

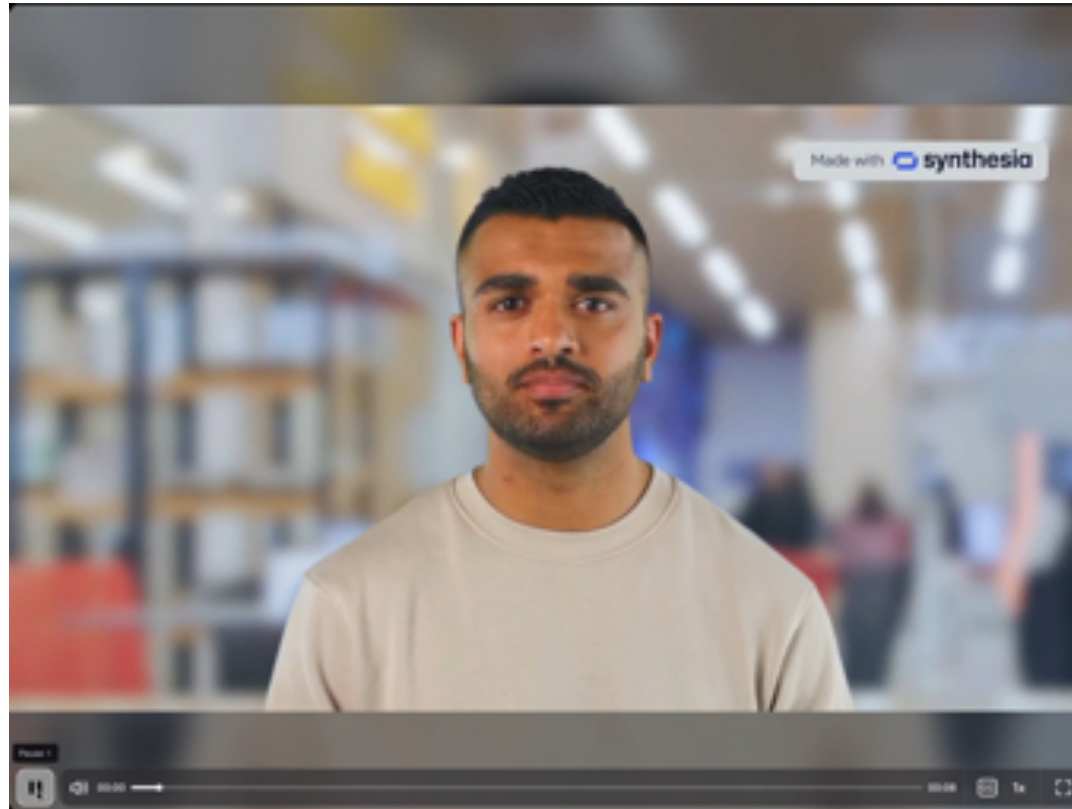
Digital Humans

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Welcome



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Digital Humans (How ChatGPT Imagines It)

> Create an image of a (realistic) digital human.



> Here is the image of a futuristic digital human, designed with sleek and streamlined features, semi-transparent with visible circuits and glowing lines, set against an abstract, tech-inspired background.



> Here is the image of a hyper-realistic digital human created using advanced CGI techniques. It features lifelike skin textures, detailed facial expressions, and realistic hair, set against a subtle, natural background.

Digital Humans (Virtual Humans)

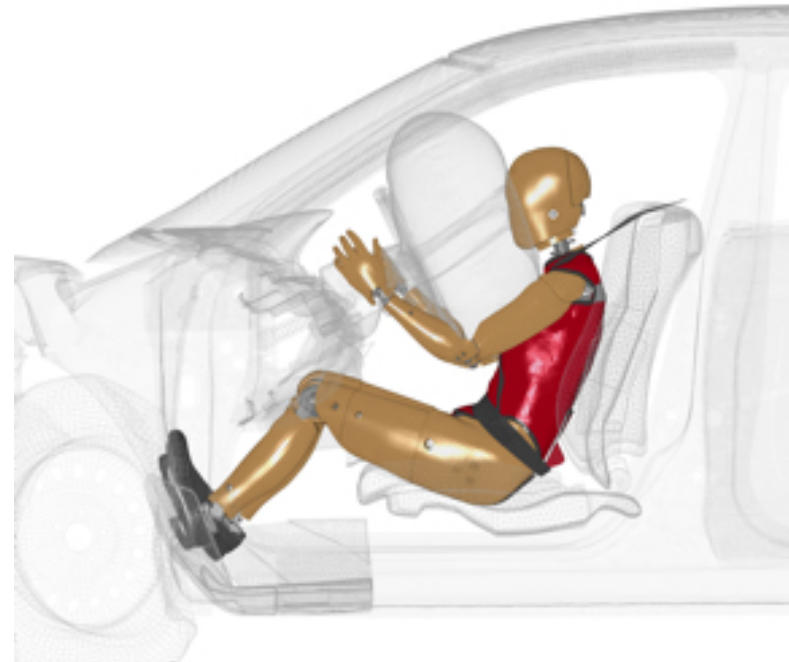
- *Software fictional* characters or human beings
- *Tools and artificial companions*
 - video games, film production
 - digital sales assistants, fashion advisors, ...
 - **virtual contact persons of the public administration**
 - simulation (ergonomic and usability studies in)
 - aerospace, automobile, machinery, furniture, ...
 - clothing industry, telecommunications, medicine, ...
 - ...
- Two main classes of digital humans
 - Avatars (graphical representation of the user)
 - (Autonomous) virtual humans (embodied agent)



