Machine Learning – Lecture 22

Wrapping Up

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Announcements

- Exam details
  - For everybody registered, we will send around detailed information (precise starting time, room assignments) about 1 week before the exam.

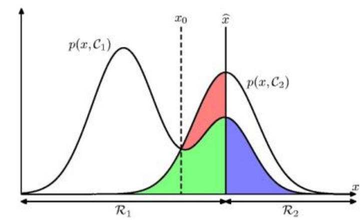
- For those who could not register for technical reasons
  - You may participate in the exam conditioned on approval by your degree program's examination board.
  - It is your responsibility to ask your examination board what conditions they impose
    - Most boards demand that you file a written request before the exam date
  - We have created a registration poll on the moodle, where you can sign up for the 1st or 2nd exam date to participate in the exam.
  - *We need this information in order to allocate sufficient space!*

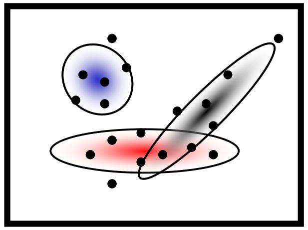
Announcements (2)

- For exchange students only
  - For those of you who need to leave Aachen before the date of the first exam, we will offer several special oral exam slots.
  - An announcement has been sent by email, please sign up on the corresponding Doodle poll.
  - *We will send around an assignment to exam slots by middle of next week.*

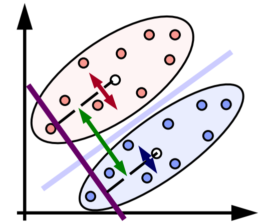
Course Outline

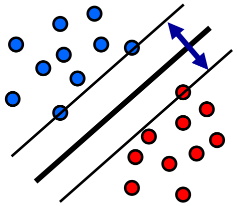
- Fundamentals
  - Bayes Decision Theory
  - Probability Density Estimation

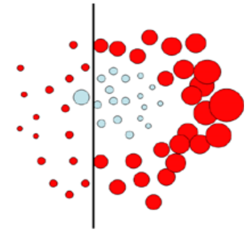


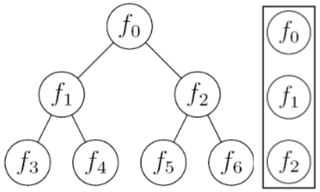


- Classification Approaches
  - Linear Discriminants
  - Support Vector Machines
  - Ensemble Methods & Boosting
  - Random Forests

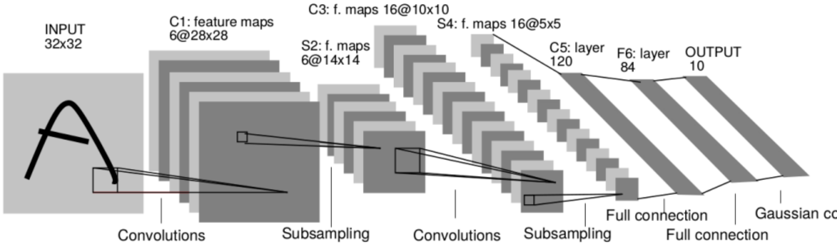








- Deep Learning
  - Foundations
  - Convolutional Neural Networks
  - Recurrent Neural Networks
  - Current Research Directions



