UNIVERSITÄT SIEGEN

Faculty of Natural Sciences and Engineering
University of Siegen

# Machine Learning In Robotics – Applications, Challenges And Potentials

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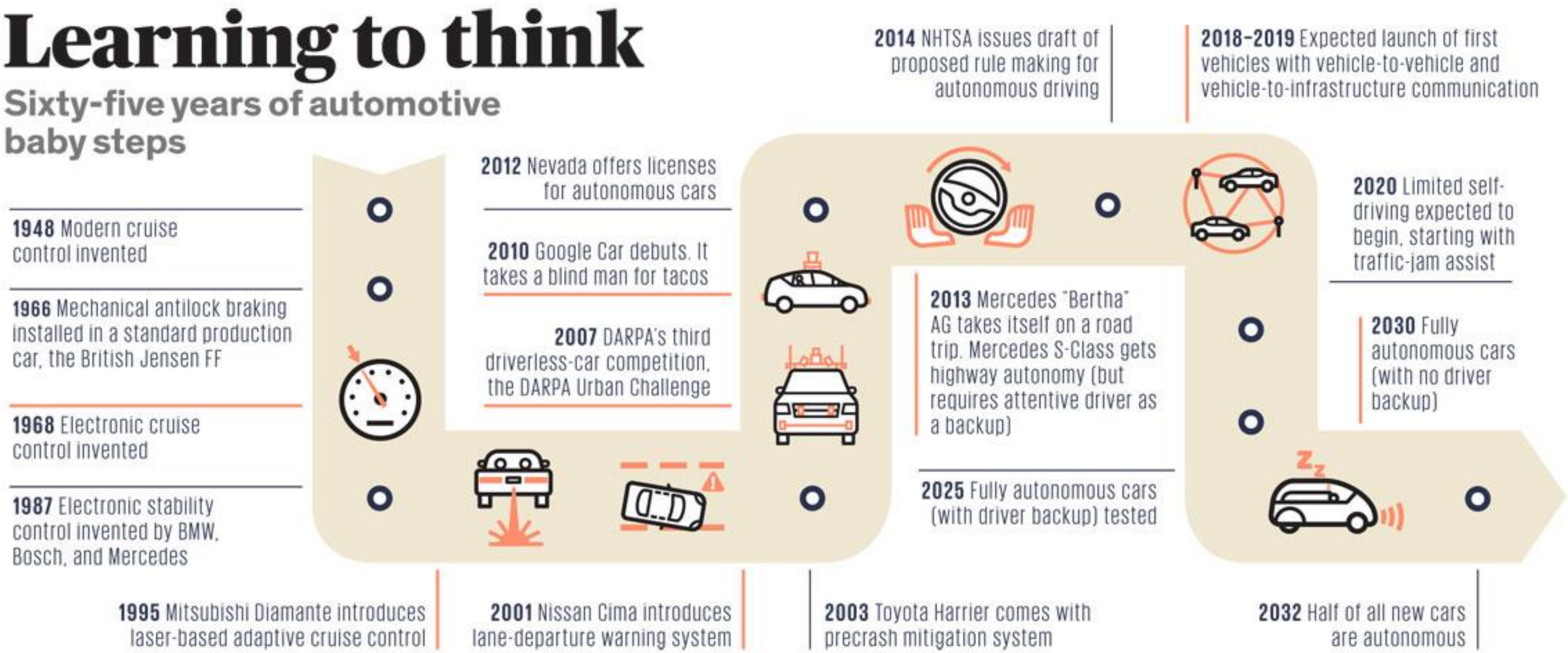
# Agenda