Avatars and Virtual Humans



Source: Avatar, 2009



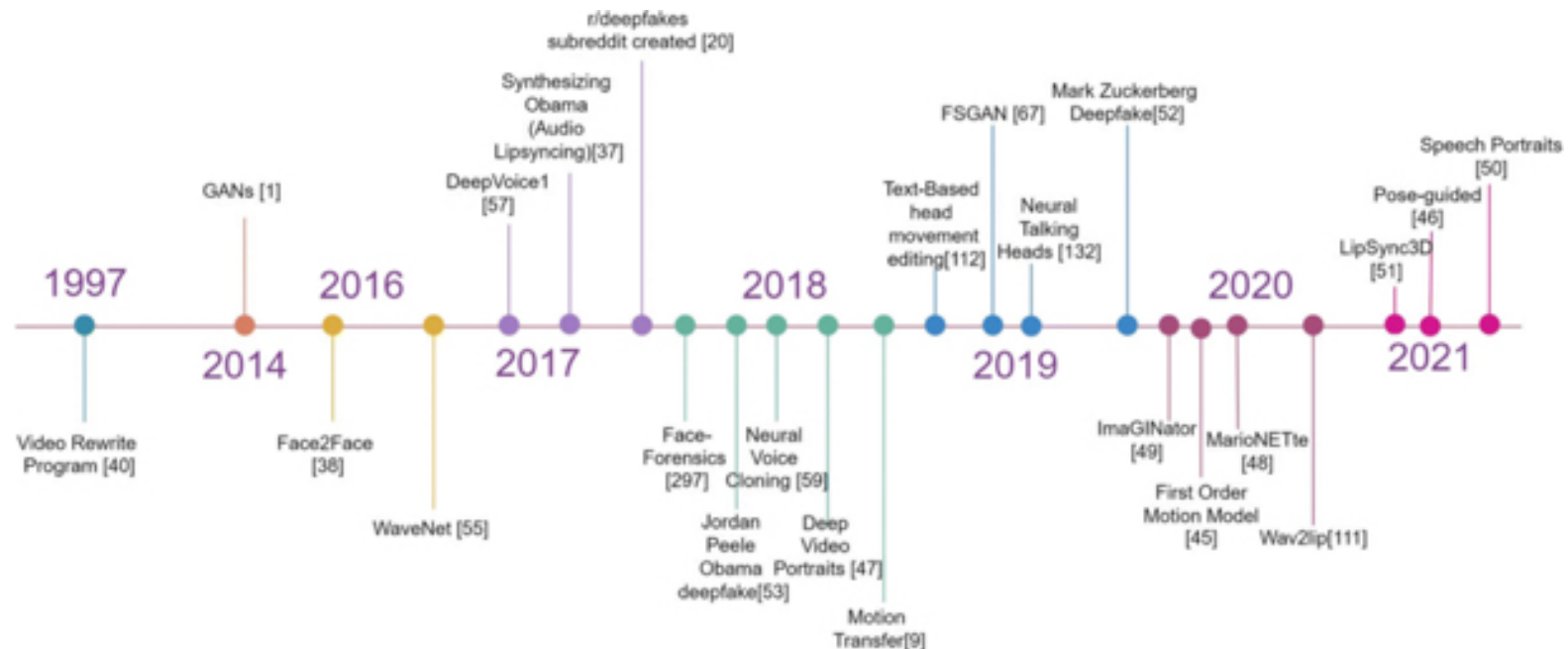
Source: Wikipedia

Face Swap (Deep Fakes)



Quelle: *Diep Nep*

Timeline of Deep Fakes Evolution



Source: M. Masood et. al, 2022

Quality Improvement of Synthetic Faces



2014



2015



2016



2017



2018



2019

81 Years Ago ...



Warren Sturgis McCulloch (16.10.1898 – 24.09.1969) Neurophysiologist & Cyberneticist
 Walter Pitts (23.04.1923 – 14.05.1969) Logician & Cognitive Psychologist

A Logical Calculus of the Ideas Immanent in Nervous Activity,
 Bulletin of Mathematical Biophysics, 5, 1943

**Turing-computable programmes can be calculated by finite
 networks of artificial neurons.**

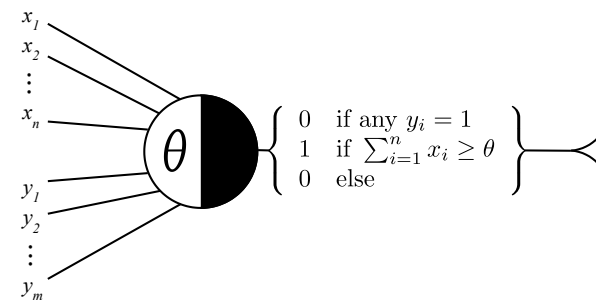
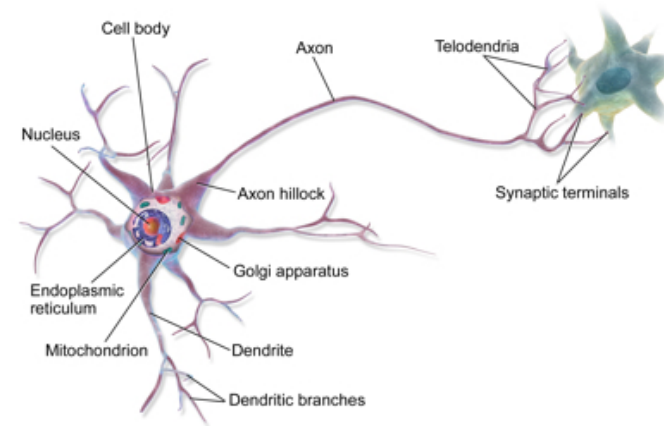


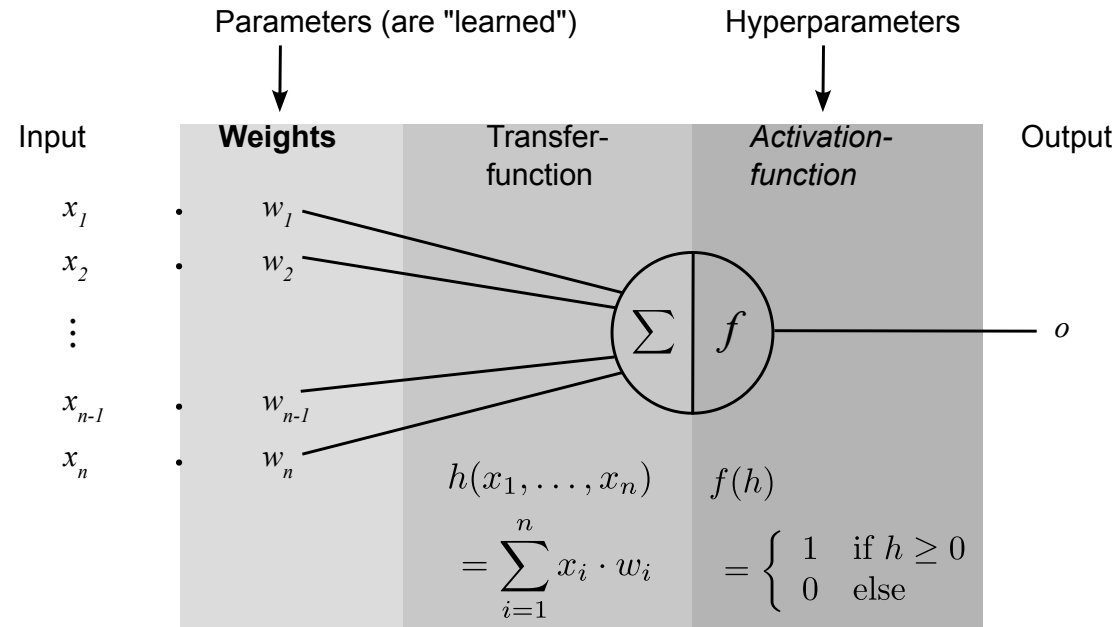
Image sources: [semanticscholar.org](https://www.semanticscholar.org) and [wikipedia.org](https://www.wikipedia.org)

Rosenblatts Perceptron (1955-1957)



Image Source:
upload.wikimedia.org

Frank Rosenblatt
(11.07.1928 – 11.07.1971)
Psychologist and Computer Scientist



- *The perceptron – A perceiving and recognizing automaton*, Cornell Aeronautical Laboratory, Report No. 85-460-1, Januar 1957
- *The perceptron: a probabilistic model for information storage and organization in the brain*, Psychological Reviews 65, 1958

Rosenblatts Perceptron Machine (1960)