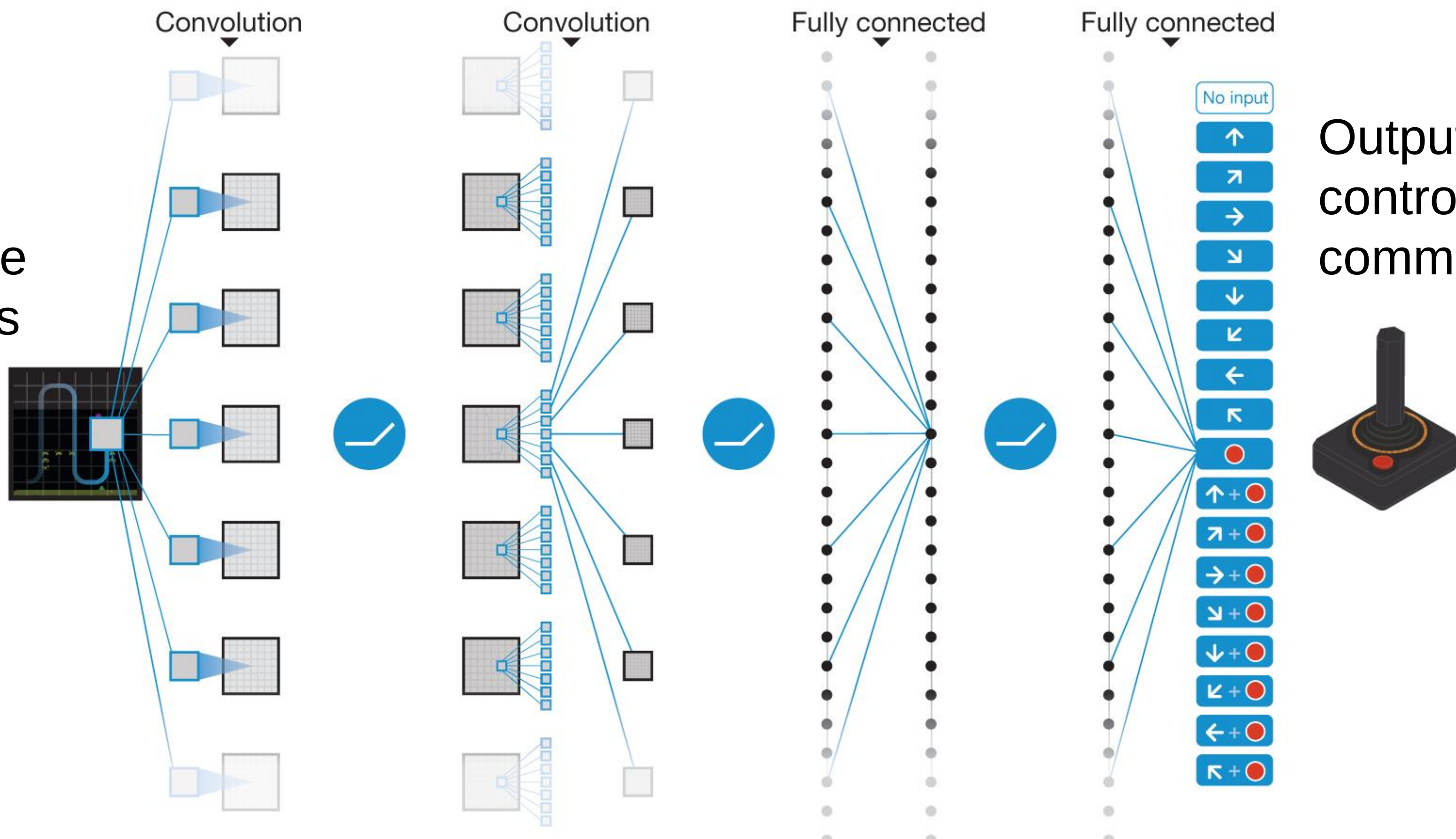
Currently Hot Research Directions

- Generative Models
  - Networks for image generation
  - Generative Adversarial Networks (GAN)
- Towards General Models of Computation
  - Memory Networks
  - Neural Turing Machines
- Deep Reinforcement Learning

