Sensory robotics

Lecture 10.

i.) Machine learning in robotics

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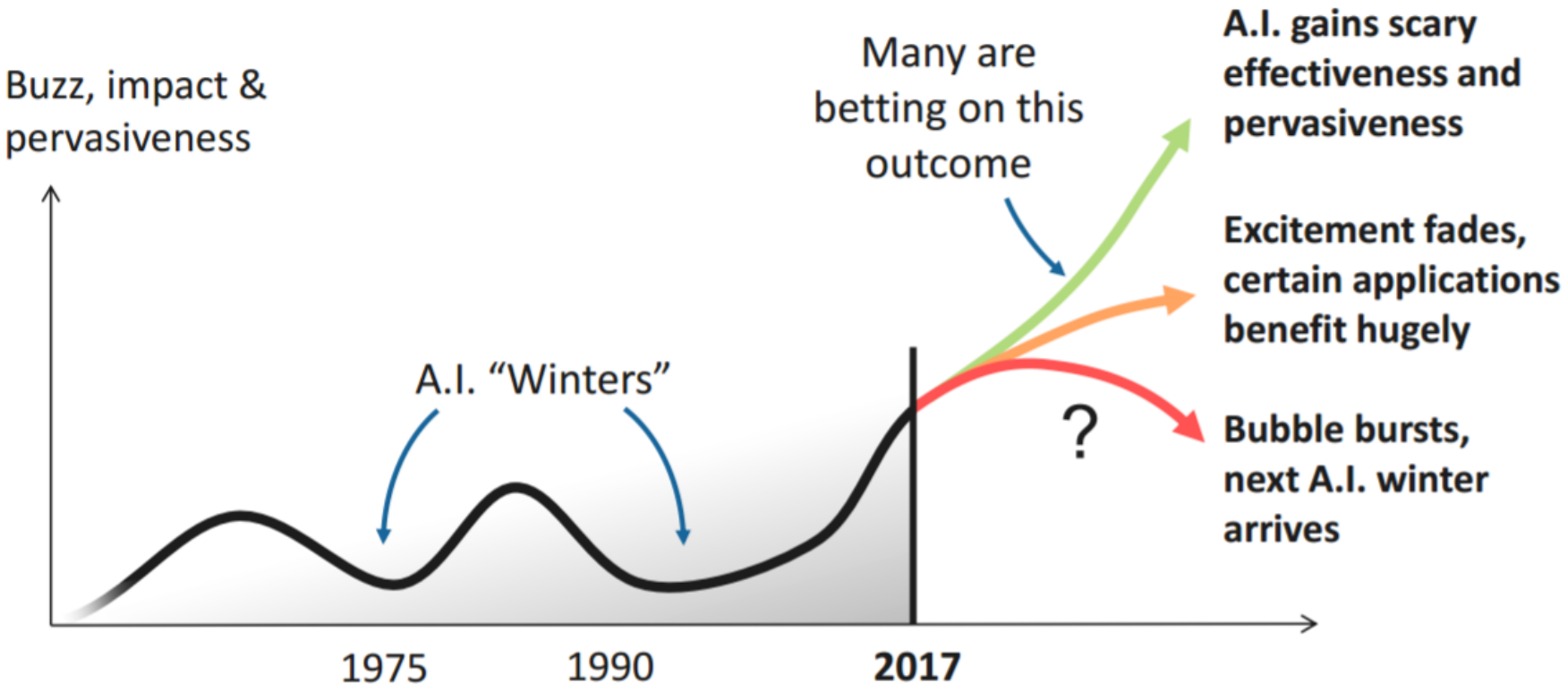
AI winters

AI is enjoying significant hype and investment



Source: https://www.quora.com

World vs. Brain computation

- Hard to compare
- "To put our findings in perspective, the $6.4*10^{18}$ instructions per second that human kind can carry out on its general-purpose computers in 2007 are in the same ballpark area as the maximum number of nerve impulses executed by one human brain per second„
- Today an NVIDIA 2080 Ti GPU card has 312 Tflops FP16 computational power (~$316*10^{12}$) or 1248 TOPS INT4
- Memory bandwith! > 227 TB weights, ~44 PByte/s realized bandwith is 372 Gbyte/s in the brain

Source: "The World's Technological Capacity to Store, Communicate, and Compute Information." Martin Hilbert and Priscila López. Science, 692-693, Feb. 11, 2011.