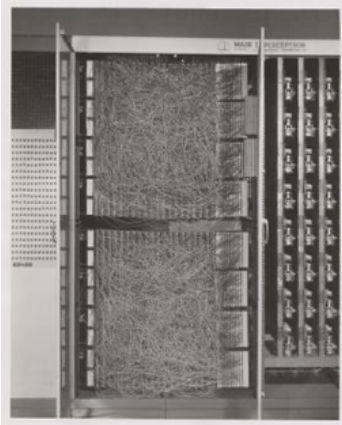
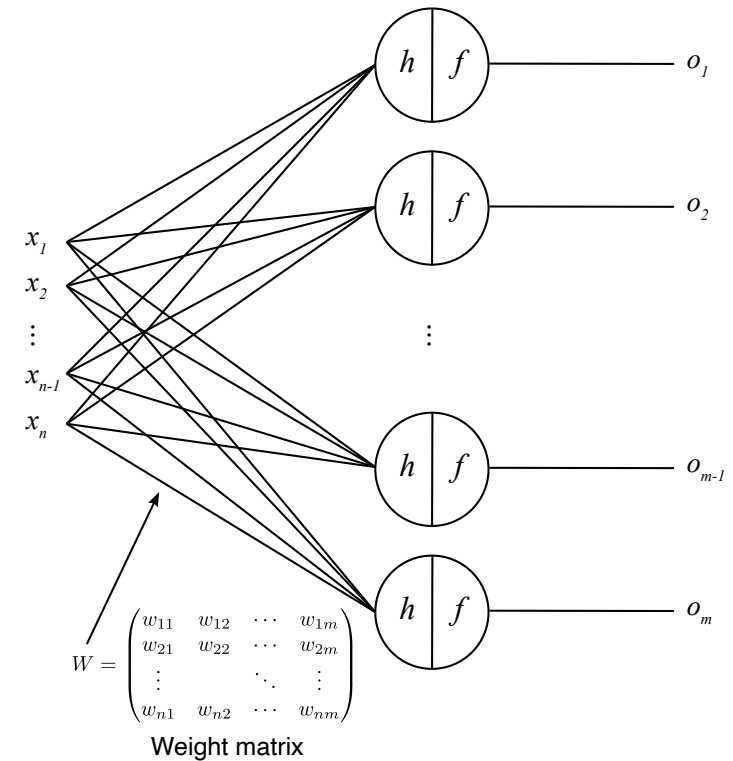


Image Source: upload.wikimedia.org

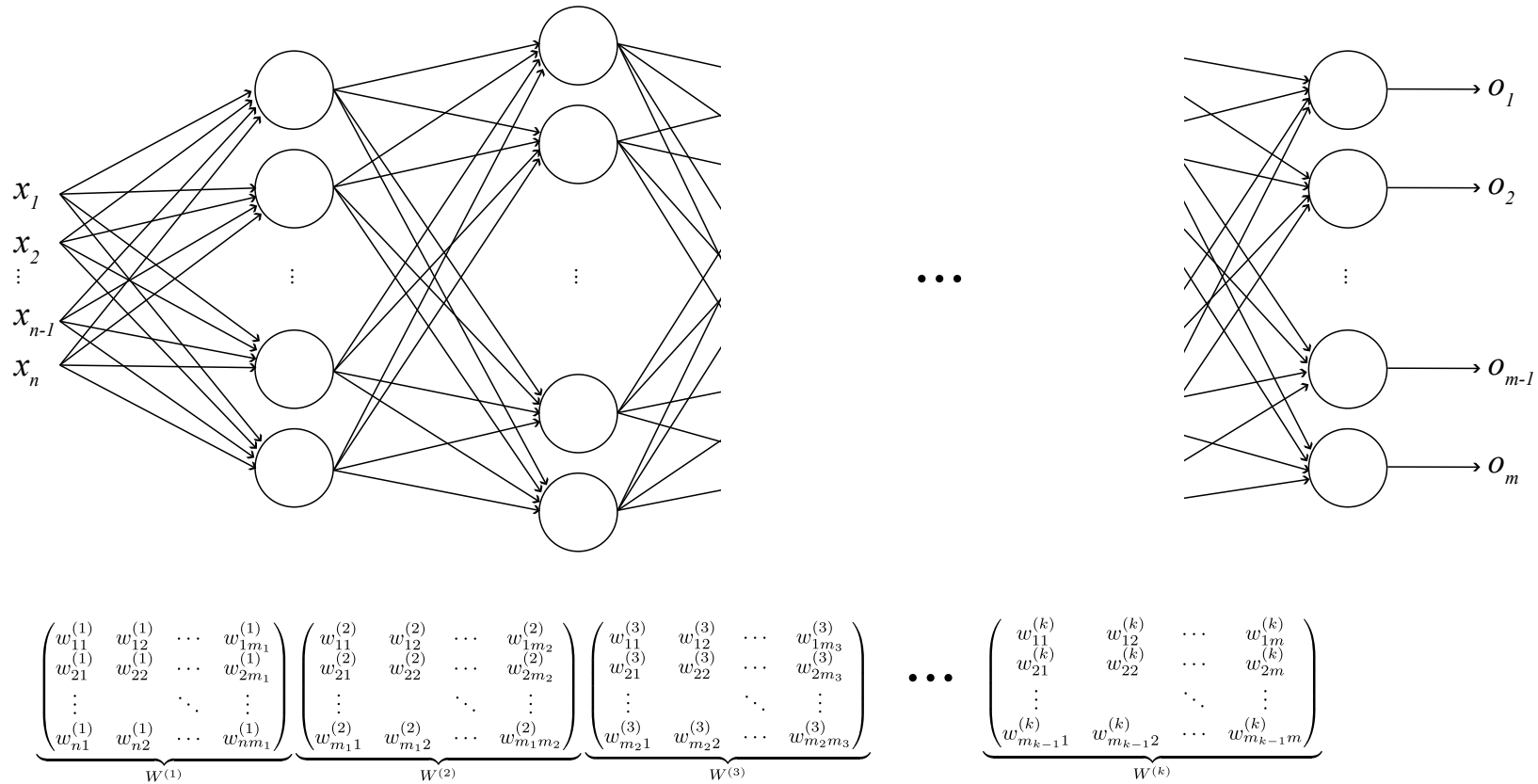


Image Source: upload.wikimedia.org

- First implementation of a perceptron on IBM 704, 1958
- Special hardware: Mark I Perceptron, 1960
- Connected to camera with 400 (20x20) pixels
- Objective: Differentiate (circle/rectangle, dog/cat, ...)
- 512 motor-driven potentiometers realise the weights

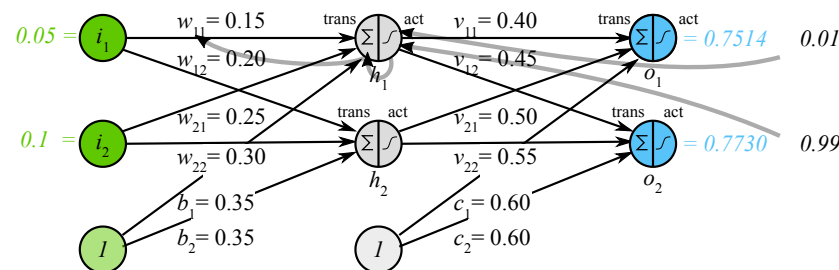


Multi Layer Perceptron as Universal Approximator



The Backpropagation Algorithm (1986)