Deep Reinforcement Learning

- Example application: Learning to play Atari games

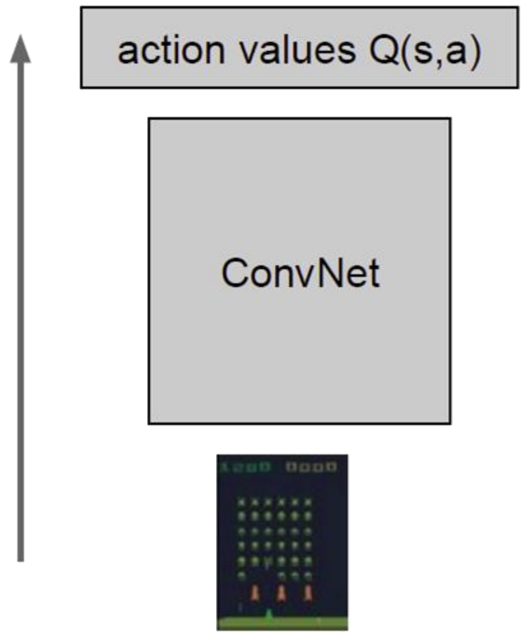
Input: pixels +game scores



Output: control commands

V. Mnih et al., Human-level control through deep reinforcement learning, Nature Vol. 518, pp. 529-533, 2015

Idea Behind the Model

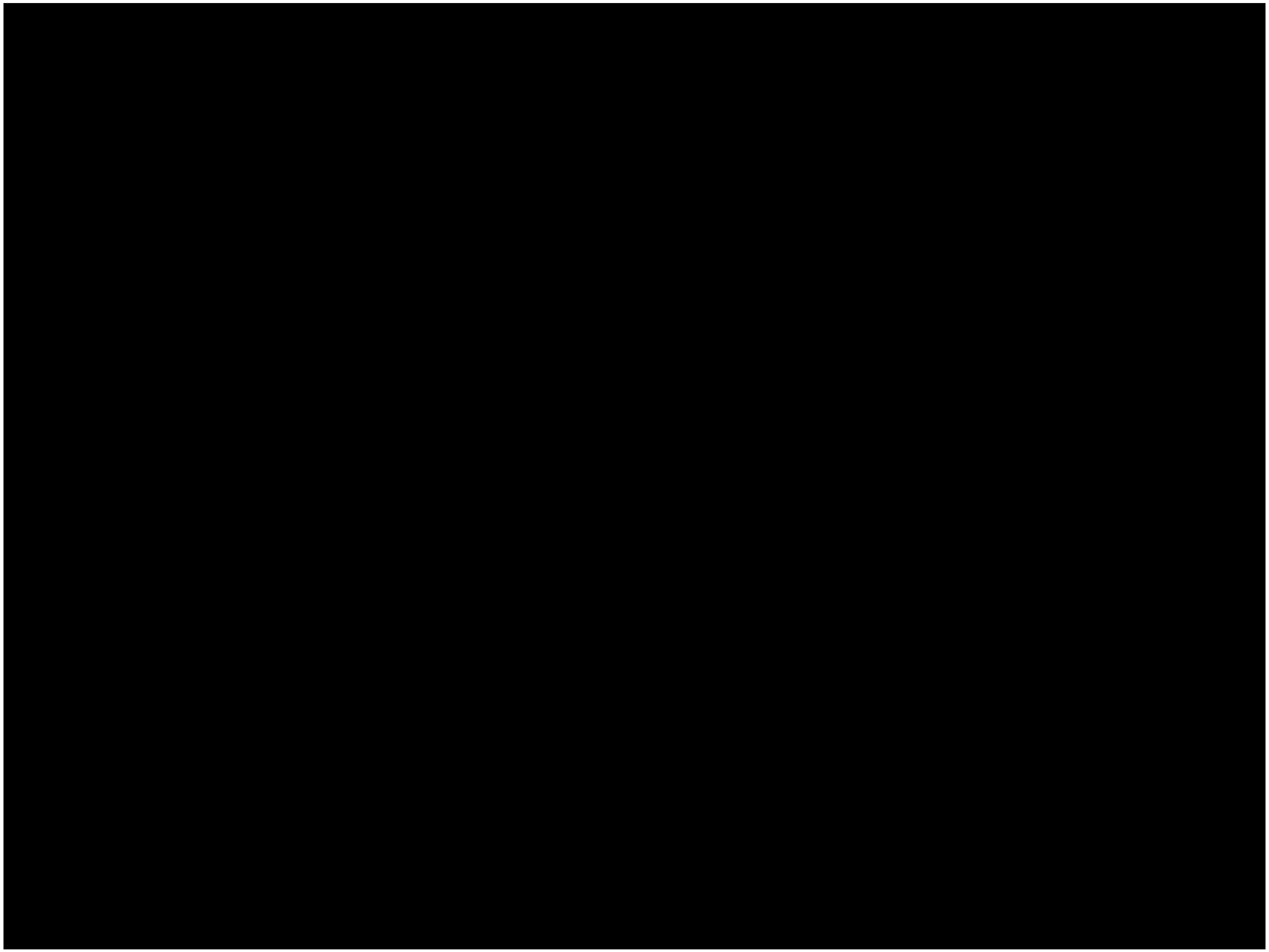


- Interpretation
  - Assume finite number of actions
  - Each number here is a real-valued quantity that represents the Q function in Reinforcement Learning
- Collect experience dataset:
  - Set of tuples {(s,a,s',r), … }
  - (State, Action taken, New state, Reward received
- L2 Regression Loss