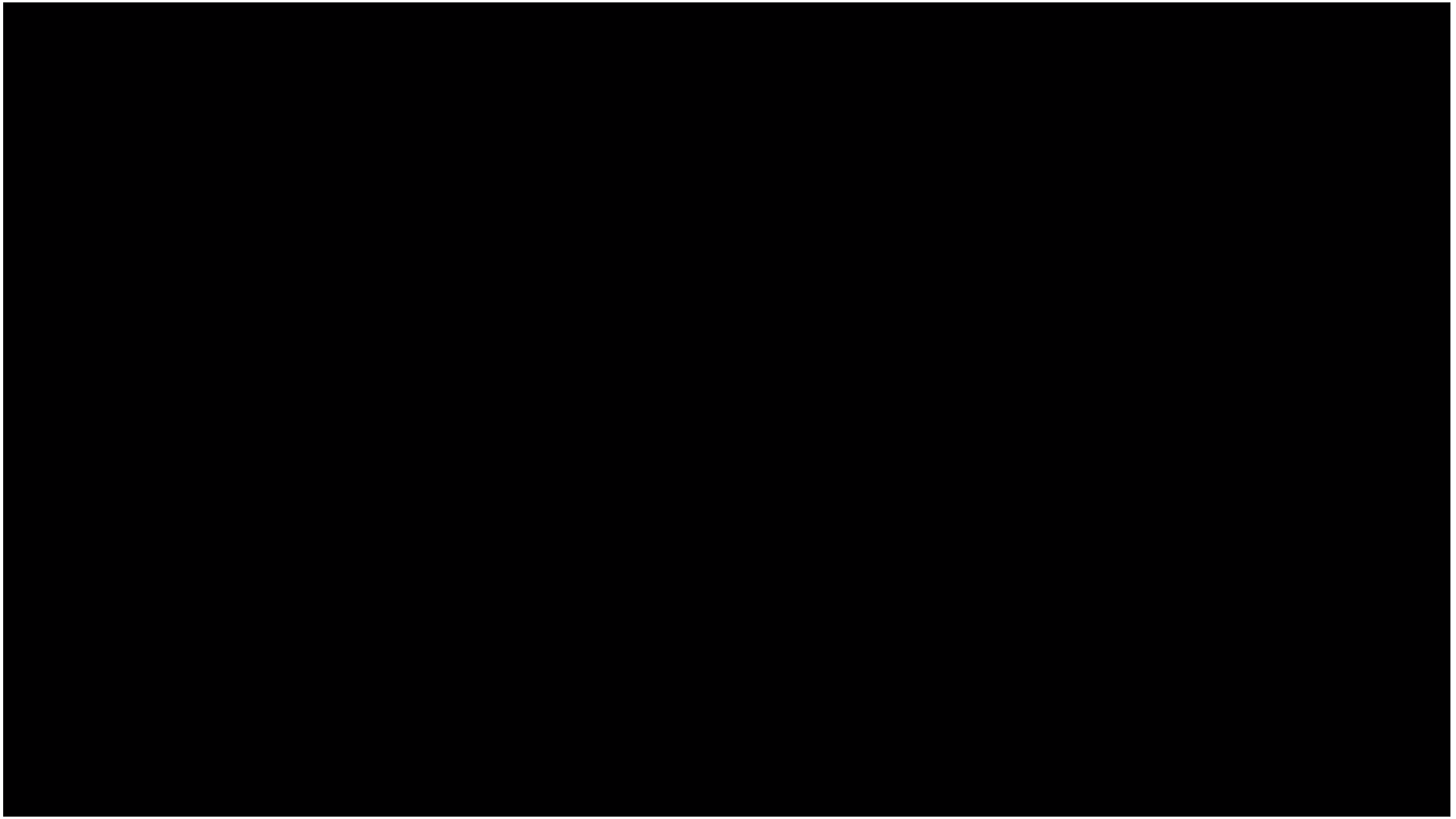
Robotics and AI – the IV. industrial revolution - history