- Efficient calculation of gradients (regarding network weights) enables **learning** on deep neural networks



$$\frac{\partial E_{total}}{\partial w_{11}} = \frac{\partial E_{total}}{\partial act_{h1}} \cdot \frac{\partial act_{h1}}{\partial trans_{h1}} \cdot \frac{\partial trans_{h1}}{\partial w_{11}} = \left(\frac{\partial E_{o1}}{\partial act_{h1}} + \frac{\partial E_{o2}}{\partial act_{h1}} \right) \cdot \frac{\partial act_{h1}}{\partial trans_{h1}} \cdot \frac{\partial trans_{h1}}{\partial w_{11}}$$

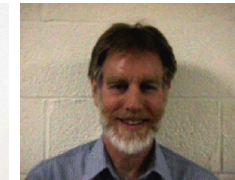
- Known since 1961, but still **the** **workhorse** for training kNNs



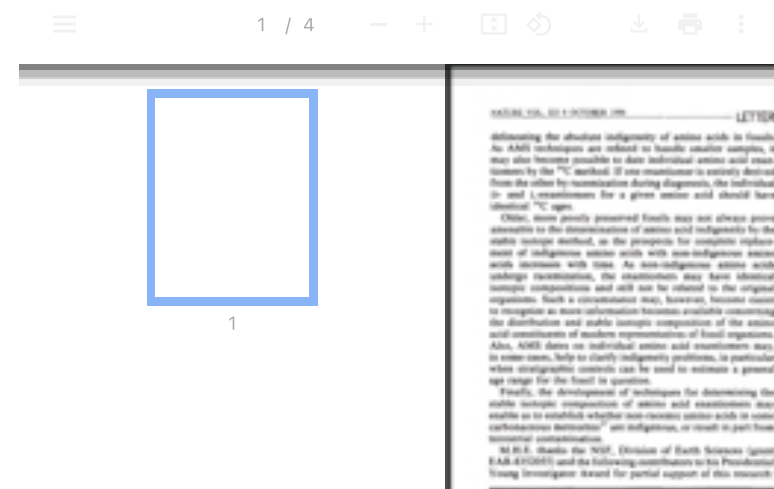
David E. Rumelhart



Geoffrey E. Hinton



Ronald J. Williams



Learning representations by back-propagating errors, Nature, 1986

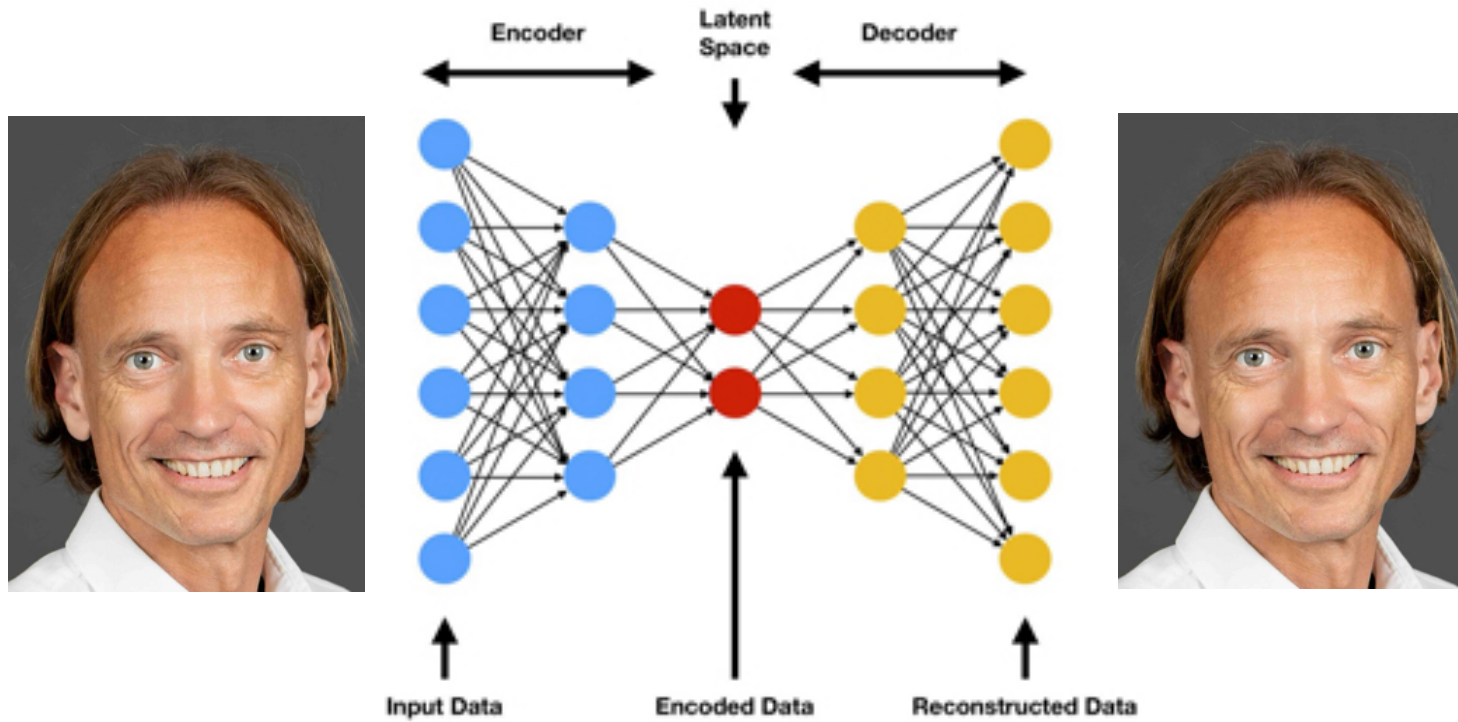
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Face Swap (Deep Fakes)