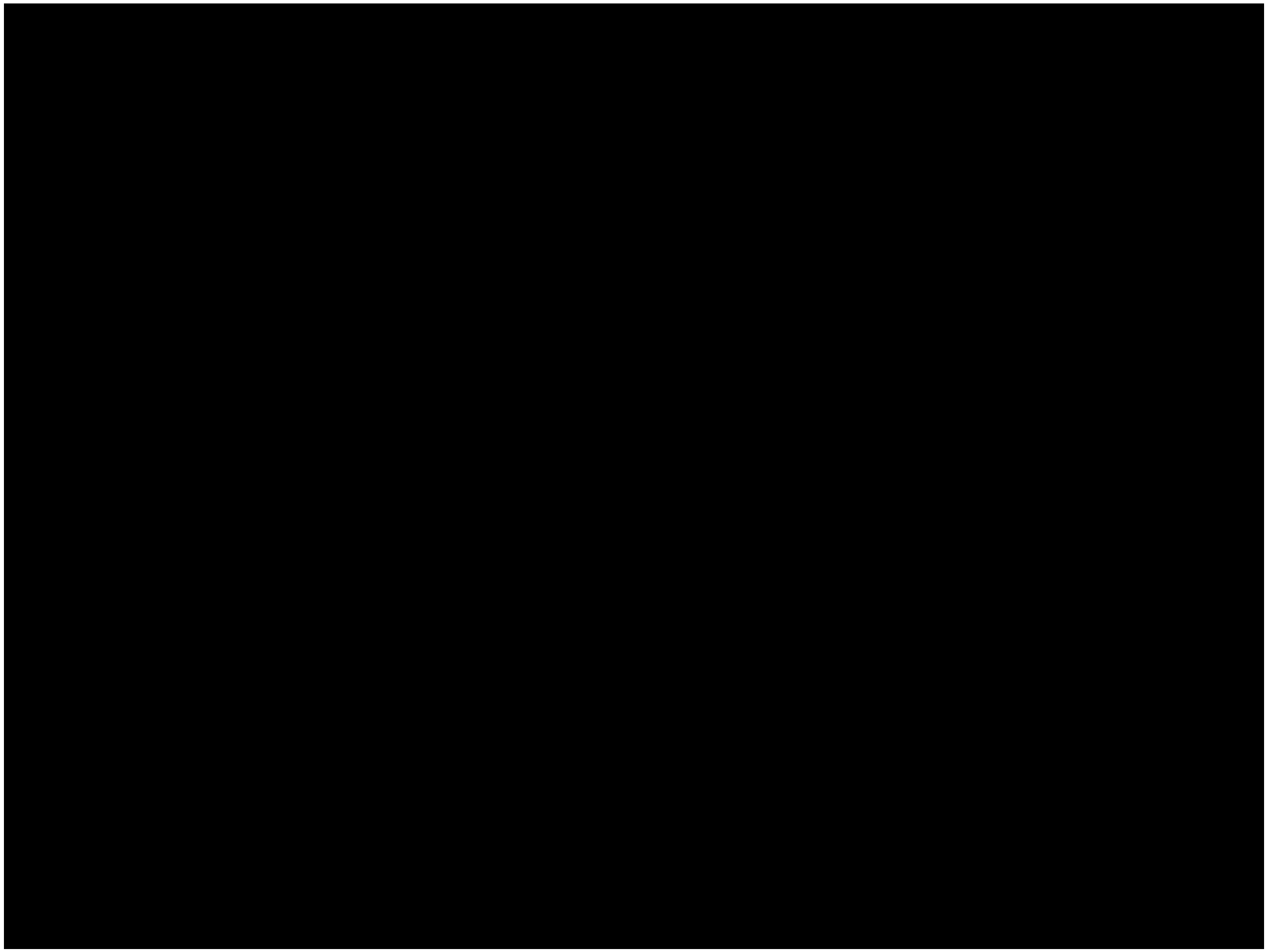
$$L_i(\theta_i) = \mathbb{E}_{(s,a,r,s')\sim \mathrm{U}(D)}\left[\left(\overbrace{\boxed{r + \gamma \max_{a'} Q(s',a';\theta_i^-)}}^{\text{target value}} - \overbrace{\boxed{Q(s,a;\theta_i)}}^{\text{predicted value}}\right)^2\right]$$

