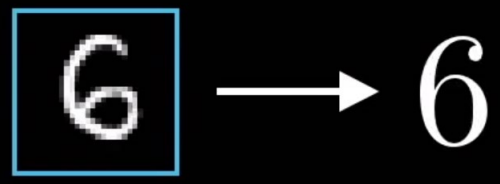
Guess → 4

Wrong!

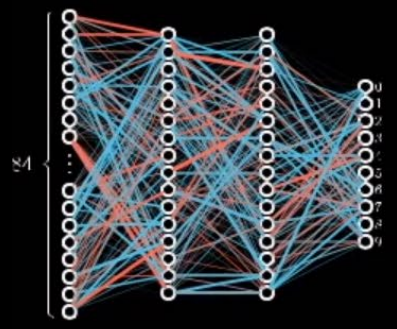
$$\frac{\text{Number correct}}{\text{total}} = \frac{90}{93} = 0.968$$



Wrong!



realita je složitější



Convolutional NN

LSTM

3Blue1Brown

text: https://www.3blue1brown.com/topics/neural-networks

videa: https://youtu.be/aircAruvnKk
https://youtu.be/IHZwWFHWa-w
https://youtu.be/Ilg3gGewQ5U
https://youtu.be/tIeHLnjs5U8

kniha: John D. Kelleher
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Language : English
Paperback : 296 pages
ISBN-10 : 0262537559
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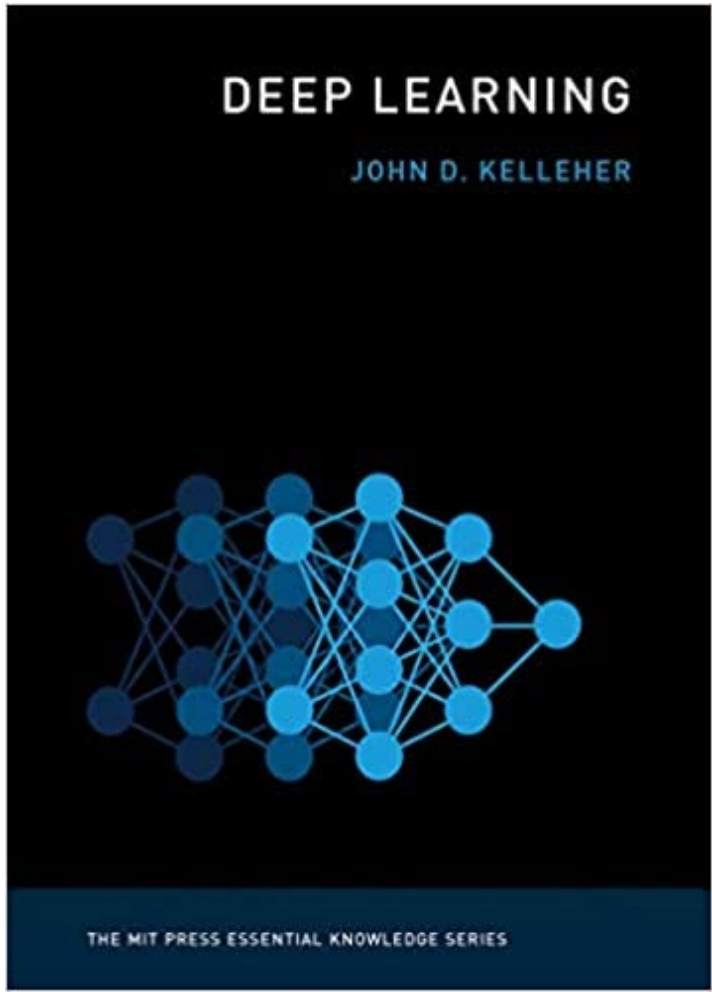
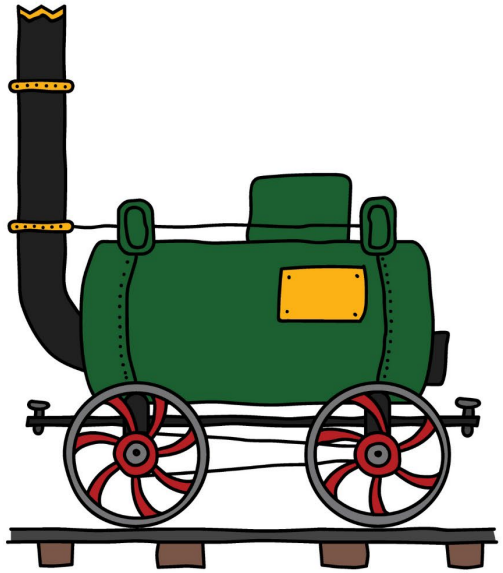
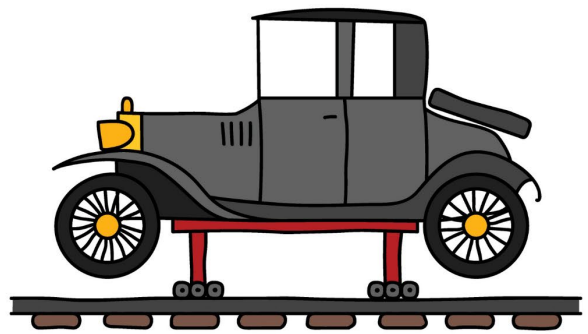