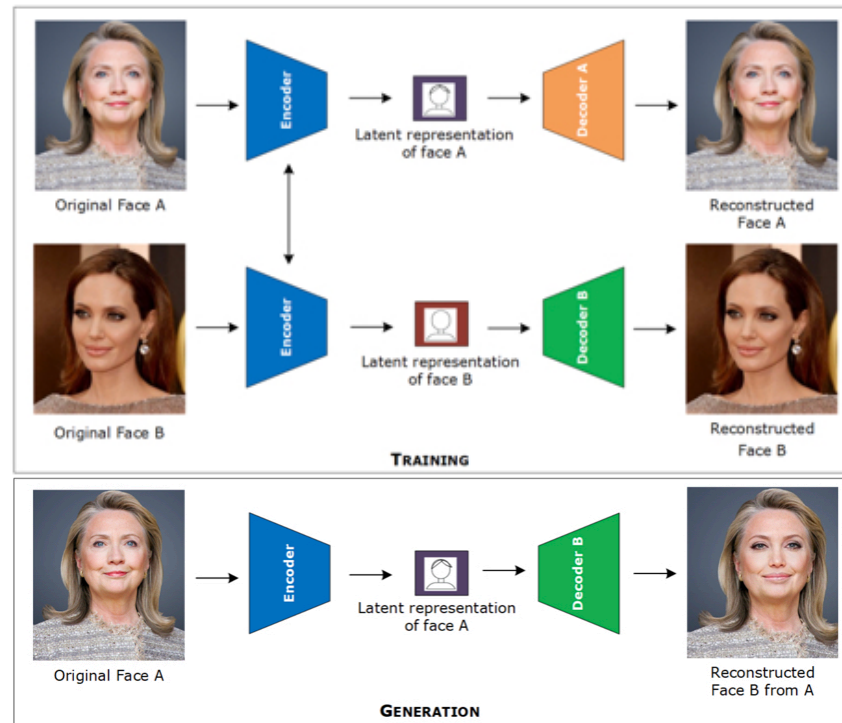


Quelle: *Diep Nep*

Autoencoder

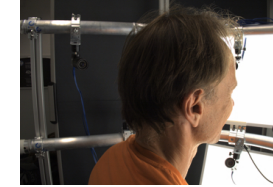
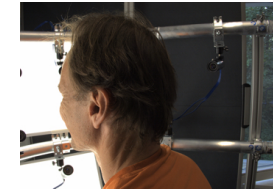
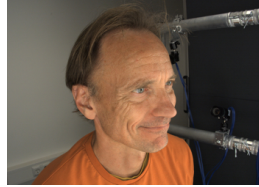


Deep Fakes (Neural Rendering of realistic Human Faces)



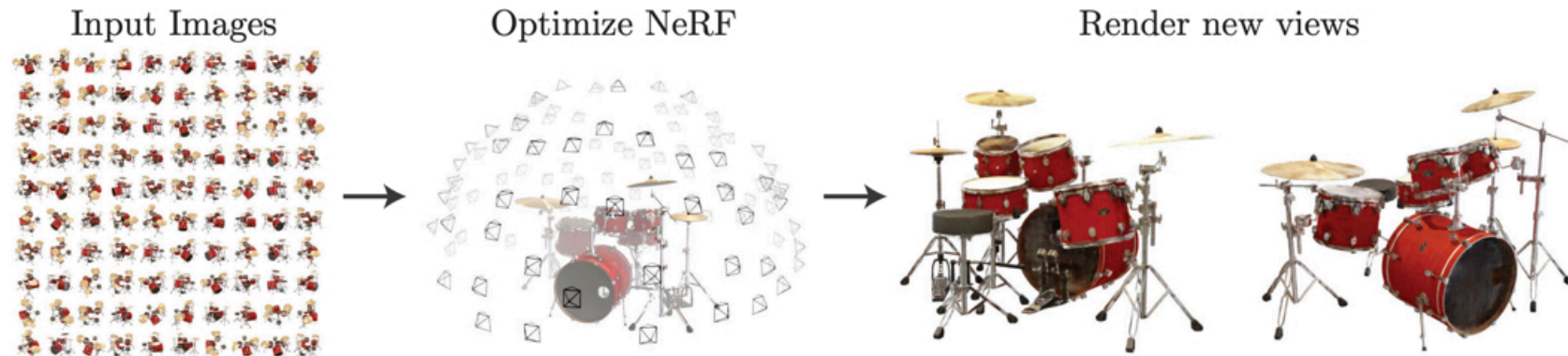
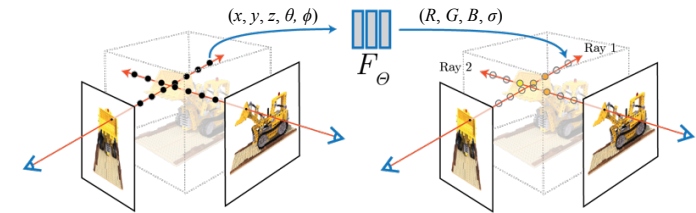
Source: M. Masood et. al, 2021

More Information



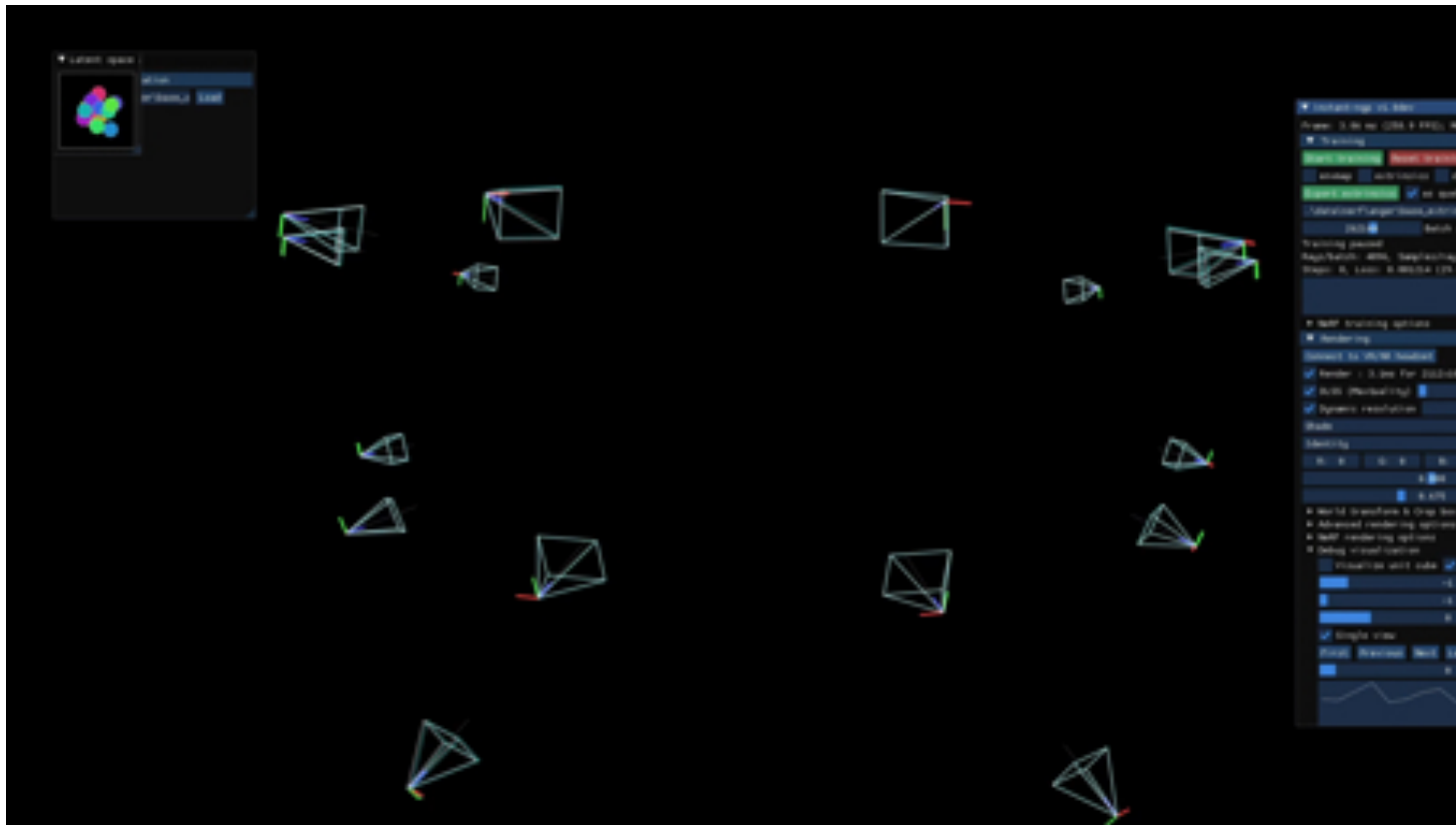
Neural Rendering (Neural Radiance Fields)