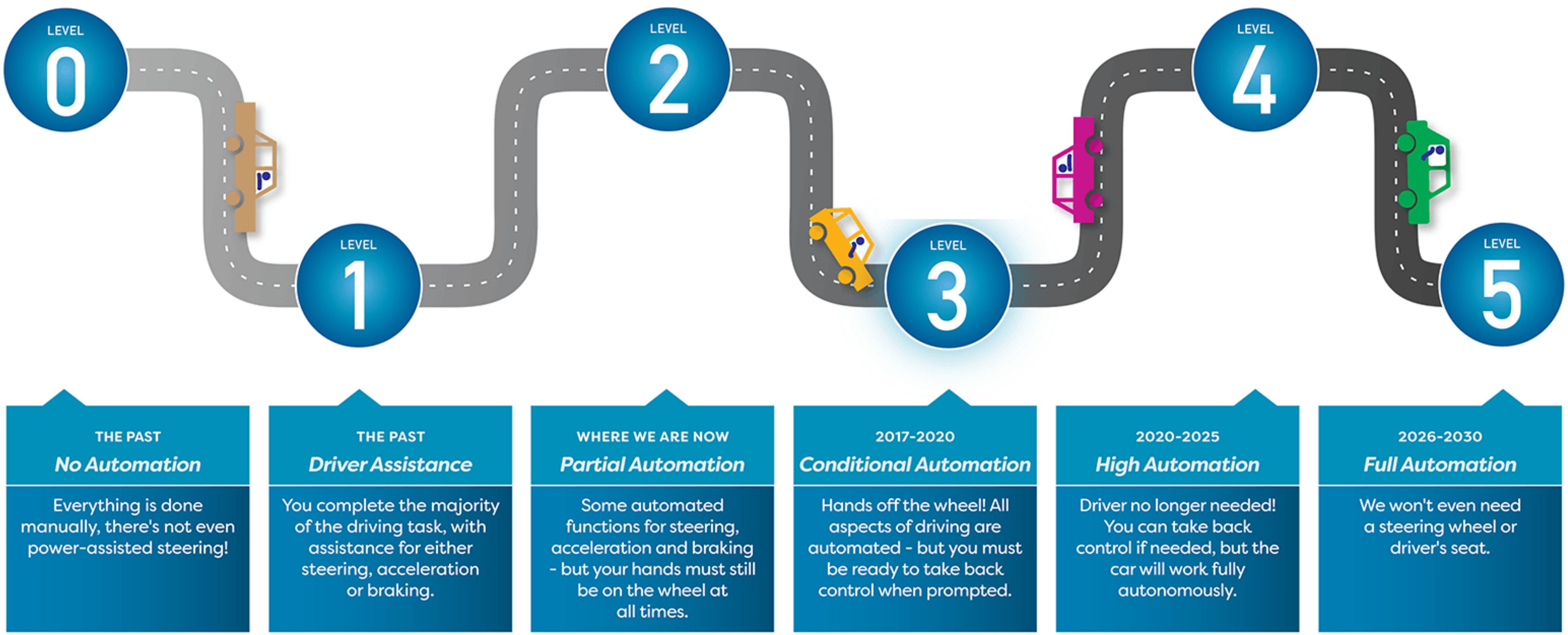
- Introduction
    1. Genesis of Robots
    2. Terminology
- Intelligent Robots
    1. How to build intelligent robots?
    2. Challenges
- Machine Learning in Robotics: Application
    1. Autonomous Driving
    2. Medical Domain
    3. Field and Service Robots
- References
- Questions?

# Autonomous Driving


Learning to think
Sixty-five years of automotive baby steps
1948 Modern cruise control invented
1966 Mechanical antilock braking installed in a standard production car, the British Jensen FF
1968 Electronic cruise control invented
1987 Electronic stability control invented by BMW, Bosch, and Mercedes
1995 Mitsubishi Diamante introduces laser-based adaptive cruise control
2001 Nissan Cima introduces lane-departure warning system
2003 Toyota Harrier comes with precrash mitigation system
2007 DARPA's third driverless-car competition, the DARPA Urban Challenge
2010 Google Car debuts. It takes a blind man for tacos
2012 Nevada offers licenses for autonomous cars
2013 Mercedes "Bertha" AG takes itself on a road trip. Mercedes S-Class gets highway autonomy (but requires attentive driver as a backup)
2014 NHTSA issues draft of proposed rule making for autonomous driving
2018–2019 Expected launch of first vehicles with vehicle-to-vehicle and vehicle-to-infrastructure communication
2020 Limited self-driving expected to begin, starting with traffic-jam assist
2025 Fully autonomous cars (with driver backup) tested
2030 Fully autonomous cars (with no driver backup)
2032 Half of all new cars are autonomous

[1]

