

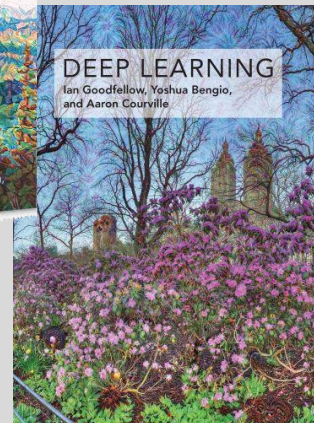
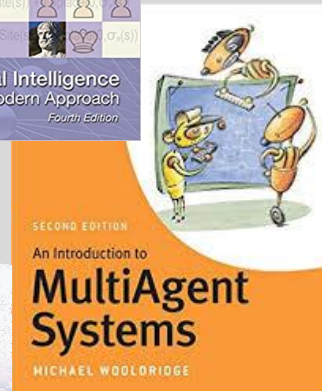
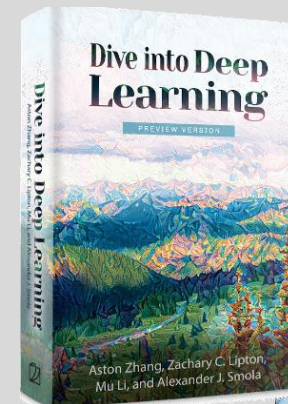
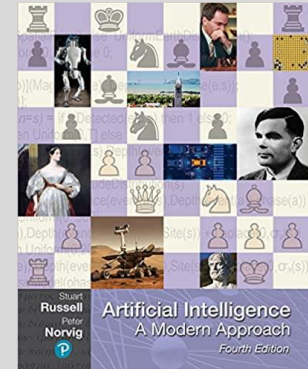


BMB3015 ARTIFICIAL INTELLIGENCE

INTRODUCTION

Course Resources

- Artificial Intelligence: A Modern Approach (2020)
 - Stuart Russel and Peter Norvig, Prentice Hall
 - <http://aima.cs.berkeley.edu/>
- An Introduction to Multiagent Systems (2009)
 - Michael Wooldridge, John Wiley & Sons
- Dive into Deep Learning (2022)
 - Aston Zhang, Zachary C. Lipton, Mu Li, and Alexander J. Smola, arXiv preprint
 - DOI: <https://doi.org/10.48550/arXiv.2106.11342>
- Deep Learning (2016)
 - Ian Goodfellow, Yoshua Bengio, Aaron Courville
 - DOI: <http://www.deeplearningbook.org>
- Lecture notes of other universities
 - YTU
 - Stanford University
 - MIT



ASSESSMENT CRITERIA

- Homework 30% (4-5)
 - Groups are allowed (3 students at maximum)
- Midterm 10%
- Final 60%
- Attendance (Bonus) 7%
- Pop-up quizzes (Bonus) 3%

Course Contents I

- **Intelligent agents**
- **Problem solving**
 - Uninformed and informed search
 - Adversarial search
 - Constraint satisfaction problems
- **Knowledge and reasoning**
 - Logical agents
 - Propositional logic and first order logic
 - Inference in first order logic
 - Knowledge representation

Course Contents II

- Planning
 - Forward and backward searches
 - Planning and acting in real world
- **Uncertainty and reasoning**
 - Probability theory
 - Bayes' rule
 - Probabilistic reasoning: Bayesian networks
 - Probabilistic reasoning over time: Hidden Markov models
- **Making simple and complex decisions**
 - Utility theory
 - Value iteration and Markov decision processes

Course Contents II

- **Learning**
 - Learning from observations: Decision trees
 - Knowledge in learning
 - Logical formulation of learning and logic programming
 - Statistical learning methods:
 - Naive Bayes, expectation maximization, neural networks,
 - Nearest neighbor models, kernel models
 - Kernel machines
 - Reinforcement learning
 - Deep Learning
- Communicating, perceiving and acting
 - Natural language processing
 - Computer vision
 - Robotics

Matlab Coders

1. Register Mathworks using your university email accounts.

✓ **Agreement canceled**

1. Download and setup latest Matlab version.

2. Online Matlab can be another option for your projects.

3. Useful Matlab toolboxes for AI

✓ Matlab Core

✓ Statistics and Machine Learning Toolbox

✓ Deep learning Toolbox

✓ Reinforcement Learning Toolbox

✓ Robotics System toolbox

✓ Image Processing Toolbox

✓ Signal Processing Toolbox

✓ Curve Fitting Toolbox

✓ Optimization Toolbox

✓ ...

Python Coders

1. Install Anaconda and a Python IDE (Visual Studio Code)

- ✓ Using Anaconda prompt set up your environment for this course

conda create -n bmb3015 python=3.12

- ✓ Activate your environment before running your programs

conda activate bmb3015

- ✓ Deactivate your environment after running your programs

conda deactivate bmb3015

2. A tutorial for a fast introduction to Python

- ✓ <http://cs231n.github.io/python-numpy-tutorial/>

Useful Installations

- `conda activate bmb3015`
 - `conda install numpy`
 - `conda install matplotlib`
 - `conda install -c conda-forge opencv`
 - `conda install scikit-image`
 - `conda install -c anaconda scipy`
 - `conda install seaborn`
 - `conda install -c conda-forge scikit-learn`
 - `conda install tensorflow`
 - `conda install keras`
- Jupyter is a browser-based solution to compile your projects.
- Colab or Kaggle platforms are cloud solutions to compile your projects.

What is Intelligence?

- Intelligence:
 - ability to think, learn, and understand things
 - instead of doing things by instinct or automatically
 - ability to solve problems
 - ability to make decisions
- Are animals intelligent?
- What do humans have other than intelligence?
 - Dualism: there is a part of human mind (soul) that is outside of nature (Descartes)
 - Materialism: mind is brain's operation according to laws of physics

Activities Requiring Intelligence

- Basic activities
 - Problem solving
 - Understanding
 - Thinking
 - Learning
 - Decision making
 - Inference
 - Planning
- Sophisticated activities
 - Perception
 - Communication
 - Movement



What is Artificial Intelligence (AI)?

Measure Against

human
performance

ideal concept of
intelligence (rationality)

Address

thought
processes &
reasoning

behaviour

Systems that think like humans	Systems that think rationally
<p>"The exciting new effort to make computers think . . . <i>machines with minds</i>, in the full and literal sense." (Haugeland, 1985)</p> <p>"[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . ." (Bellman, 1978)</p>	<p>"The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985)</p> <p>"The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)</p>
Systems that act like humans	Systems that act rationally
<p>"The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990)</p> <p>"The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)</p>	<p>"Computational Intelligence is the study of the design of intelligent agents." (Poole <i>et al.</i>, 1998)</p> <p>"AI . . . is concerned with intelligent behavior in artifacts." (Nilsson, 1998)</p>

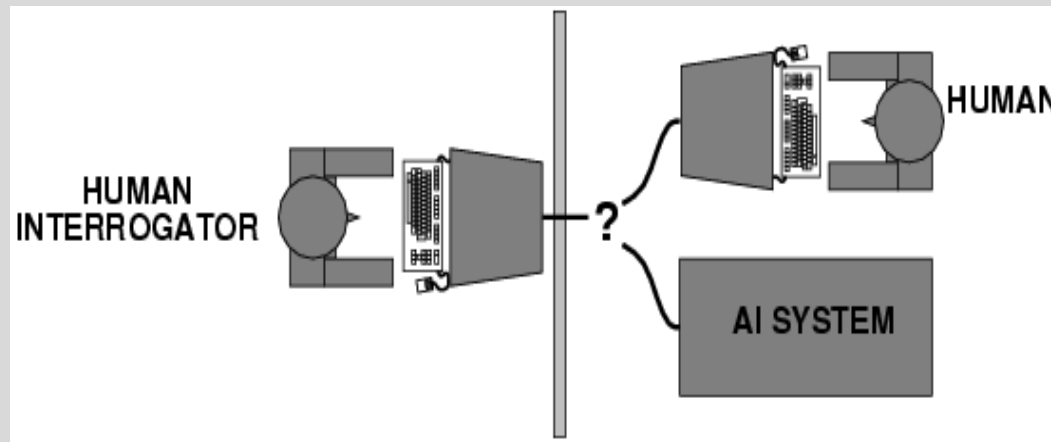
Thinking Humanly:

The Cognitive Modeling Approach

- Knowing the actual workings of human mind
 - introspection
 - psychological experiments
- Design computer programs according to this knowledge
- Cognitive science combines
 - computer models from AI
 - psychological experiments on actual humans
- Goal is modelling precise and testable theories of workings of human mind
 - But humans are not rational all the times

Acting Humanly:

The Turing Test Approach



- Turing test by Alan Turing (1950)
- Requires computer to know
 - **Natural language processing**: for communication in a language
 - **Knowledge representation**: to store what it knows or hears
 - **Automated reasoning**: to answer questions and draw new conclusions
 - **Machine learning**: to adapt to new circumstances and to detect patterns
- Total Turing test
 - requires **computer vision** and **robotics** to perceive/manipulate objects

Acting Humanly: Eliza

- Simulates a therapist
 - 1965 by Joseph Weizenbaum
 - significantly enhanced by George Dunlop.
 - 1999 version is available online
- Case I
 - Human: My dog's mother died recently
 - Eliza: Tell me more about your mother
- Case II
 - Human: I'm having trouble sleeping.
 - Eliza: Why do you say you are having trouble sleeping?
 - Human: Because I can't sleep.
 - Eliza: Is it because you cannot sleep that you came to me?

Thinking Rationally:

The «Laws of Thought» Approach

- The field of «Logic»
 - Precise notation for statements about
 - all kinds of things in the world
 - relations among these things
 - Typical form
 - facts+rules→conclusions
- «Socrates is a man; all men are mortal;
therefore Socrates is mortal »

Thinking Rationally:

The «Laws of Thought» Approach

- Programs can solve any problem described by logical notation BUT
 - Knowledge is not 100% certain all the times
 - Without guidance solving problems may not be practical
 - Even problems with just a few dozen facts can exhaust the computational resources

Acting Rationally:

The Rational Agent Approach

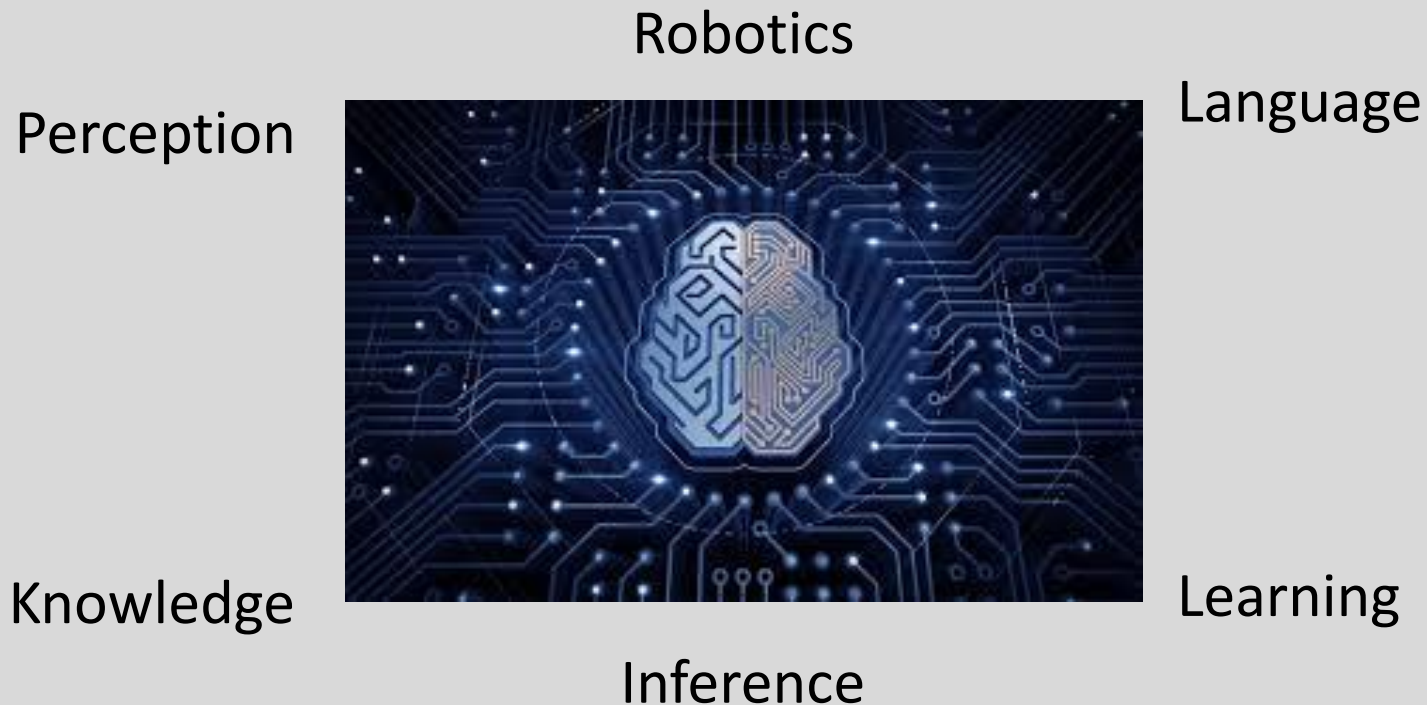
- An agent is just something that acts
- A rational agent acts
 - to achieve the best outcome given what it knows
 - may be expected to work under uncertainty
 - feasibly with limited computational resources
 - May also limit rationality
- Advantageous since
 - More general than «laws of thought» approach
 - More suitable for scientific development than the approaches based on human behaviour or human thinking

Goals of AI

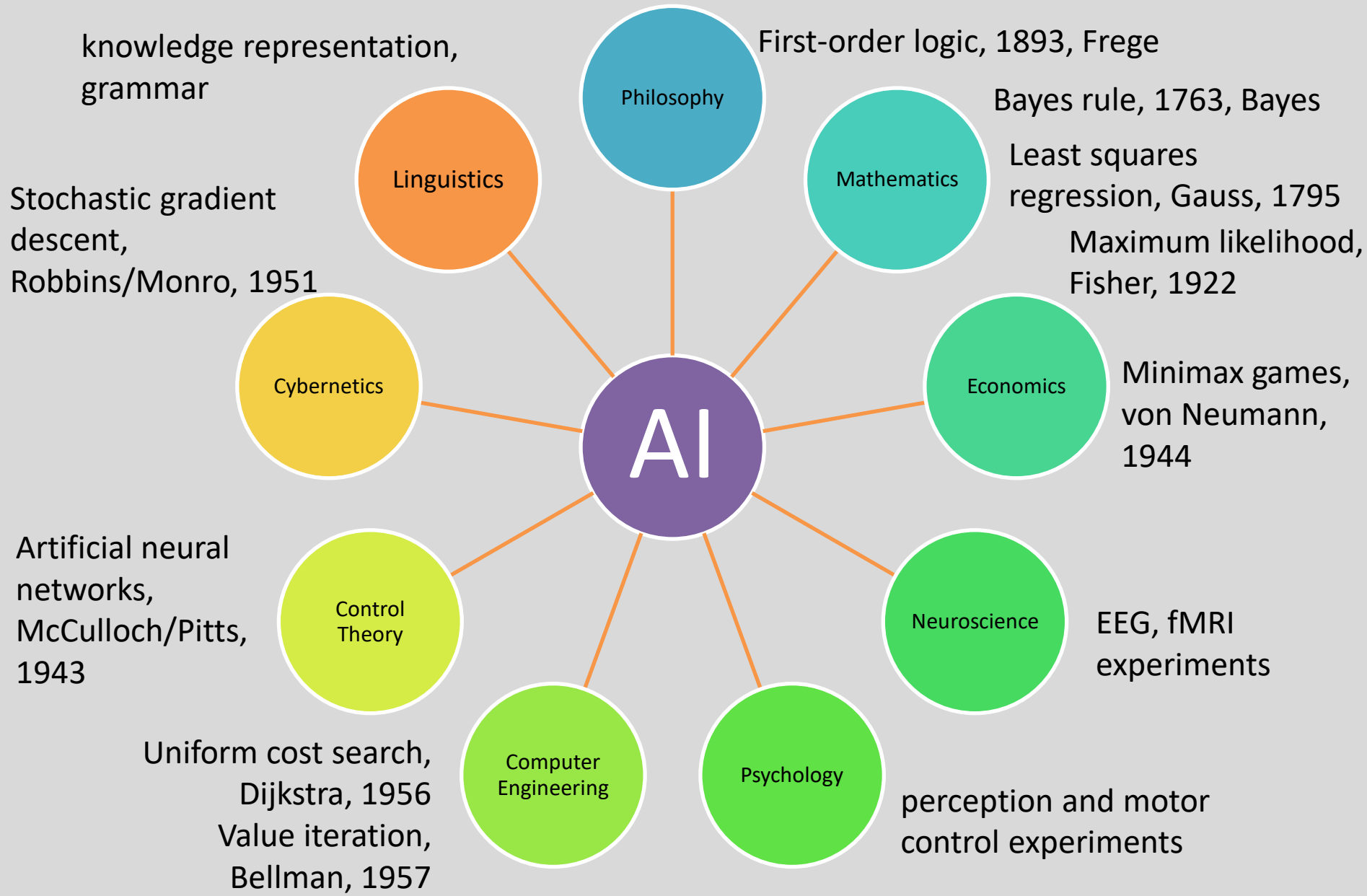
- AI as a field
 - tries to understand & build rational agents
 - Not humans!
- Main goals
 - more intelligent and useful machines
 - AI tools to benefit society
 - better understanding the human intelligence
 - AI agents to have close-to-perfect intelligence