INDUSTRY 4.0
REVOLUTION



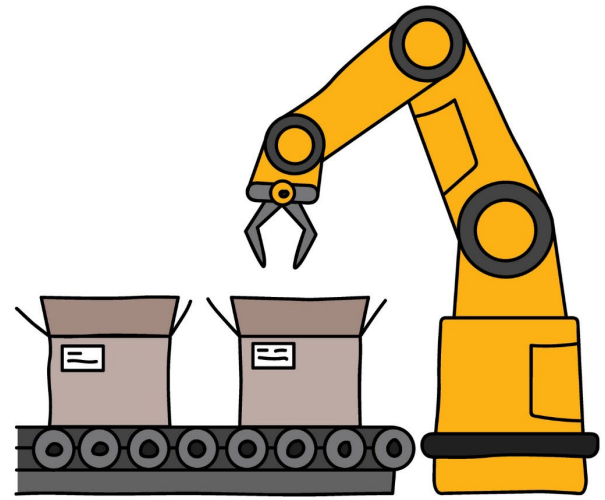
Industry 1.0

The Industrial Revolution begins. Mechanization of manufacturing with the introduction of steam and water power



Industry 2.0

Mass production assembly lines using electrical power

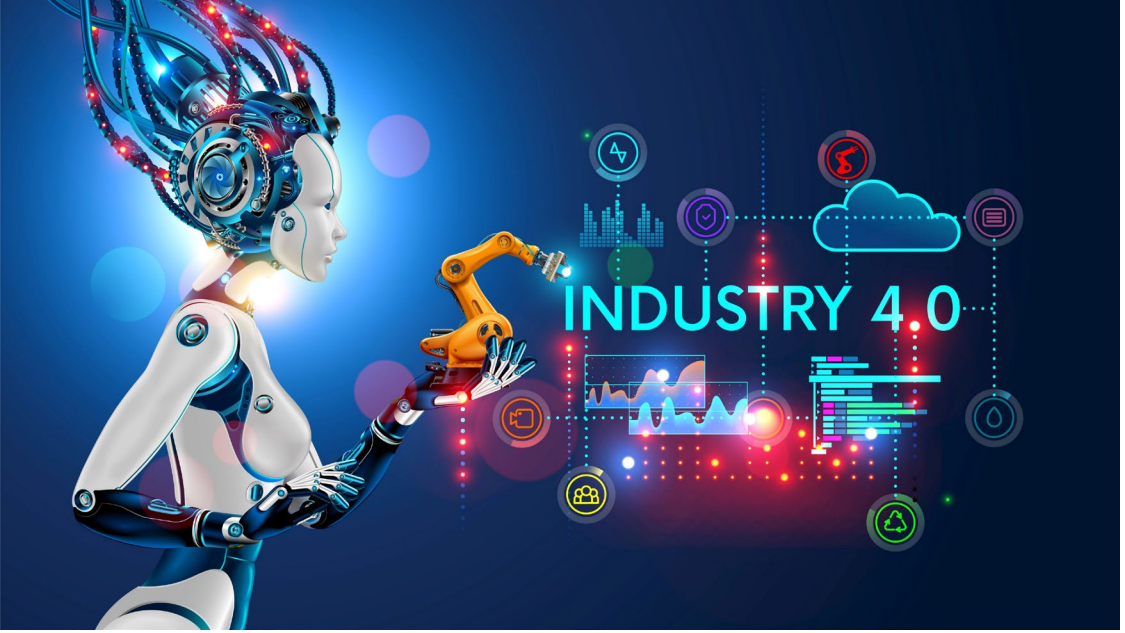


Industry 3.0

Automated production using electronics, programmable logic controllers (PLC), IT systems and robotics