- Representing a scene as a fully-connected (non-convolutional) network
- **Input:** 5D coordinate (3D location (x, y, z) and viewing direction (θ, ϕ))
- **Output:** Volume density σ and view-dependent radiance (R, G, B)
- New views can be generated via ray tracing



Mildenhall et. al, NeRF: Representing Scenes as Neural Radiance Fields for View Synthesis, ECCV 2020 (Best Paper Honorable Mention)

Neural Radiance Fields (a General Reconstruction Method)

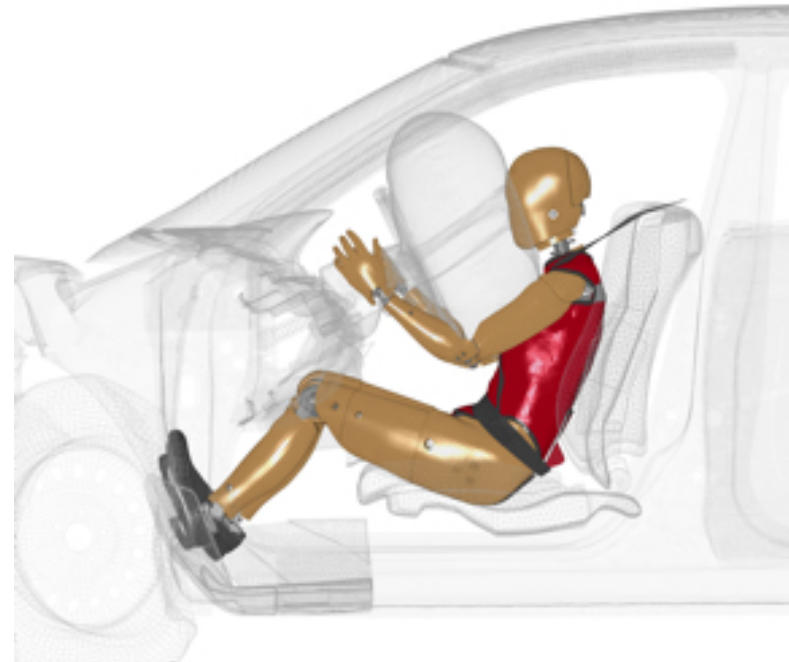


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Avatars and Virtual Humans



Source: Avatar, 2009



Source: Wikipedia

Motion Capturing



Character Animation using a Skeleton



Facial Animation using Blendshapes

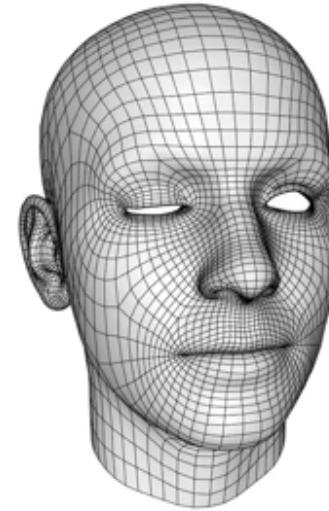


Linear Delta-Blendshapes

- Facial expressions by blending example poses

$$\vec{x}_i = \vec{x}_i^{(0)} + \sum_{k=1}^n w_k \left(\vec{x}_i^{(k)} - \vec{x}_i^{(0)} \right)$$

- Examples (blendshapes) have identical triangulation
- Linear interpolation per vertex $\vec{x}_i$
- Weights w_k typically are in $[0, 1]$.
(see what happens at 200% on [Youtube](#))



How many Blendshapes?



Dave Model

How many Blendshapes?



50 blendshapes [Nvidia "Dawn" Demo, 2003]



> 900 blendshapes [© Weta Digital]

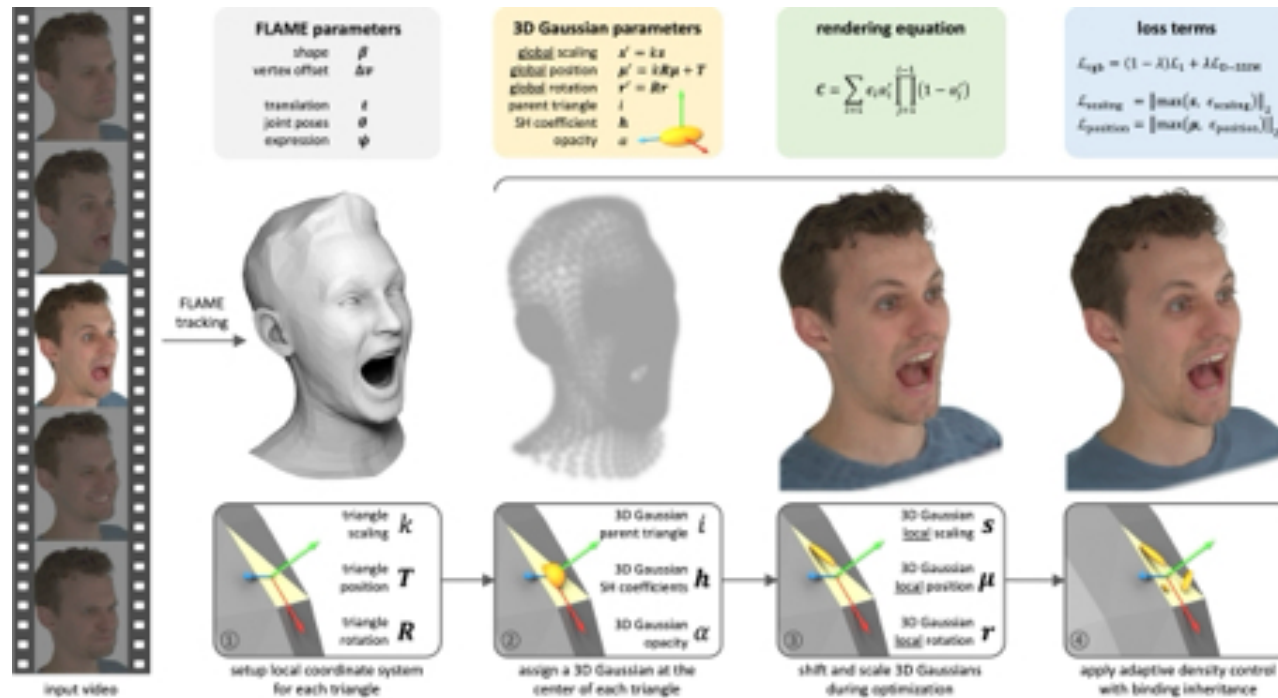
How many Blendshapes?