- Google (2013): Google acquires 14 robotic companies (e.g. Boston Dynamics) - GoogleX, CEO Astro Teller
- Eric Schmidt (2013): "If someone wants to have a job for 10 years, then it's worth to do something that computers do badly"
- Google (2014) acquires DeepMind
- Google DeepMind (2015) Machine learn to play Atari games as a professional
- Tesla (2015): introduces self-driving autopilot

Robotics and AI – the IV. industrial revolution - history

- Elon Musk at al. (2015): Establishment of OpenAI – 1 billion USD
- Google (2016.03) AI win against a professional GO player
- Elon Musk (2016-11): "Automation" will sooner or later require the introduction of a generic basic income for everyone, as robots are taking on more and more jobs.
- Google (~ 2017.) Starcraft II. Getting stronger…
- AlphaGO zero, alpha zero (2017.)
- RVR (2019) Skynet (????) SAI? Safety?
- -> Data, data, data - it is worth to understand it

AlphaGO zero



Source: https://www.youtube.com/watch?v=tXlM99xPQC8

Alpha zero

- *„Elephants don't play chess",* but…
- Alpha zero works („thinks") like human, based on the patterns of the actual position suggest a few „good" moves
- It learnt without any human knowledge, based on only the rules
- It took only a few hours to beat the full 3000 years history of chess
- Plays creative chess
- Far beyond human players, chess has about 7 stages (for humans), go has about 14 stages (for humans)

AI safety

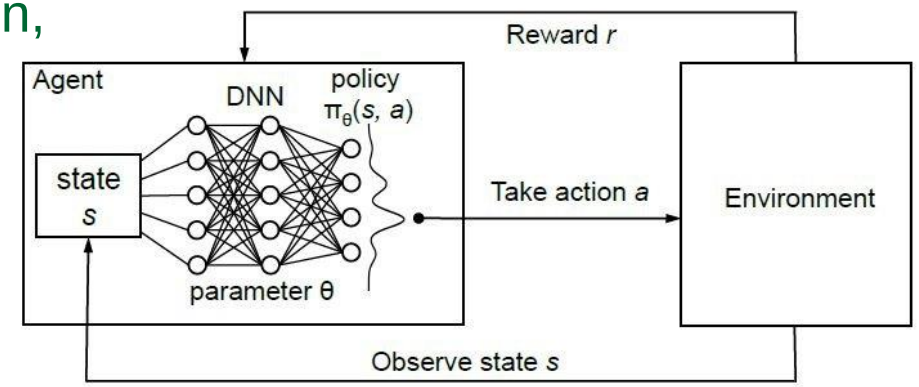
- Asimov's laws cannot be implemented
- AI-ETHICS? Legal regulations.
- Something needs to be done before Skynet becomes self-awareness
- Serious problem can be caused even without real intelligence
- Manipulation: Influencing voting - targeted Ads
- Killer: Military technique, how do you decide who to kill?
- Benign: Prejudice. Gorilla detection. Facebook bubble.
- OpenAI - shared knowledge
- What should the next generation learn in schools?

AI – the most dangerous weapon

Source: https://www.youtube.com/watch?v=9fa9lVwHHqg

Reinforcement learning

- Reinforcement learning: taking actions in order to collect and maximize the reward (reward comes when it successes). Usually reward received in the end, like playing atari games or chess.
- No labelled input/output pairs is needed.
- Deep reinforcement learning applies deep convolutional neural networks.
- Applications: robotic manipulation, strategic games (Go, chess, starcraft, world-of-tanks, etc.), prosthetics, equipment for surgeries, mobile robotics, surveillance, imitation learning.