A Perfect Intelligent (Rational) Agent

- Agents do not satisfactorily have all these abilities combined yet!
- Machines have narrow tasks, millions of examples unlike humans.



Foundations of AI



A Brief History I

- **1943** McCulloch & Pitts: Boolean circuit model of brain
- **1950** Turing's «Computing Machinery and Intelligence»
- **1952-69** Look, Ma, no hands!
- **1950s** Early AI programs, including Samuel's checkers program, Newell & Simon's Logic Theorist, Gelernter's Geometry Engine
- **1956** Dartmouth meeting: «Artificial Intelligence» adopted
- **1965** Robinson's complete algorithm for logical reasoning
- **1966-74** AI discovers computational complexity, Neural network research almost disappears
- **1969-79** Early development of knowledge-based systems
- **1980-88** Expert systems industry booms

Expert Systems

- Programs designed to solve expert problems by using knowledge and inference

EXPERT SYSTEMS

- The result is indefinite
- Use expert knowledge
- Can solve a new problem by using its own knowledge
- Mostly use AI languages such as Lisp or Prolog

PROCEDURAL PROGRAMS

- The result is definite
- Based on simple algorithms
- Dependent on a new compilation to solve a new problem
- Use programming languages such as Pascal, Basic, C, Java

Early Medical Expert Systems

- try to diagnose patients based on reported symptoms and medical test results
 - Mycin (1972) by Stanford University
 - for detecting blood infections
 - GermAlert (1993) by Washington University
 - for detection and reporting of emergency hospital infections
 - Oncocin (1979) by Stanford's School of Medicine
 - for managing patients already diagnosed with cancer and being treated with chemotherapy

If-conditions

the infection is primary-bacteremia

AND the site of the culture is one of the sterile sites

AND the suspected portal of entry is the gastrointestinal tract

THEN

there is suggestive evidence (0.7) that infection is bacteroid

(Mycin)

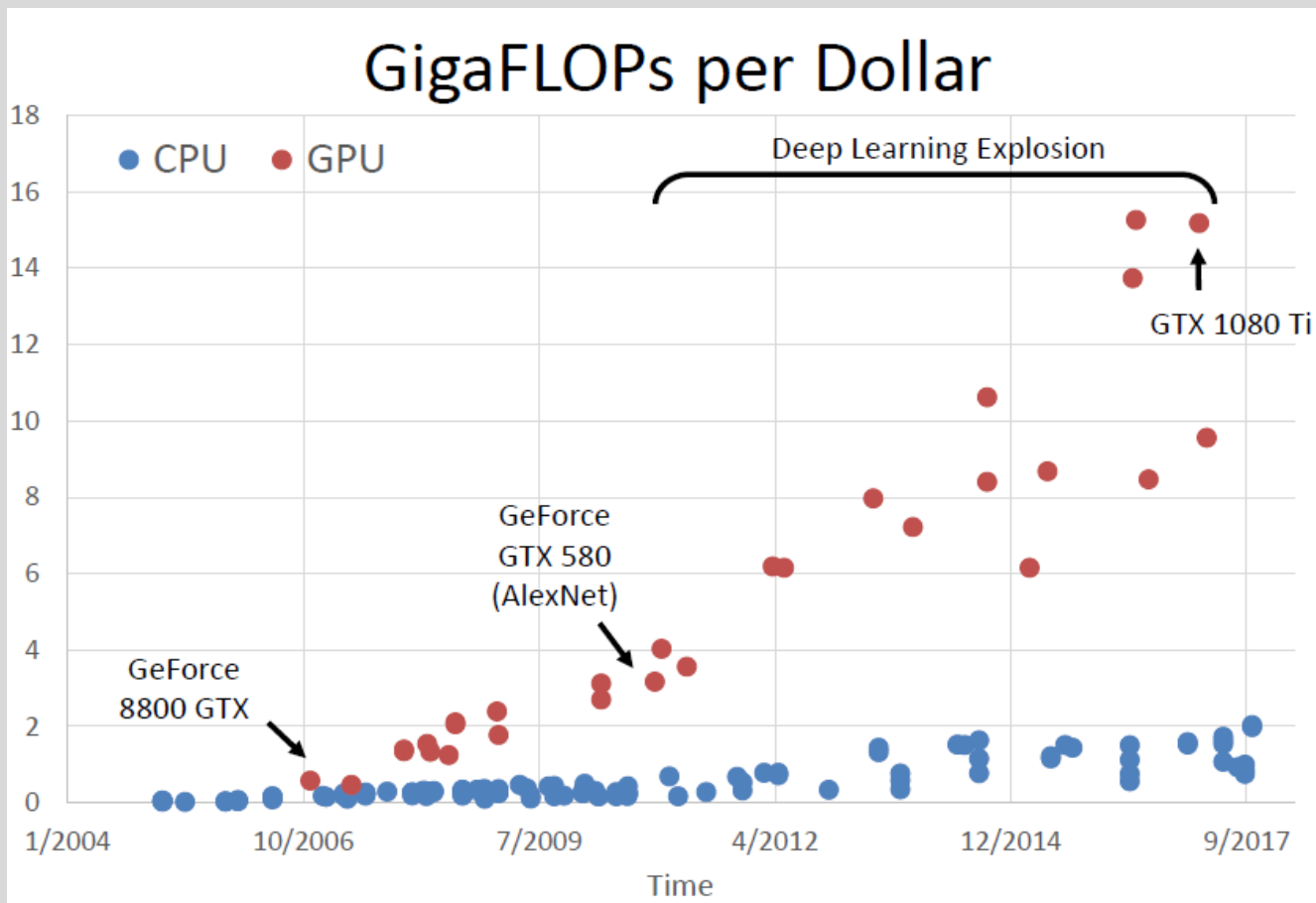


A Brief History II

- **1988-93** Expert systems industry busts: «AI Winter»
- **1985-95** Neural networks return to popularity
- **1988** Resurgence of probability
- **1995** Agents, agents, everywhere
- **2010-...** The deep-learning explosion
- **2016-** Autopilot as an advanced driver assistance system by Tesla
- **2017** AlphaZero by Google DeepMind generalized game player for shogi, chess, and Go
- **2022** ChatGPT (Chat Generative Pre-trained Transformer) by OpenAI
- **Today** Human-level AI back on the agenda?