Meet Mike, SIGGRAPH 2017

> **750** blendshapes

Gaussian Avatars



Qian et al. "GaussianAvatars: Photorealistic Head Avatars with Rigged 3D Gaussians", CVPR 2024

Gaussian Avatars



Qian et al. "GaussianAvatars: Photorealistic Head Avatars with Rigged 3D Gaussians",
CVPR 2024

High Quality Facial Capturing at HSRM



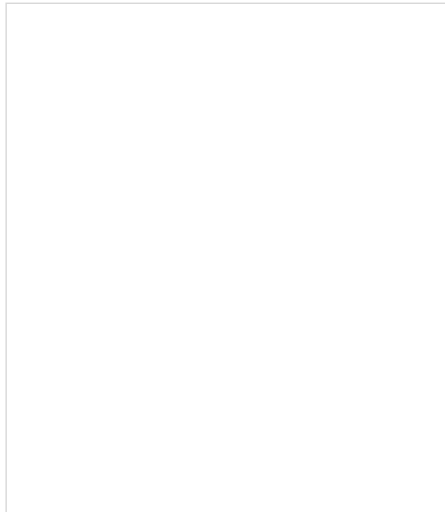
16 synchronized 12MP, 30fps cameras

Expressions Measured at HSRM

Additional Data

- Skulls

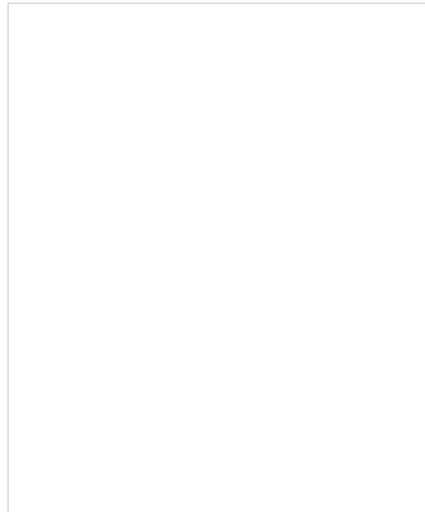
- 60 CT scans
- 2 surface scans



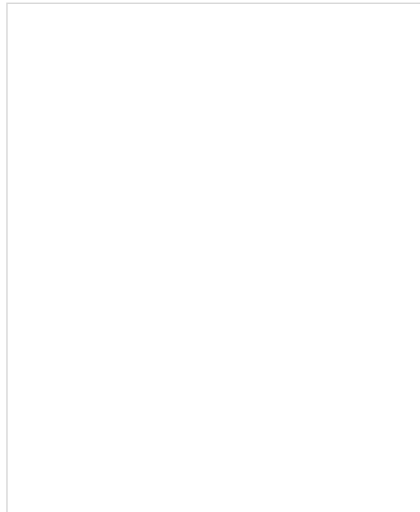
Skull extracted from CT
(University Medical Center Mainz)

- Heads

- 43 CT scans
- 39 surface scans



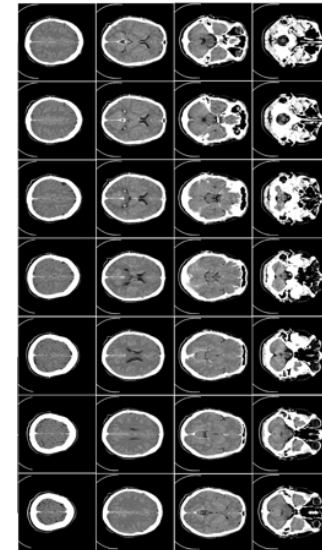
Skin extracted from CT
(University Medical Center Mainz)



Head scan
(ten24 3D Scanstore)