Source: Koo et al. "Deep Reinforcement Learning for Network Slicing with Heterogeneous Resource Requirements and Time Varying Traffic Dynamics." arXiv preprint arXiv:1908.03242 (2019).

Machine learning in robotics

- New definition of the robot (Carnegie Mellon CS Department website): *"Where AI meets the real world."*
- Areas where machine learning probably has the biggest impact on robotics:
  - Computer and machine vision – (automotive) industry
  - Imitation learning – like imitating human walking
  - Self-supervised learning – generates their own training examples
  - Assistance and medical technologies – surgery, psychiatry
- "One of the most important things is that you have to somehow communicate to the robot what it means to succeed" – problem of labeling

Computer or machine vision in robotics

- Feature extraction has been learnt compared to classical image processing
- 2D object detection, classification, semantic segmentation – use ImageNet or prepare your own data, at least 1000 images / category
- Face and facial expression recognition
- Stereo vision with multiple cameras
- Handle high resolution images – visual saliency map
- Human performance can be reached
- 3D functionlities are getting harder (image flow or video processing)

Visual SLAM / Visual Odometry, Navigation, Localization

- Obtain robust correspondences across image pairs – registration, sensor fusion.
- Depth from stereo is an old problem and is far from solved.
- Another application is to localize in a pre-recorded map using deep learning
- Workig in real-time – appropriate hardware is needed

Autonomous vehicles

- Tesla uses cameras for a autonomous driving
- Instead of building a pipeline with visual odometry fused with GPS/INS, object detection, tracking, semantic segmentation etc, one can map the sensor inputs directly to steering wheel/breaking/ accelerator using training data and a deep NN.
- NVIDIA can able to simulate all US roads in a few days.
- AiMotive
- LIDARS vs. cameras vs. Radars – LIDAR emualtion based on moving camera(s)

Robotic manipulation

- Directly train a robot to map visual inputs to control signals for the manipulator(s) using reinforcement learning.
- Two possible ways, (beause of time need and amortization) buy dozens of robotic arms to physically collect data OR use simulators (e.g.ROS)
- Simulators are getting better, but still there is a (huge) „gap” between virtual and reality

Deep learning in robotics

- Image processing
- Image processing in robotics

Source: https://www.youtube.com/watch?time_continue=5&v=iaF43Ze1oeI&feature=emb_logo

Deep learning in robotics

- Learning of visual-motor coordination

Source: https://www.youtube.com/watch?time_continue=7&v=l8zKZLqkfII&feature=emb_logo

Deep learning in robotics

- Grasping based on image („blind”)

Source: https://www.youtube.com/watch?v=Q9tDHuidzak&feature=emb_logo

Deep learning in robotics

- Continuous visual feedback

Source: https://www.youtube.com/watch?time_continue=2&v=H4V6NZLNu-c&feature=emb_logo