# Machine Learning in Action—Autonomous Driving

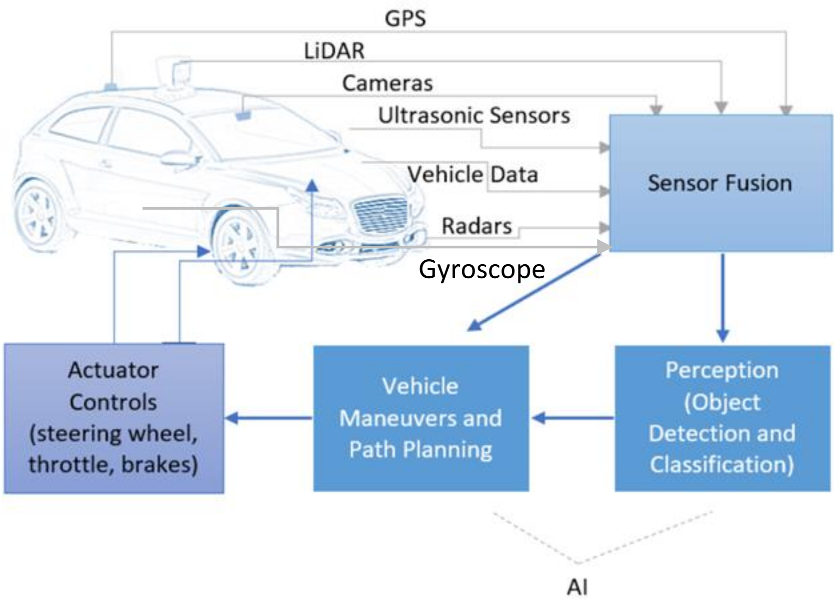


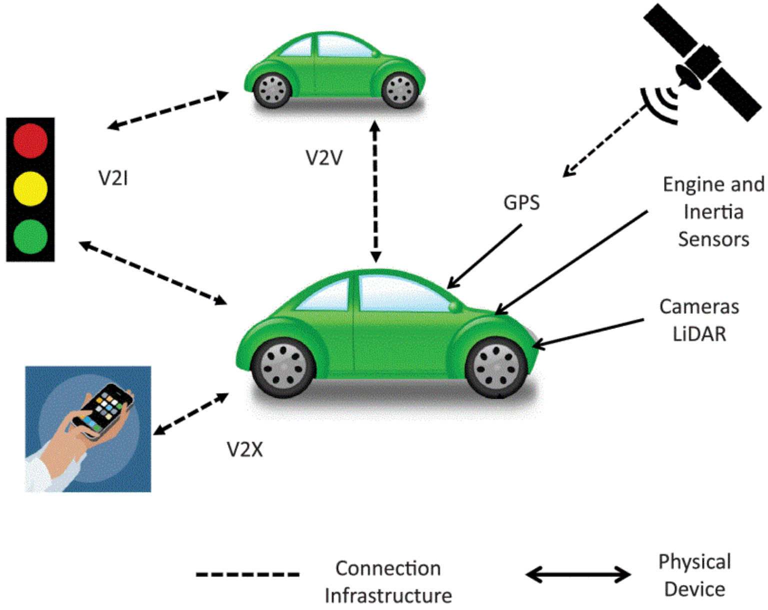

The National Highway Traffic Safety Administration (NHTSA)

agency of the Executive Branch of the U.S. government

**[2]**

# Autonomous Driving

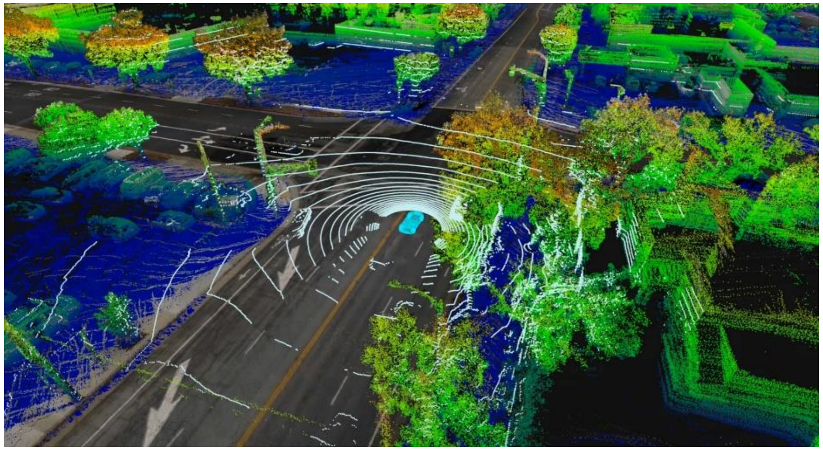



[3] [4]