- FSTT

- 43 skull/head pairs from CT



FSTT from CT scans

A Multilinear Headmodel



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Simulating Weight Changes



scan

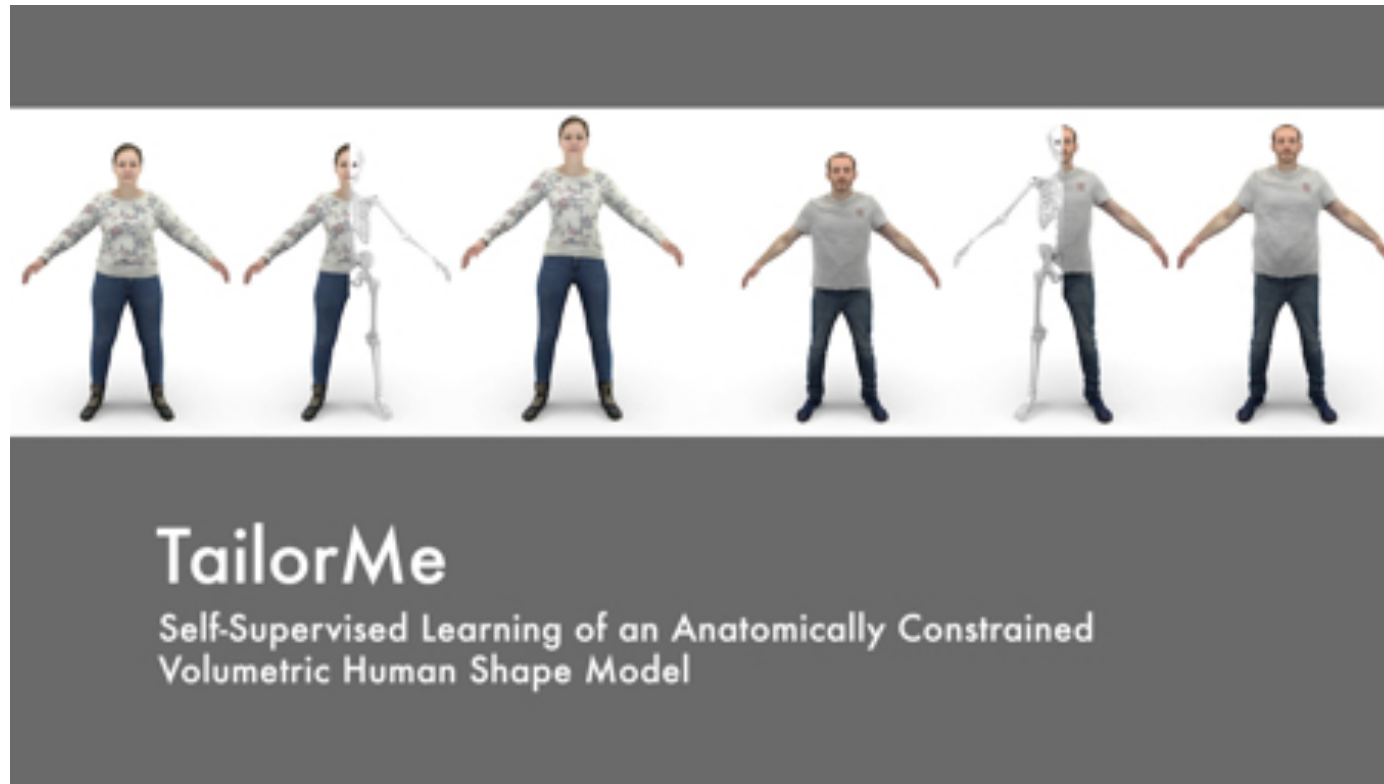


skinny



fat

Learning A Human Shape Modell



Learning a Human Shape Model

Learning the Physics of Facial Motion



Learning Facial Motion

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Avatars in the Metaverse



<https://unionavatars.com/realistic-avatars-and-the-metaverse/>

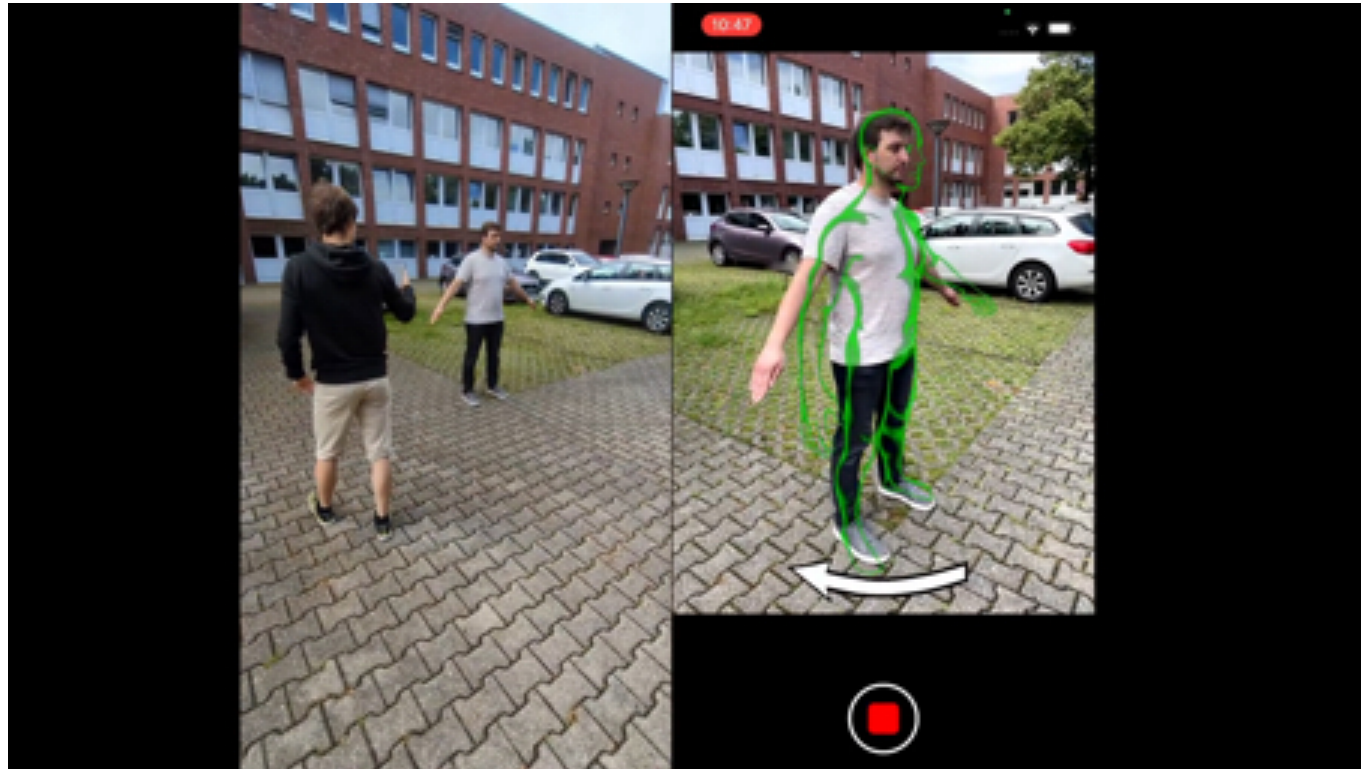
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Interaction with Avatars



Physically plausible Interaction

Individual Avatars for Everyone



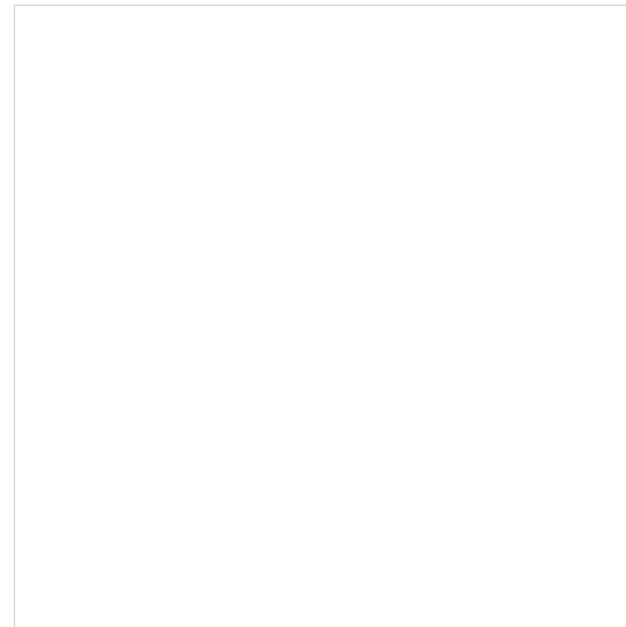
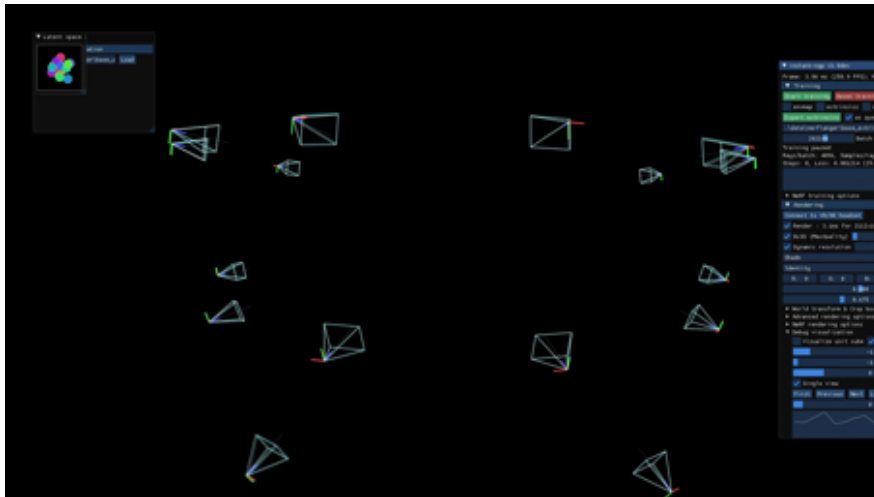
Generating an avatar using a smartphone

Summary

- Digital Humans are a combination of
 - advanced 3D graphics
 - artificial intelligence
 - machine learning
- They allow human-like interactions in the digital world etc. in
 - customer service
 - entertainment
 - medicine
 - ...
- As these technologies continue to develop,
 - they will play an even greater role in the future and
 - potentially **take over a large part of daily interactions** in the digital world

Thank you for your Attention!

“Wir können nicht weit in die Zukunft sehen, aber wir können sehen, dass noch viel zu tun ist.”
- Alan Turing, 1950



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