Industry 4.0

The 'Smart Factory'. Autonomous decision making of cyber physical systems using machine learning and Big Data analysis. Interoperability through IoT and cloud technology.



mass customization

rychlá a levná výroba na míru

personal fabrication

single person market

výroba pro jednu osobu

kratší logistické řetězce

inshoring

malá universální továrna v každém malém městě

důležité jsou informace, design,

nikoliv produkt a jeho výroba

make - it yourself

digitální dvojče

dd
strojů
materiálů
požadavků → dd výrobku, výroby

Linie4
99 %
Login
SMD 4

digitální dvojčata

žádné pevné výrobní linky, pružná výrobní cesta

výroba pro více dodavatelů

výrobek je informační kontejner - pravidla výrobní stroje

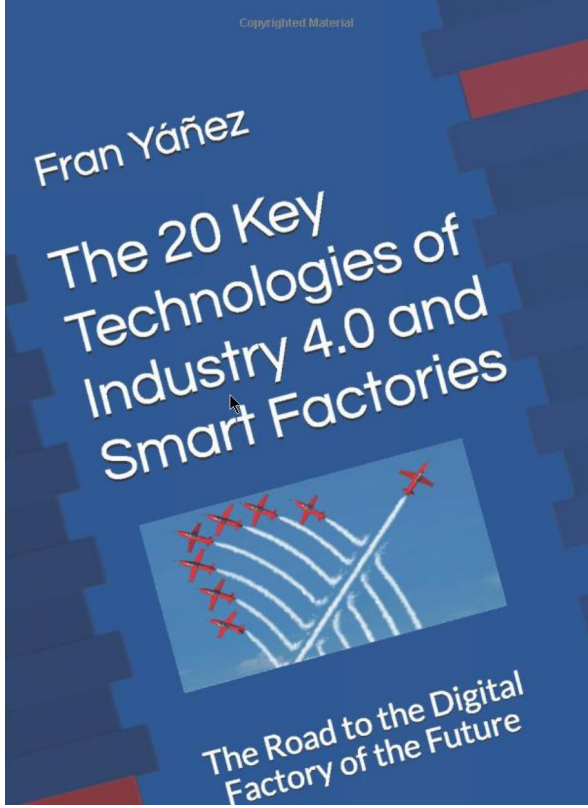
flexibilita, nové stroje, roboti, tiskárny, koboti