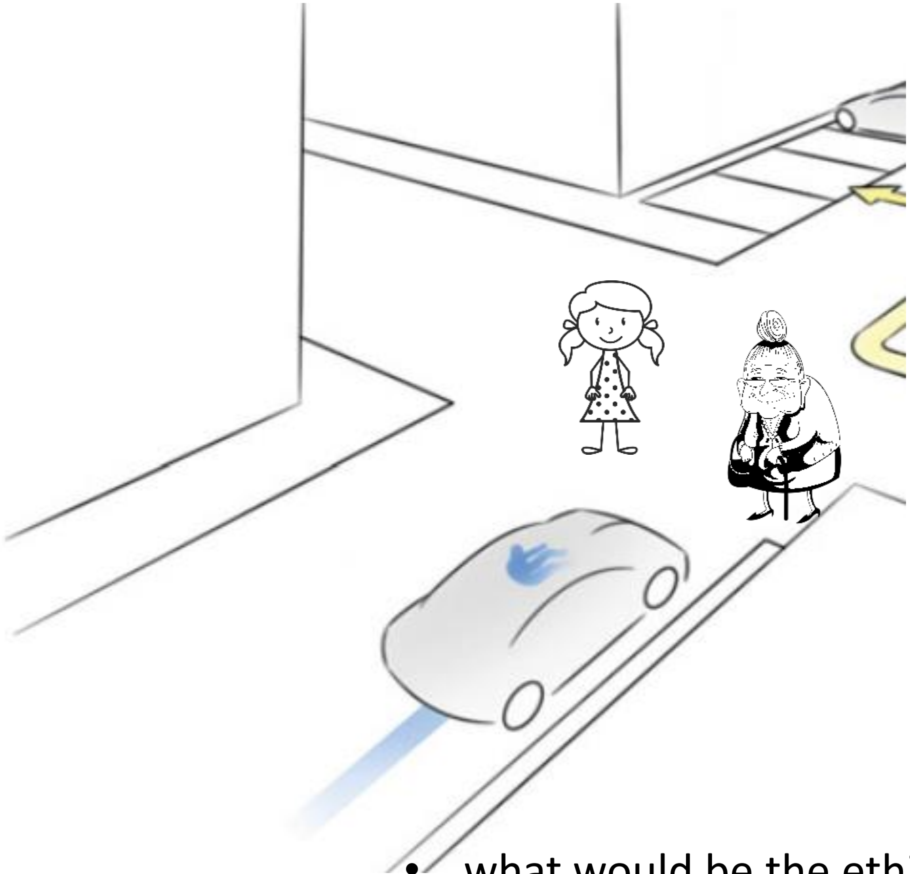
# Machine Learning in Action—Autonomous Driving

- Main approaches to autonomous driving
  - Lidar (High Definition Maps)
  - Vision sensing + deep learning (scene semantics)



[5] [6]

# Why Ethics Matters?



- what would be the ethically correct decision?
- Who should take the responsibility of that action? [7]