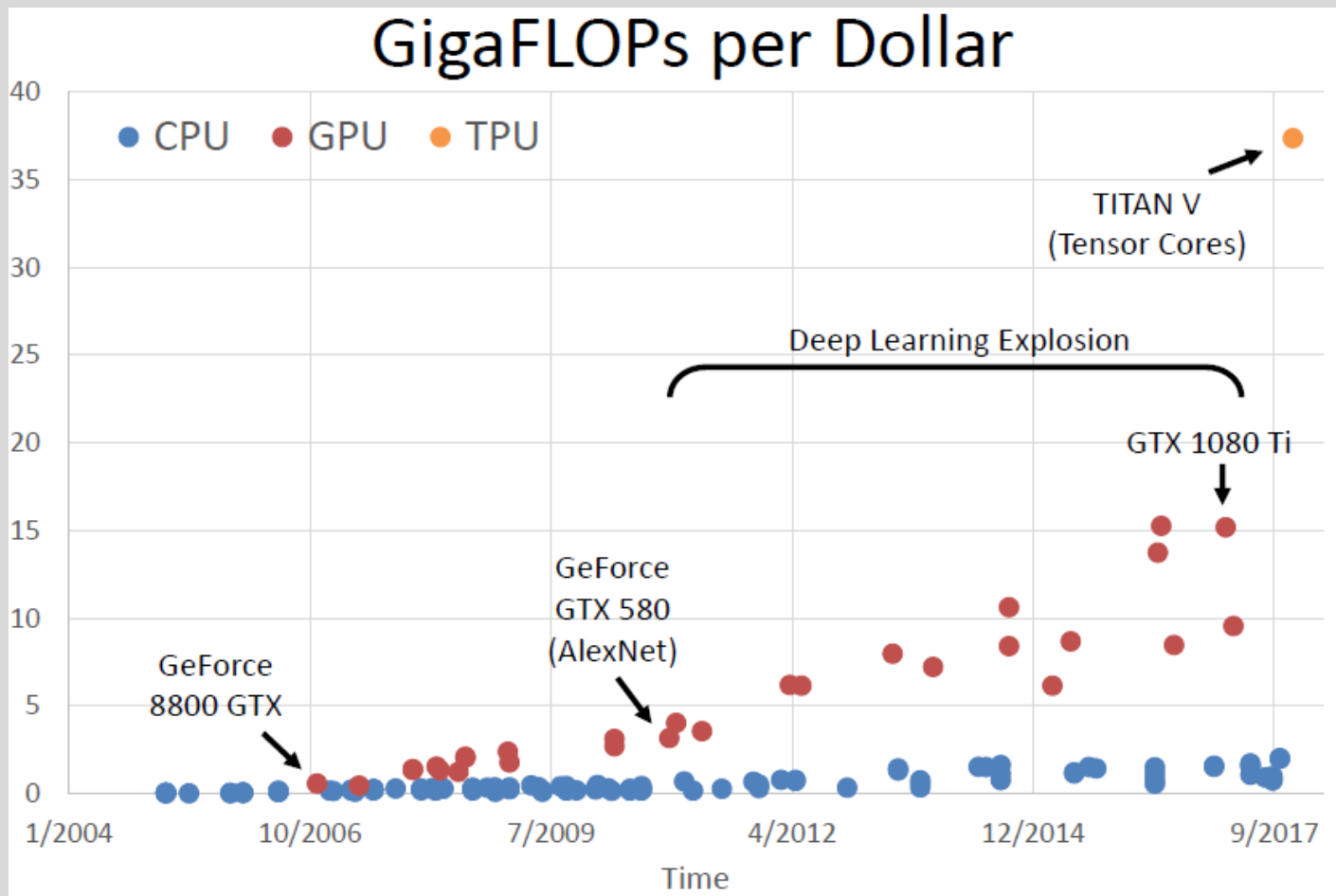
Deep Learning Explosion

- After increase in computational resources



Deep Learning Explosion

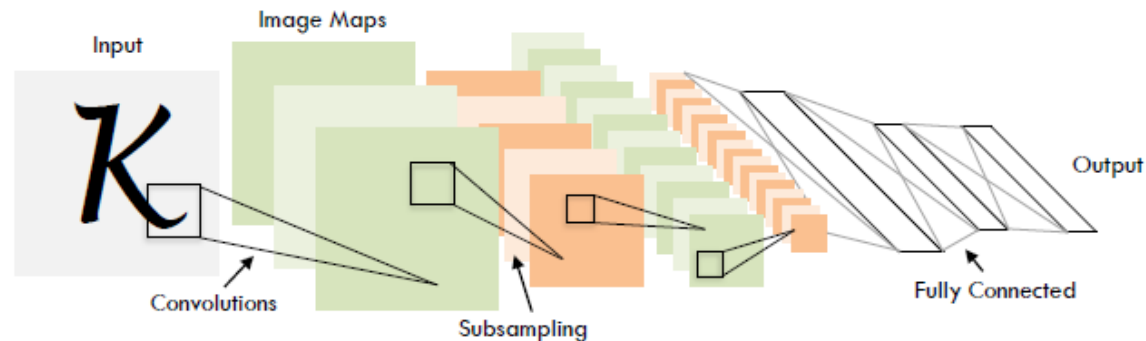
- After increase in computational resources



Deep Neural Networks Not Invented Overnight

1998

LeCun et al.



of transistors



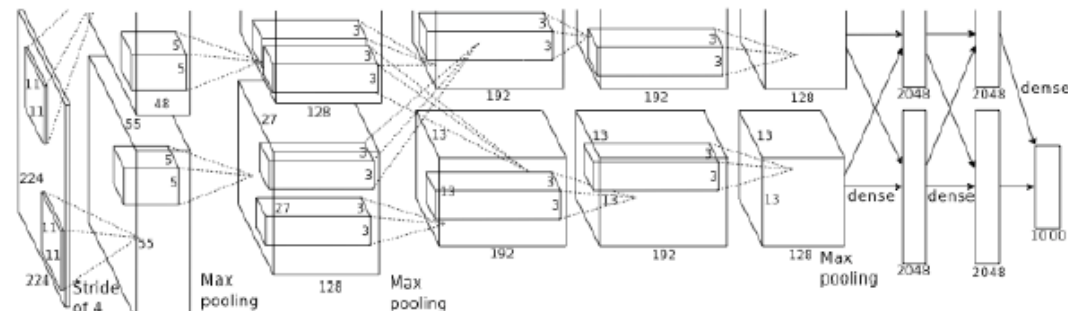
10^6

of pixels used in training

10^7 **NIST**

2012

Krizhevsky et al.



of transistors



10^9

GPUs



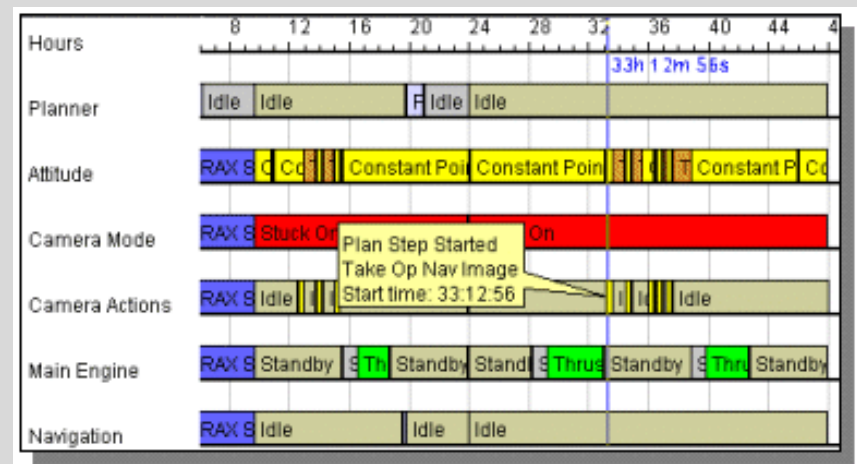
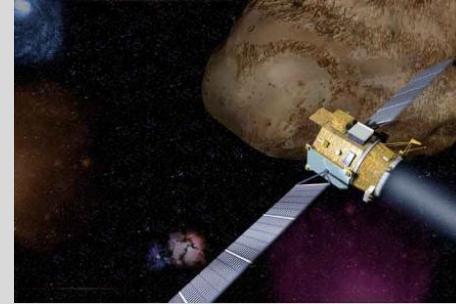
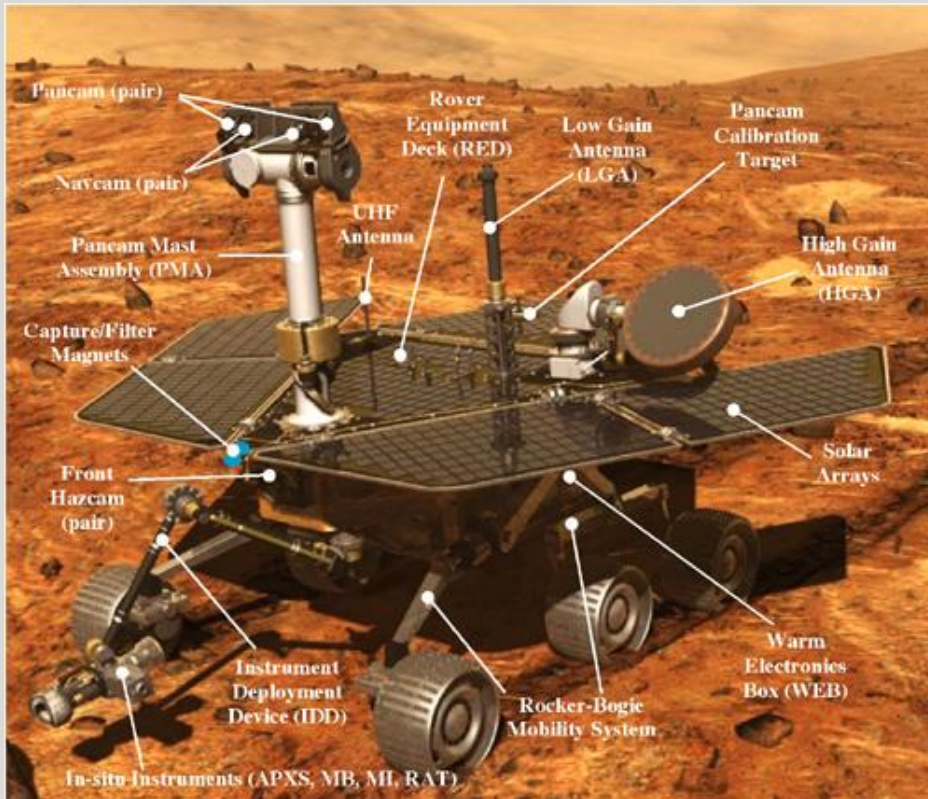
of pixels used in training