méně pracovníků s obecnými dovednostmi

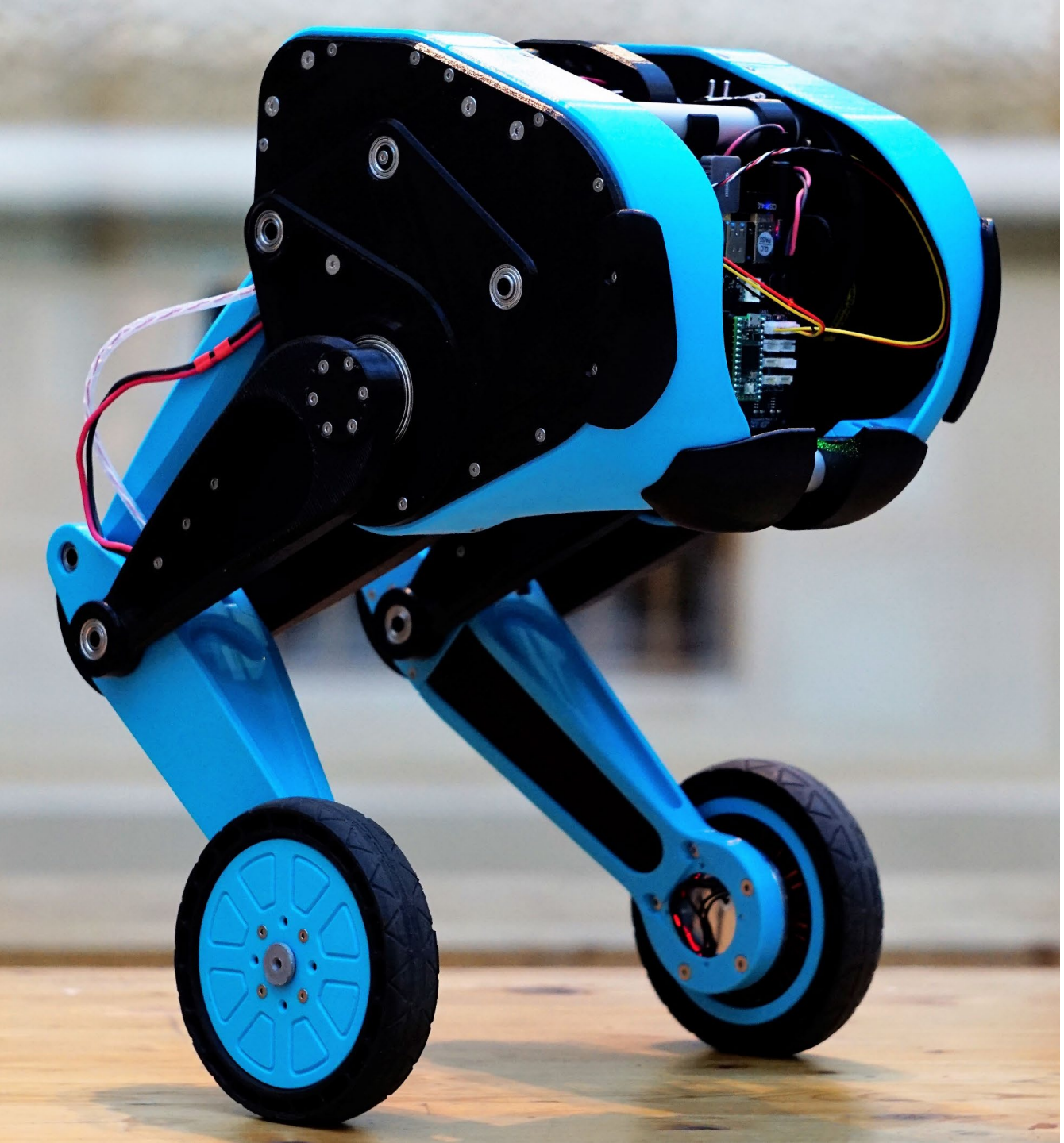
flexibilní, individualizovaná zajímavá práce, není nutné školení

všechna data uložena, výrobek má paměť

data

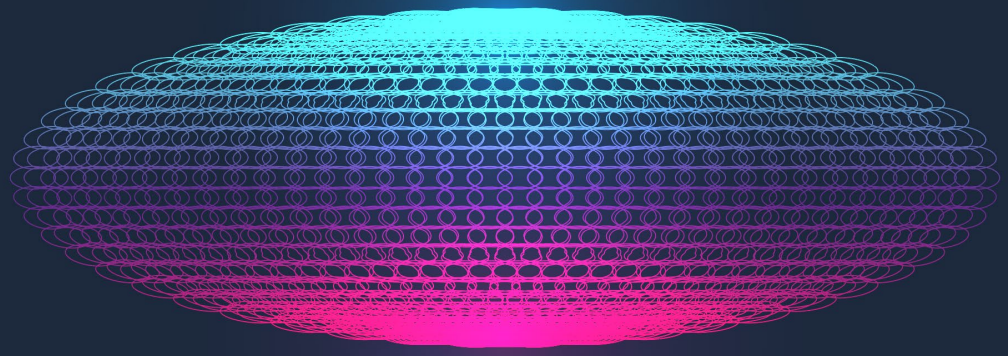


Videa:
[MILL TALK: What Is Industry 4.0 and How Did We Get Here?]
[The Autonomous Factory of the Future by Siemens]