Imitation learning

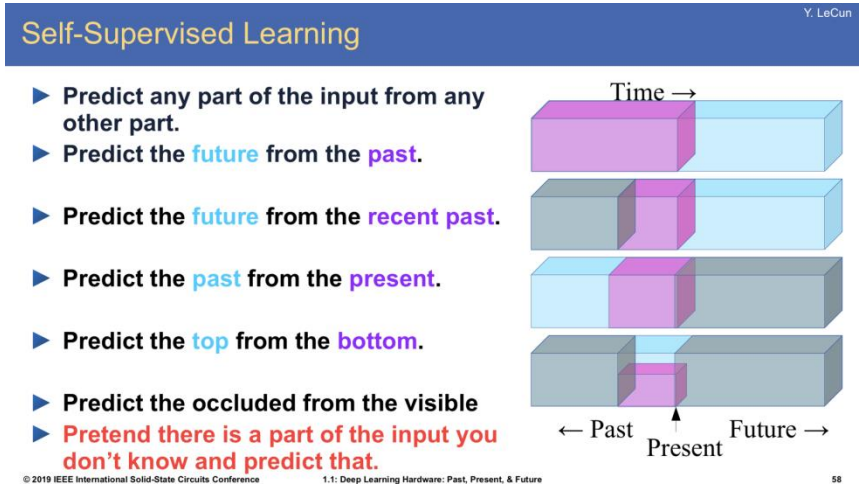
- Biped robot in the lab. > 20 motors, how to control it?
- A case of reinforcement learning
- Bayesian or probabilistic models – bayesian belief networks
- Applications are outside the factory: contruction, agriculture, search, rescue, military, etc. (field robotics)
- Includes inverse optimal control methods, programming by demonstration
- Applied in humanoid robotics, legged locomotion, off-road rough-terrain mobile navigator

Learn to walk

Source: https://www.youtube.com/watch?v=gn4nRCC9TwQ

Self-supervised learning

- Generate their own training examples
- Close range captured data to interpret even long-range sensory data
- Autoencoders
- Photo-restoration
- Image-super resolution