10^{14}

IMAGENET

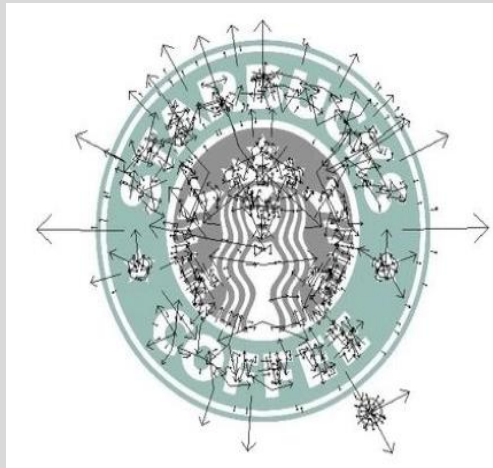
Current Achievements

- Autonomous planning and scheduling
 - NASA's on-board autonomous planning program controlled the scheduling of operations for a spacecraft



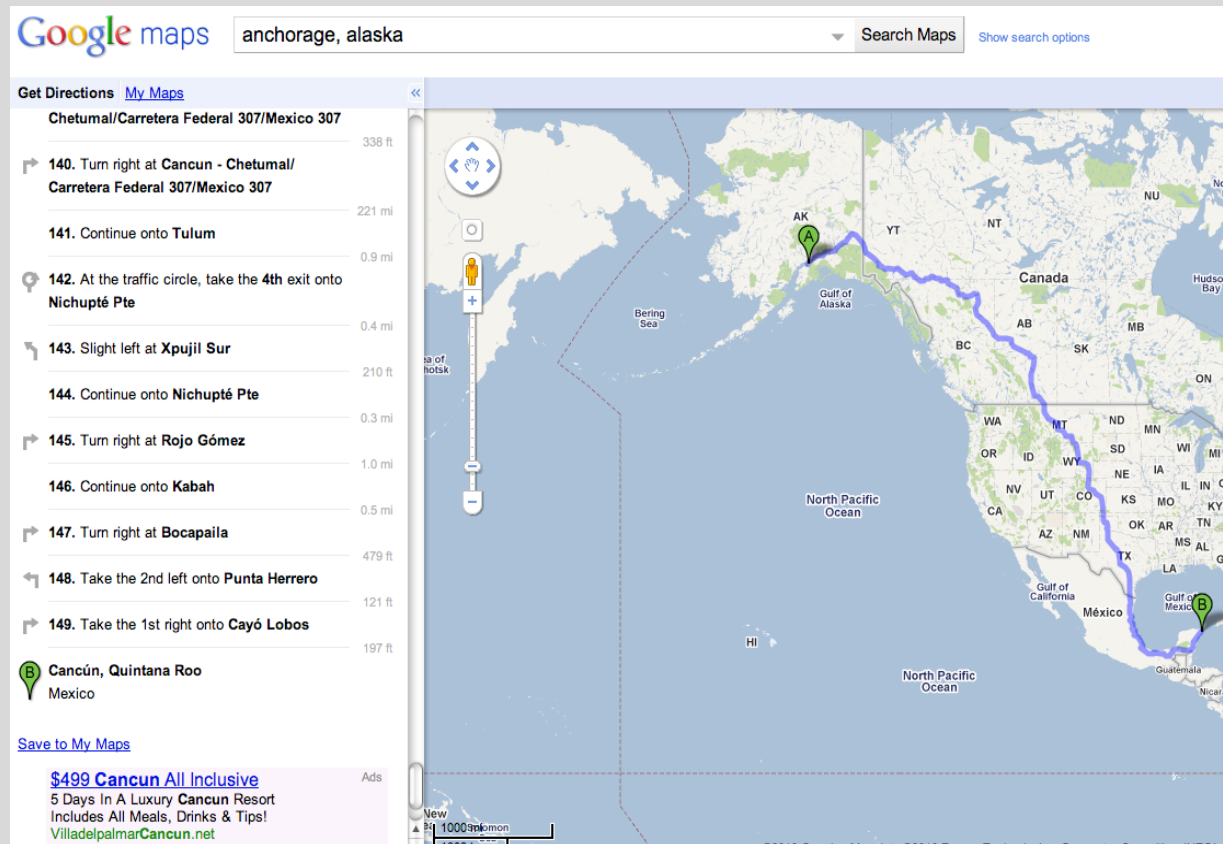
Current Achievements

- Content-based image retrieval
 - Scale-invariant feature transform by Lowe (2004)
 - Convolutional neural networks



Current Achievements

- Path planning
 - Google maps find shortest possible path between initial location to the goal



Current Achievements

- Language understanding and problem solving
 - `Proverb` solves crossword puzzles better than most humans
 - Google sets relate words to a subset of other words
 - Google translate translates between any two languages
 - Better chatbots and messaging assistants
 - Document-based or visual question answering



Automatically create sets of items from a few examples.

Enter a few items from a set of things. ([example](#))

Next, press *Large Set* or *Small Set* and we'll try to predict other items in the set.

- tigers, lions, bears, cats, dogs, birds, horses, reptiles, fish, pet breeders,
- rabbits, *pet health*, *pet food*, *pet supplies*, exotic pets, small mammals, iguanas,
- *animal medications*, pet rescue, *pet adoption*, *veterinary jobs*, pets general,
- elephants, livestock, insects, other, small
- pets, marine life, spiders, amphibians, aquariums, pets, wolves, monkeys, flowers, pigs, wildlife, dolphins, frogs, giraffes, turtles, butterflies, sheep, ferrets, dinosaurs, farm animals

([clear all](#))

Examples:

[green, purple, red](#) [chicken dance, macarena, ymca](#) [alexander, gladiator, troy](#) [hilary duff, kelly clarkson](#) [more...](#)



Automatically create sets of items from a few examples.

Enter a few items from a set of things. ([example](#))

Next, press *Large Set* or *Small Set* and we'll try to predict other items in the set.