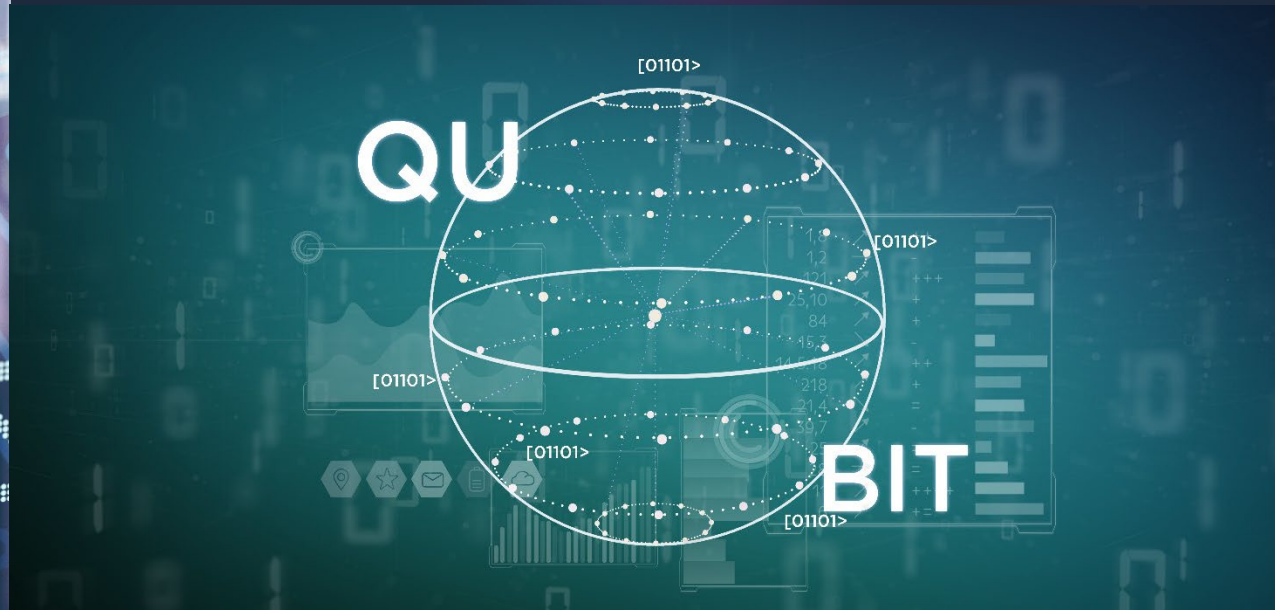


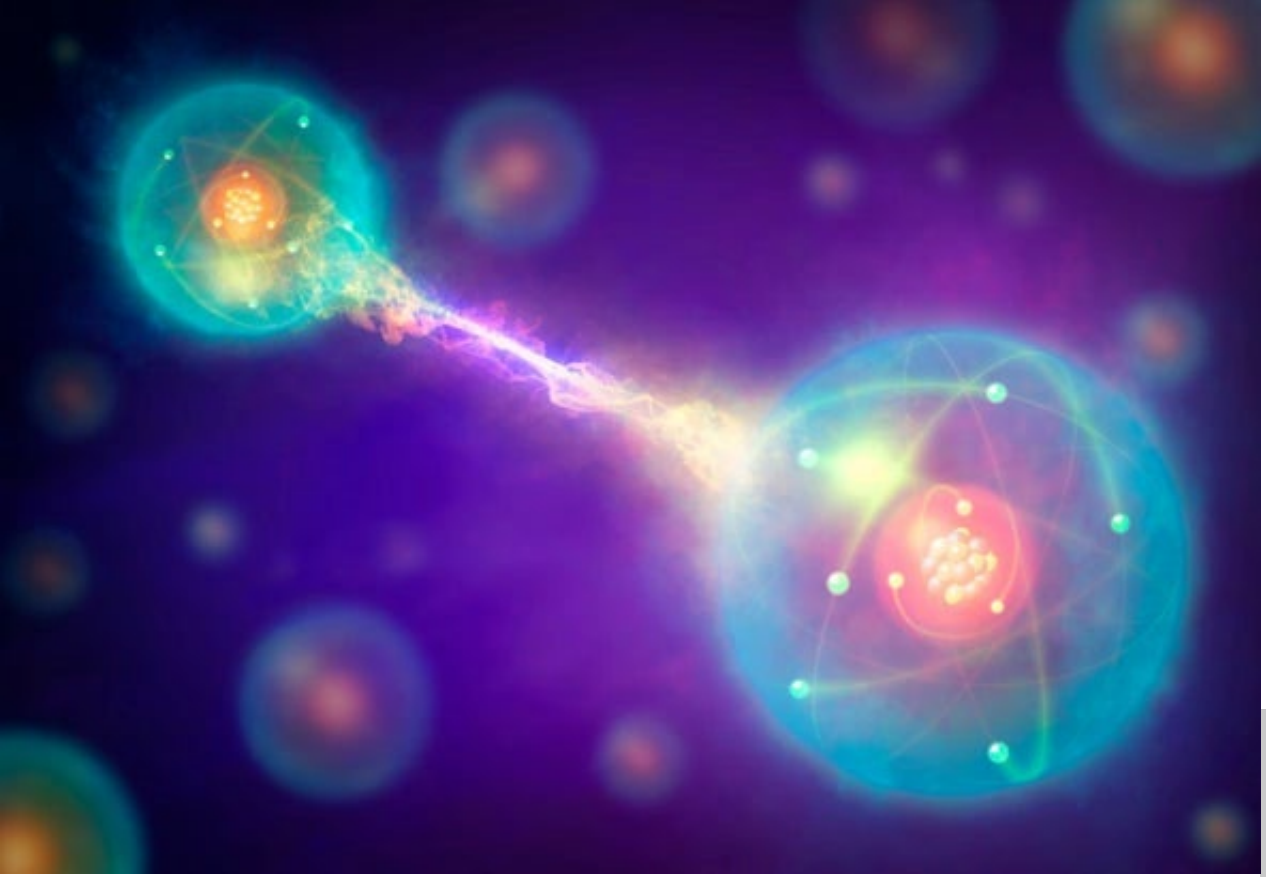
Boston Dynamics

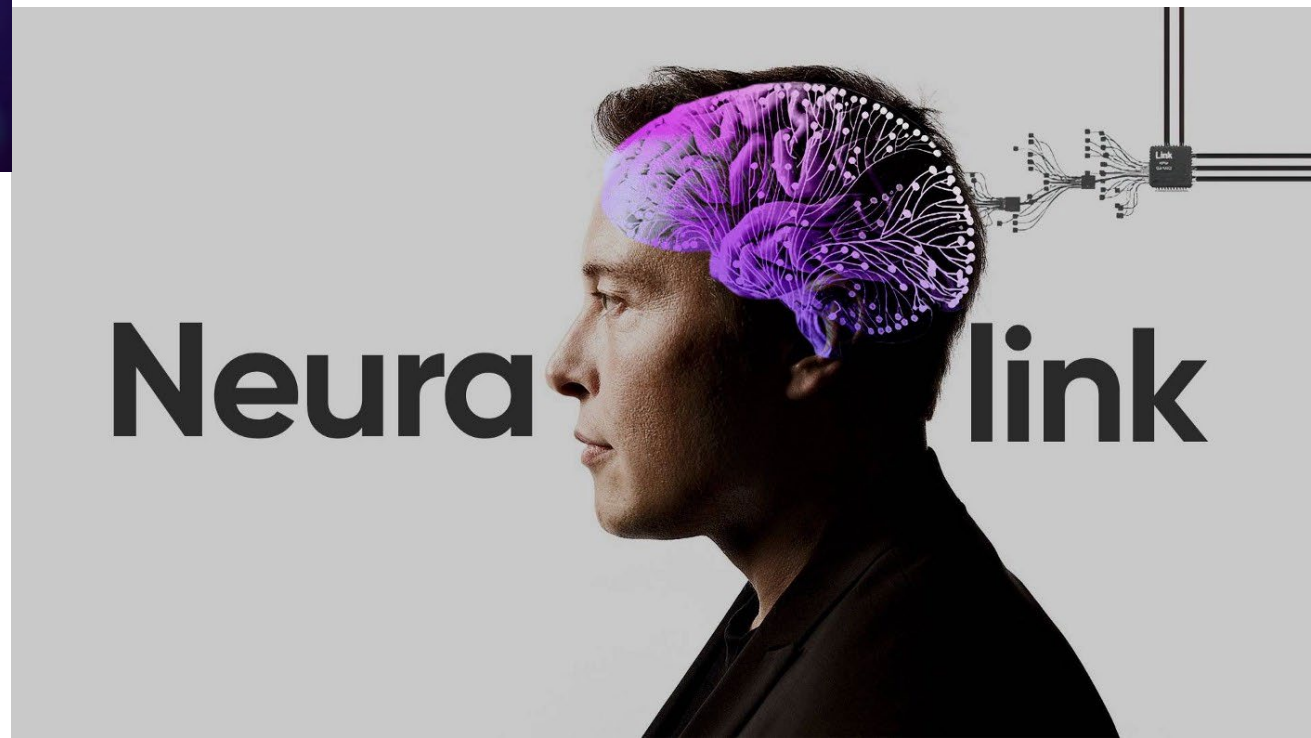
INTERNET OF THINGS



QUANTUM
COMPUTING






Neura link

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VŠECHNOPÁRTY Karla Šípa
Fokus Václava Moravce. 3. část
Host Lucie Výborné – Radiožurnál
CNN Prima News Interview
360° Pavlíny Wolfové, CNN Prima
Máma a táta na síti. Podcast nadace Avast
Vzdělávání pro budoucnost. TEDxPragueED 2018
O robotech, lidech a neznámé budoucnosti. Robot 100 a blog