Current reward + estimate of future reward, discounted by γ

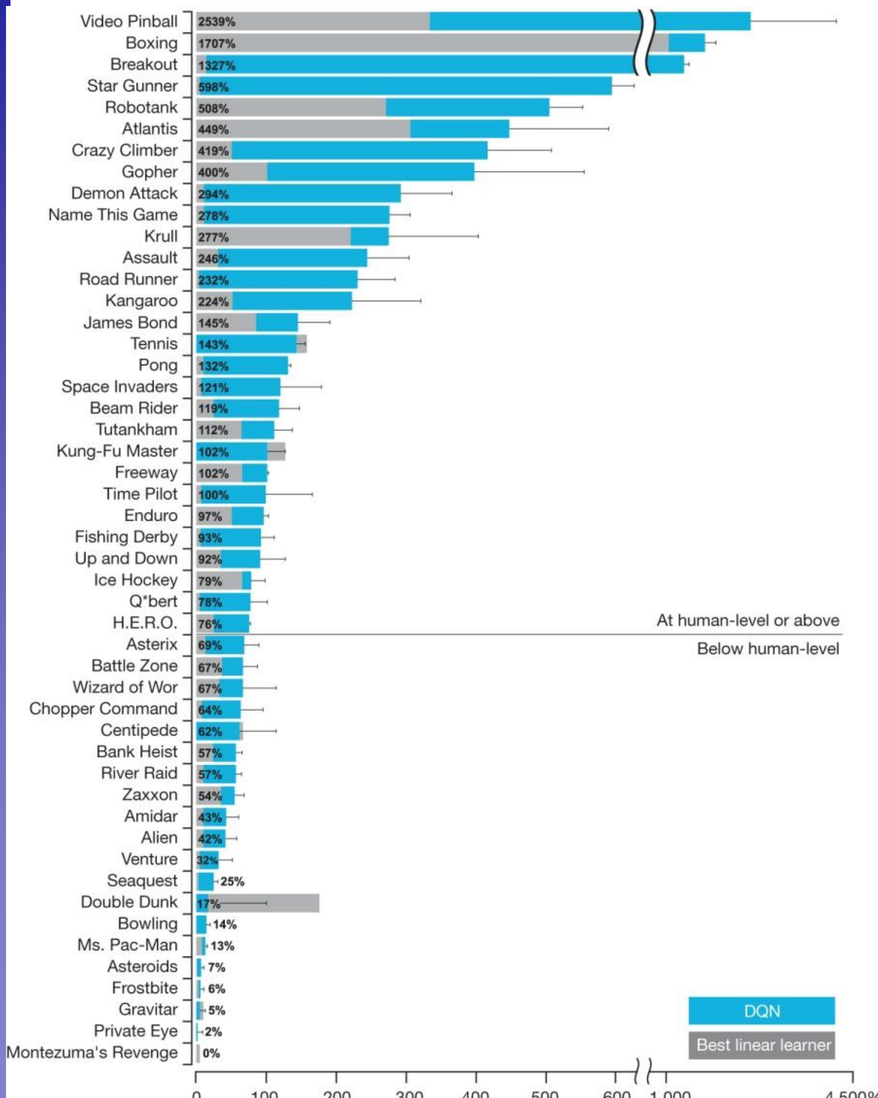
Results: Space Invaders

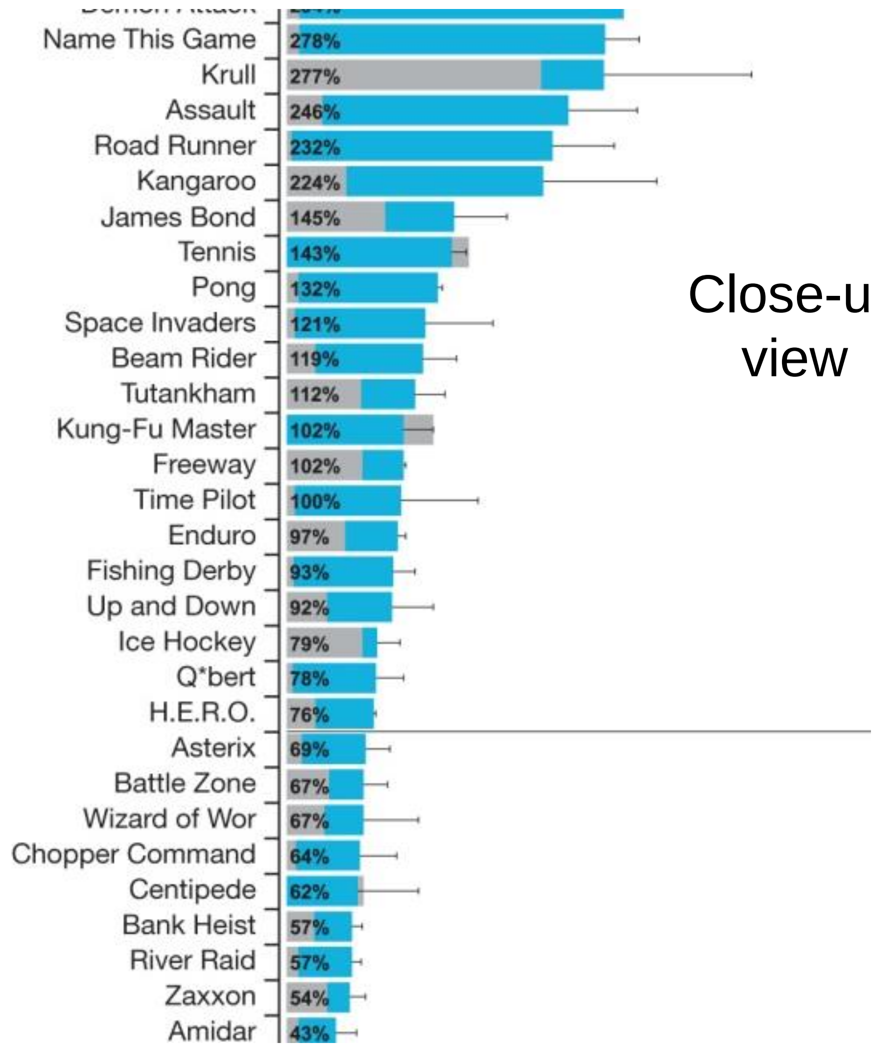


Results: Breakout



Comparison with Human Performance





Close-up view

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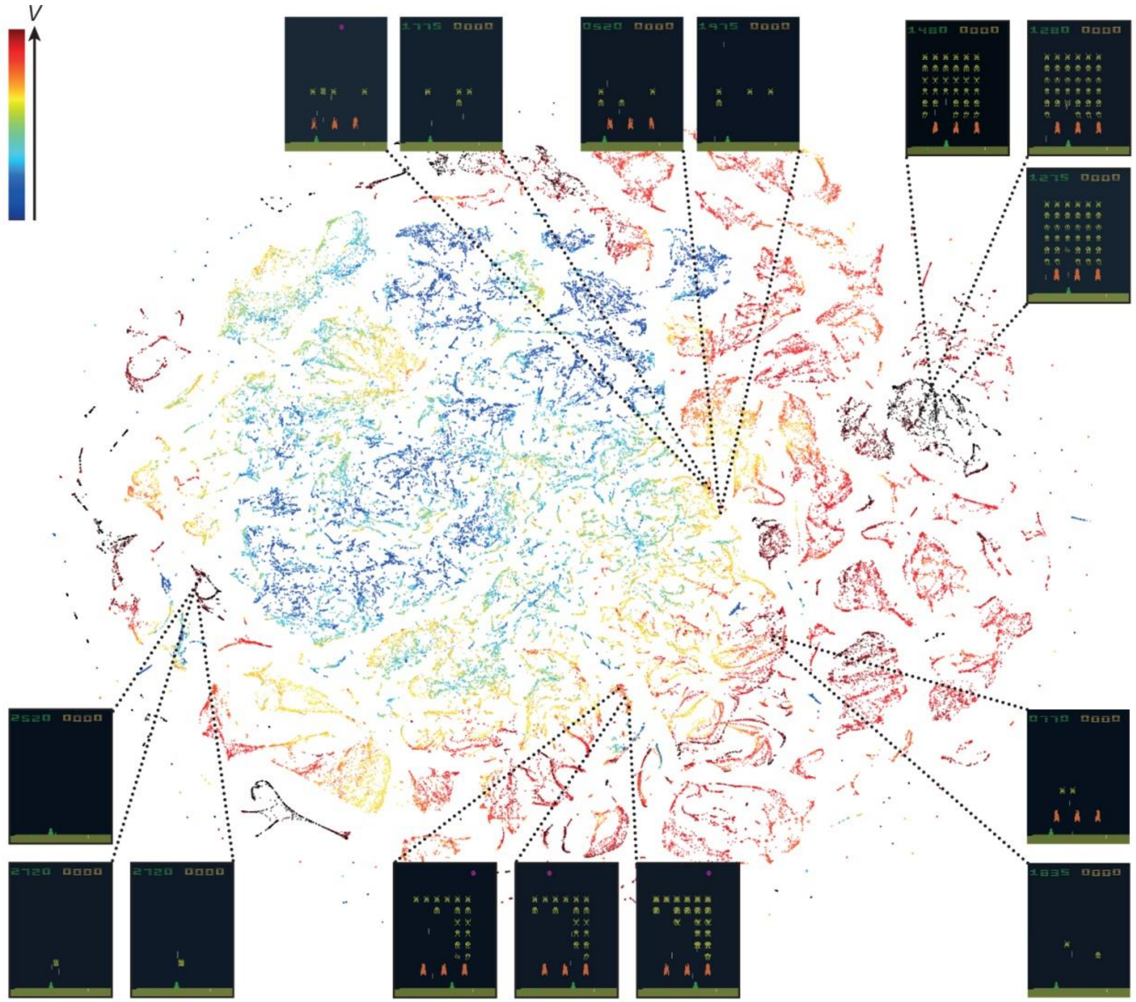
Learned Representation



- t-SNE embedding of DQN last hidden layer (Space Inv.)

Success Story: Alpha Go

Applications: Autonomous Driving

- Reinforcement Learning
  - Learning to drive purely by RL is actually not such a good idea...
  - …at least not in real traffic.

- Working in a simulated environment can help keep down the cost, but…