# Ethical Issues Regarding Autonomous Cars

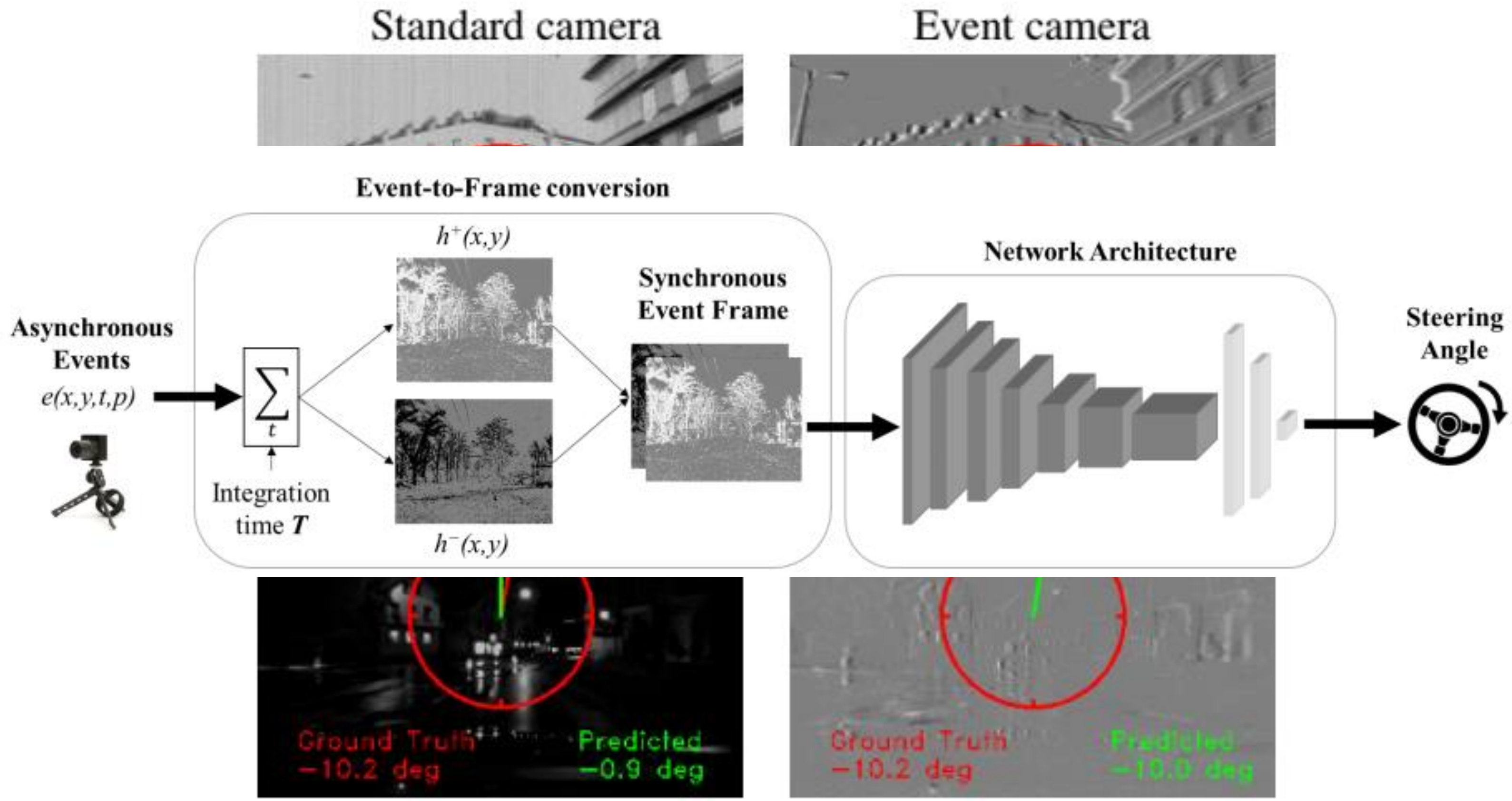
- Liability comes into play: If an autonomous car causes a crash, it itself cannot be held morally accountable for the outcome since it is not a moral agent.
- Do robot cars present an existential threat to the insurance industry?
- How susceptible would robot cars be to hacking? If under attack, whether a hijacking or ordinary break-in, what should the car do: speed away, alert the police, remain at the crime scene to preserve evidence, or maybe defend itself?
- Do we resign ourselves to a world with disappearing privacy rights?
- How will society manage a declining and already insufficient supply of donated organs?
- How do we get those legacy models—which may be less safe, in addition to incompatible with newer technology—off the roads?