-
-
-
-
-

([clear all](#))

cat, man, ls, cp, rm, mkdir, mv,
cd, pwd, rmdir, chmod, ln,
grep, touch, find, ps, chown,
df, less, tar, chgrp, du, sort,
date, echo, kill, tail, wc,
mount, sed, passwd, dd, head,
vi, which, gzip, lpr, who, file,
su, umount, diff, cut, uname,
exit, basename, clear, sleep,
whoami, mknod

Large Set



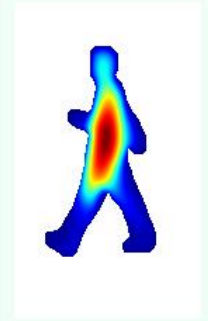





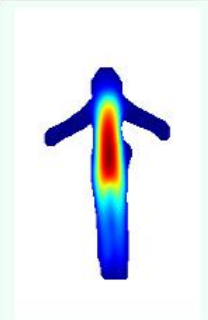
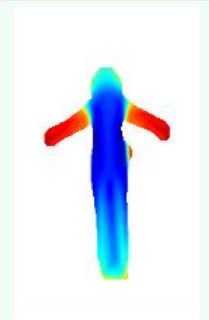
Small Set (15 items or fewer)

Examples:

[green, purple, red](#) [chicken dance, macarena, ymca](#) [alexander, gladiator, troy](#) [hilary duff, kelly clarkson](#) [more...](#)

Current Achievements

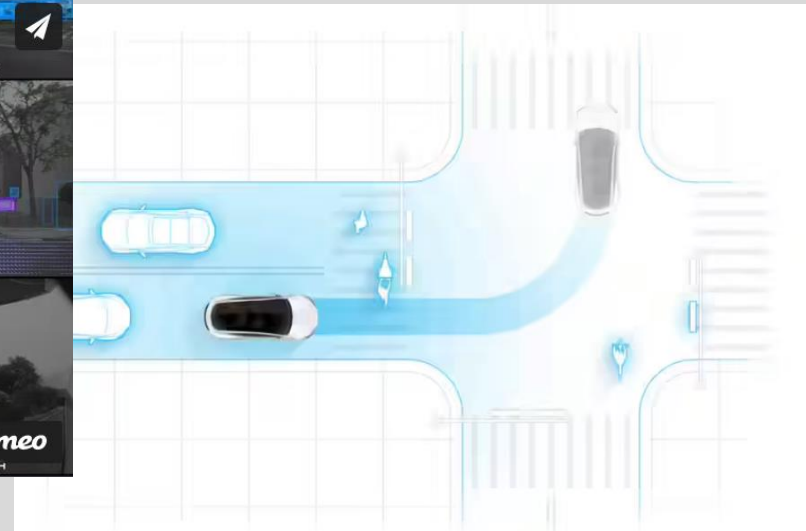
- Action recognition
 - Using cameras with depth-sensing capability or 2-D images meaningful features are extracted and learnt

Input Sequence	Foreground mask	Solution of Poisson eq.	Space-Time "Saliency"	Measure of "Plateness"	Measure of "Stickness"
					
					