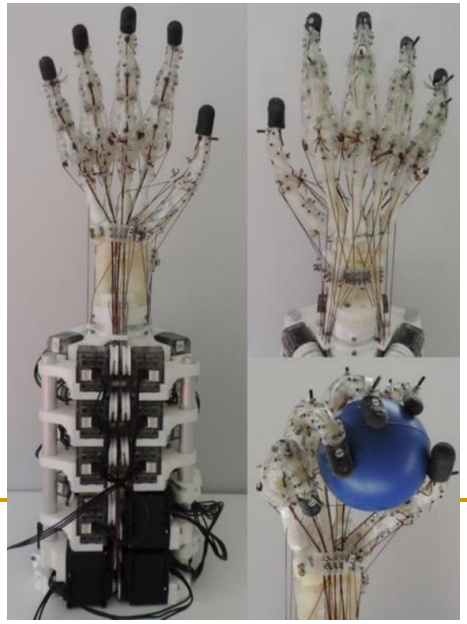


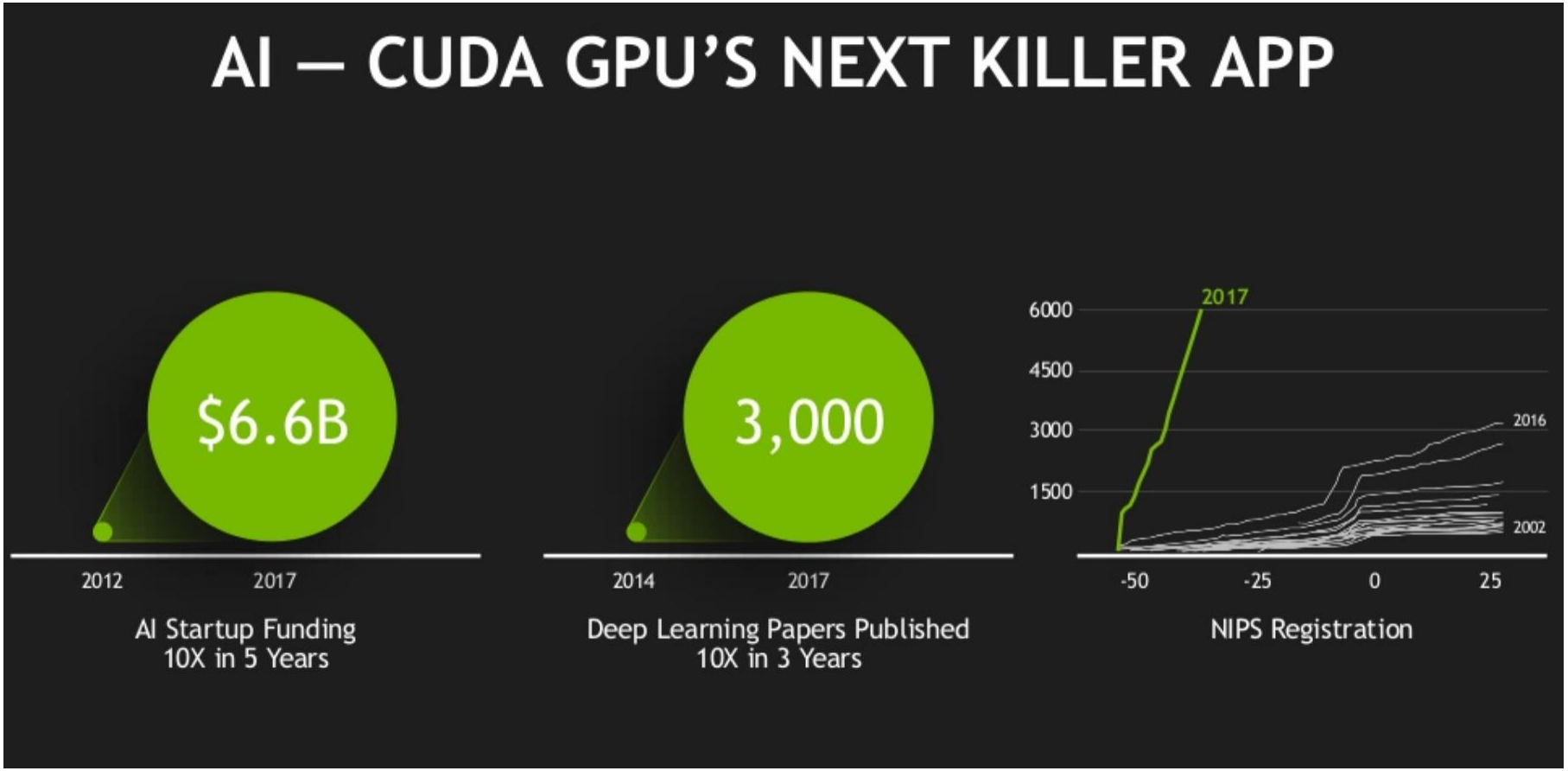
- Detect human activity, use as learning patterns
- E.g. robot reminder the milk was left out of the fridge
- E.g. road detection with a camera
- LeCun: „The future is self-supervised learning with massive amounts of data and very large networks."

Source: LeCun's self-supervised learning slide at ISSCC 2019

Assistance and medical technologies

- Device that can sense, process sensory information, and perform actions that benefit people with disabilities and seniors.
- Exoskeletons, robots for rehabilitation, surgical robots, mobile wheelchairs.
- Cybathlon: challenge for people living with disabilities
- Prosthetics, human-machine interfaces
- Brain activity: image restoration
- Elon Musk's visions:
  AI directly connected to human brain





- (from NVIDIA GTC 2017)

Useful materials

- Top Conferences for Machine Learning & Arti. Intelligence
  - CVPR : IEEE Conference on Computer Vision and Pattern Recognition
  - NIPS : Neural Information Processing Systems (NIPS)
  - ECCV : European Conference on Computer Vision
  - ICML : International Conference on Machine Learning (ICML)
- ArXiv, Medium.com, MIT News
- Deep learning tutorials – AI channels
  - https://github.com/aymericdamien/TensorFlow-Examples
  - Two Minute Papers (youtube)
  - http://deeplearning.net/reading-list/tutorials/

Robot simulators and hardware

- Simulator environments:
  - NVIDIA ISAAC PLATFORM FOR ROBOTICS
  - Famos Robotic
  - Robot Operating System (ROS)
- OpenAI Gym
- Real data can not be replaced by synthetic data
- NVIDIA's architecture and GPUs
- Google architecture – TPUs are only in cloud

End of lecture 10.

i.) Machine learning in robotics

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