  - The environment needs to be realistic enough and needs to include realistic behaviors by other traffic participants.
  - *If we already have good models for such realistic driving behavior, what do we then actually need RL for?*
  - RL will only teach us acceptable driving behavior (within the bounds of the reward function), it will not teach us good driving.
  - *Better: Learning from humans*

Example Driving Simulator: CARLA

A. Dosovitskiy, G. Ros, F. Codevilla, A. Lopez, V. Koltun, CARLA: An Open Urban Driving Simulator, CoRL 2017.

Imitation Learning

(a) Aerial view of test environment (b) Vision-based driving, view from onboard camera (c) Side view of vehicle

- Imitation Learning
  - Learn from demonstrations of human driving
  - But… we cannot fully imitate the human behavior, since we may want to drive to a different location
- Conditional Imitation Learning
  - Learn driving behaviors directed by high-level commands

F. Codevilla, M. Mueller, A. Lopez, V. Koltun, A. Dosovitskiy, End-to-end Driving via Conditional Imitation Learning, ICRA 2018.

Imitation Learning

F. Codevilla, M. Mueller, A. Lopez, V. Koltun, A. Dosovitskiy, End-to-end Driving via Conditional Imitation Learning, ICRA 2018.

References and Further Reading

- DQN paper
  - www.nature.com/articles/nature14236

- AlphaGo paper
  - www.nature.com/articles/nature16961