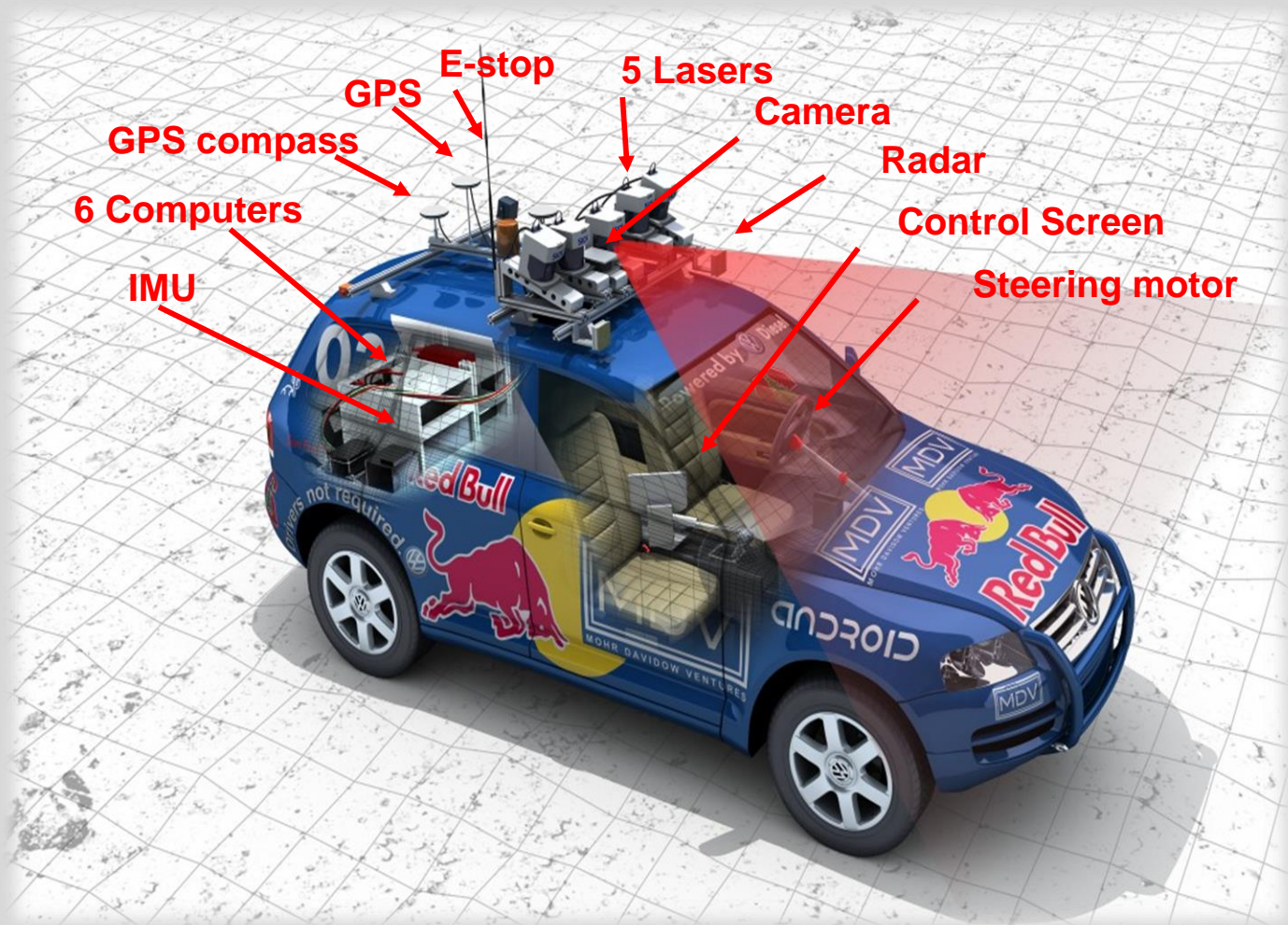


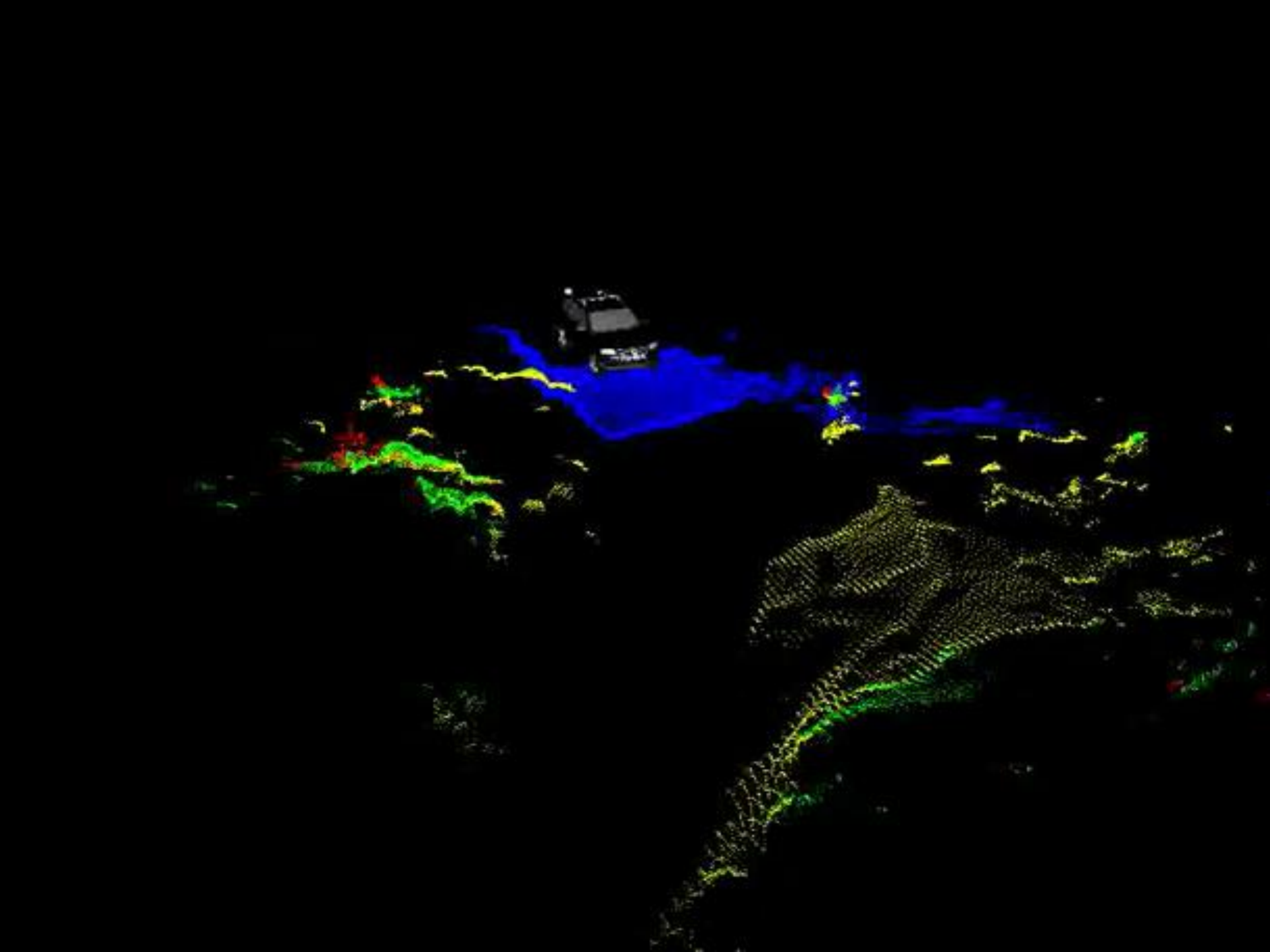
Current Achievements

- Autonomous control
 - Stanford University's self driving car driving autonomously 98% of the time from Pittsburgh to San Diego
 - Tesla's autopilot AI Team

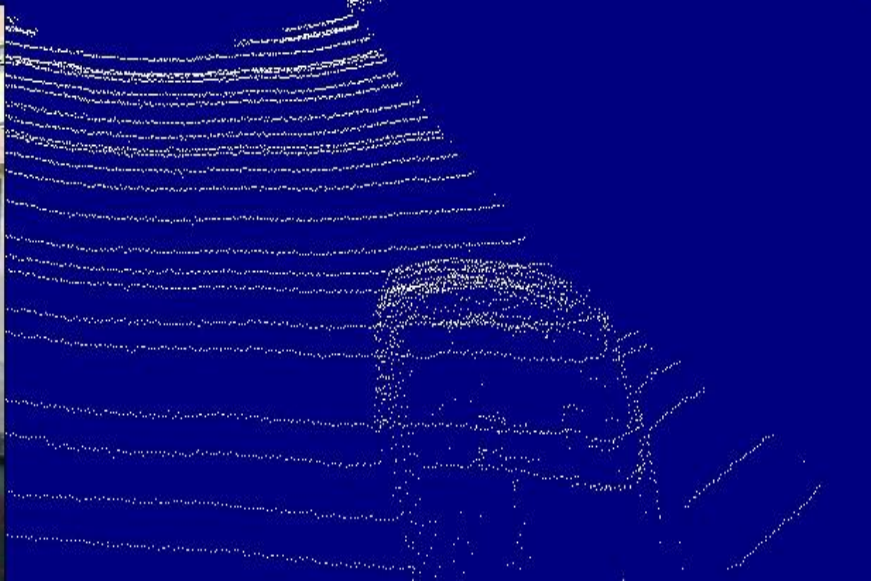
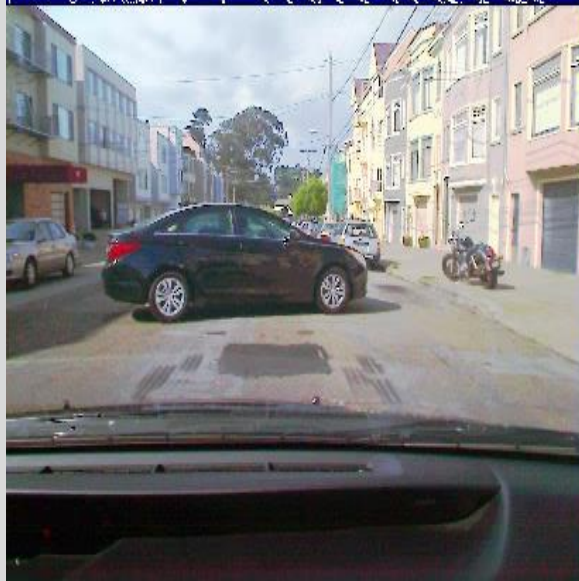
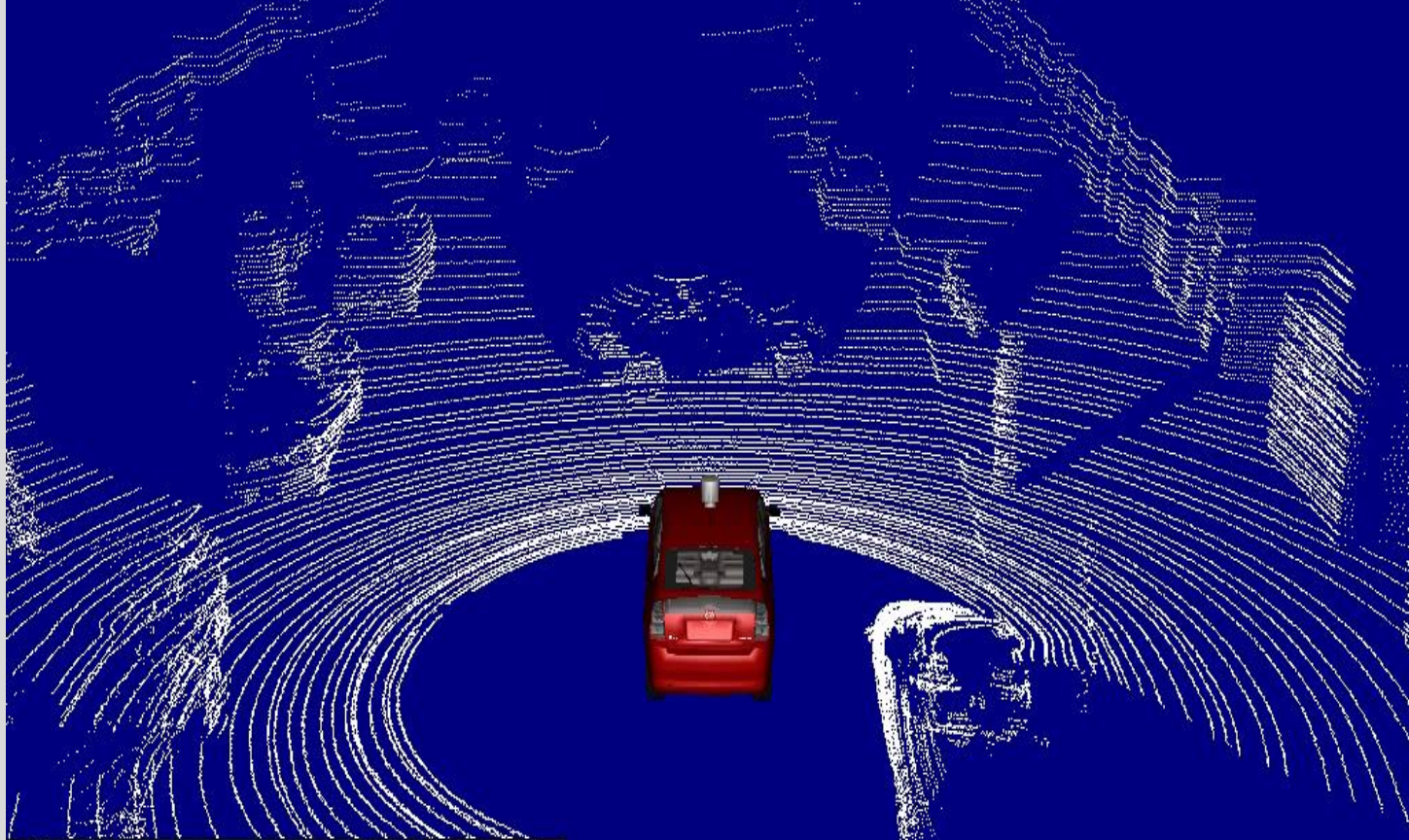


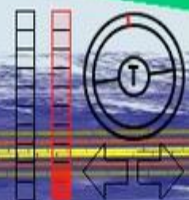
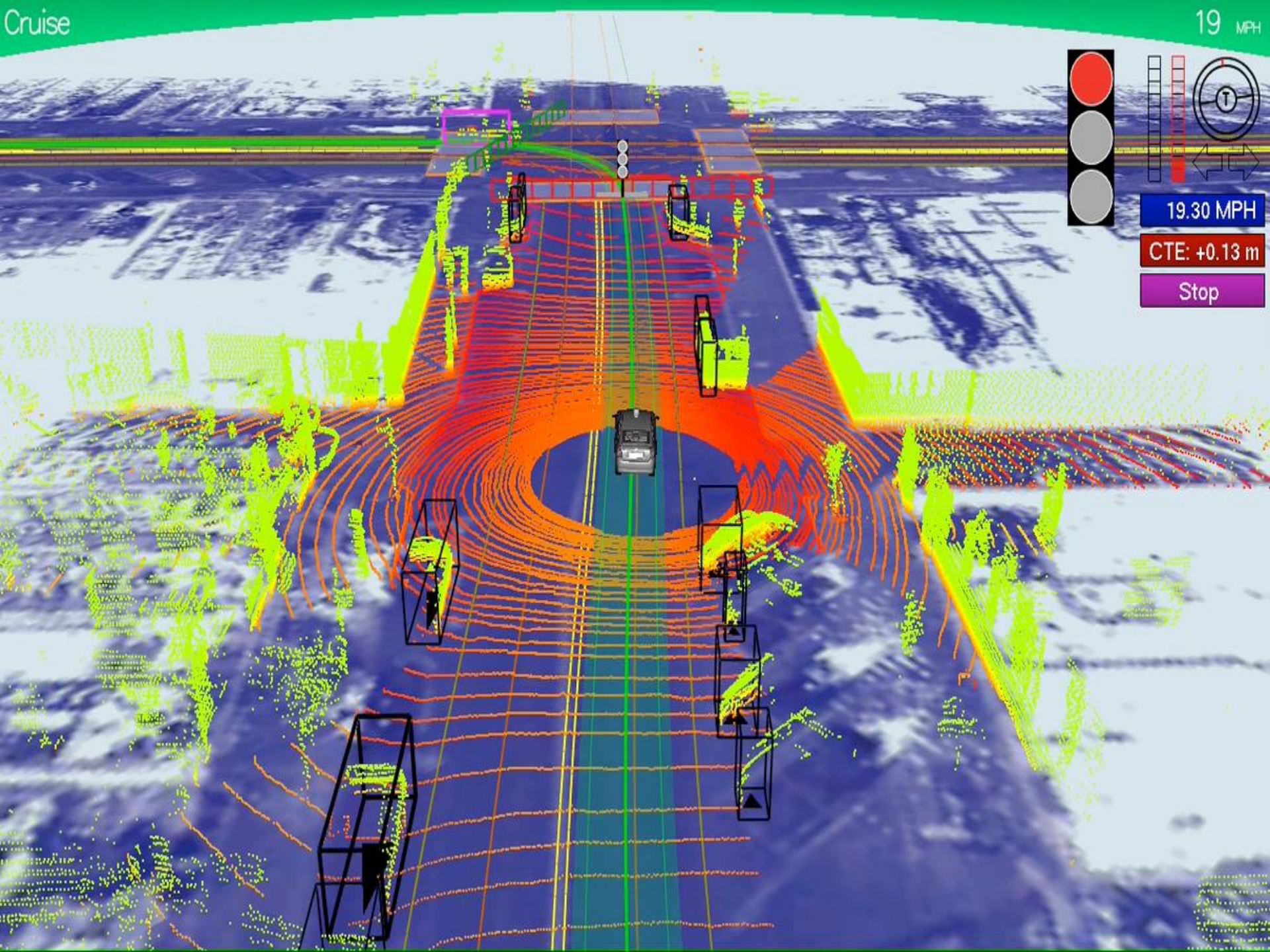
Self-driving Cars











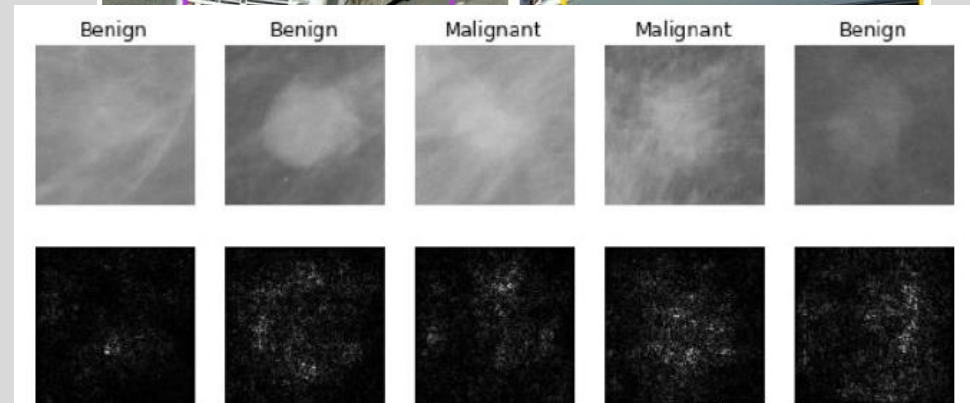
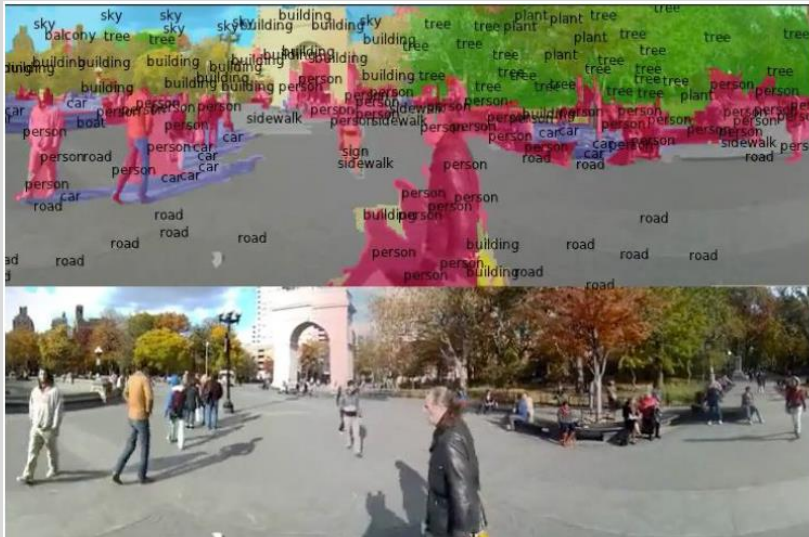
19.30 MPH

CTE: +0.13 m

Stop

Current Achievements

- Object Detection and Segmentation with convolutional neural networks (CNNs)
 - Ren, He, Girshick, Sun 2015
 - Farabet et al., 2012
 - Levy et al. 2016



Current Achievements

- Image Captioning with convolutional neural networks (CNNs) and recurrent neural networks (RNNs)
 - Vinyals et al., 2015; Karpathy and Fei-Fei, 2015

No errors



A white teddy bear sitting in the grass

Minor errors



A man in a baseball uniform throwing a ball

Somewhat related



A woman is holding a cat in her hand



A man riding a wave on top of a surfboard



A cat sitting on a suitcase on the floor



A woman standing on a beach holding a surfboard

Current Achievements

- Game playing
 - Deep Blue defeated the reigning world chess champion Garry Kasparov (1997)
 - DeepMind's AlphaGo defeated the go champion Lee Sedol (2016)



Ethics and Risks

- AI for the good or the bad?
- Possible threats
 - Loss of jobs
 - Loss of privacy rights
 - eavesdropping, tracking of personal choices
 - Loss of accountability
 - the wrong decisions of say a diagnostic agent
 - Loss of lives