# Autonomous Cars Challenges

- In many countries in the region the transportation systems and the experience of driving are challenged by the lack of a regulatory environment, sound infrastructure, adherence to traffic laws, and safe driving practices.
- Safety rules are often violated in some regions, autonomous vehicles with current technologies would freeze or not function properly.
- Inclement weather presents another challenge for autonomous vehicles in these regions.
- Deeper examination so that the safety, reliability, and robustness of these highly complex systems can be assured. The path to fully autonomous vehicles will depend greatly on the future developments in the areas of improved decision-making and demonstrating safety.
- Privacy and cybersecurity

# Event-based Vision meets Deep Learning on Steering Prediction for Self-driving Cars

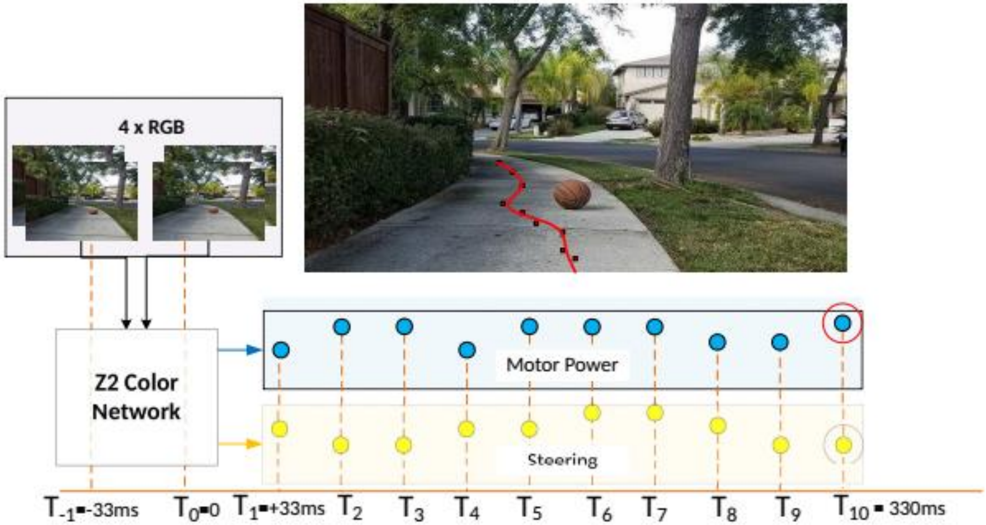
- Deep learning + event frames (ResNet inspired) [7]

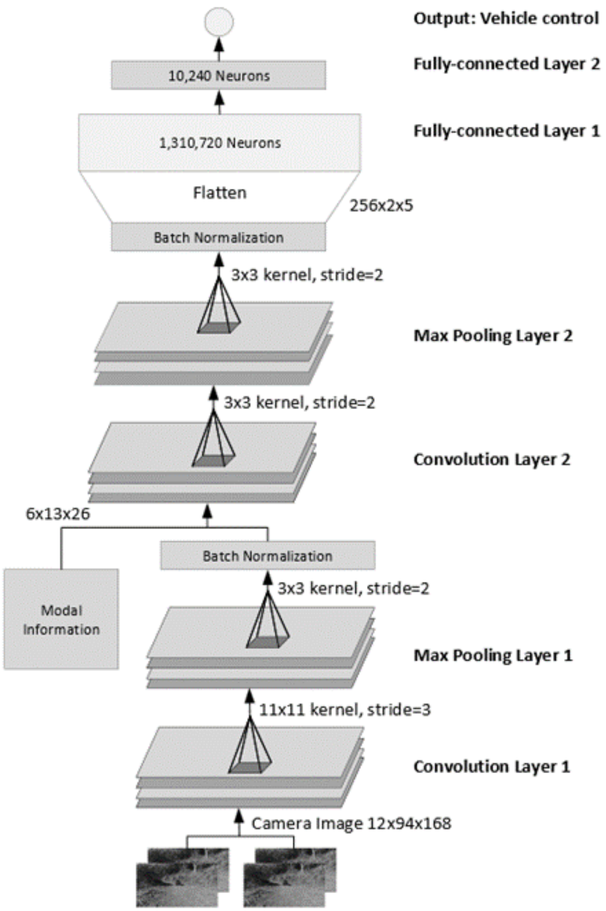



[8]

# MultiNet: Multi-Modal Multi-Task Learning for Autonomous Driving

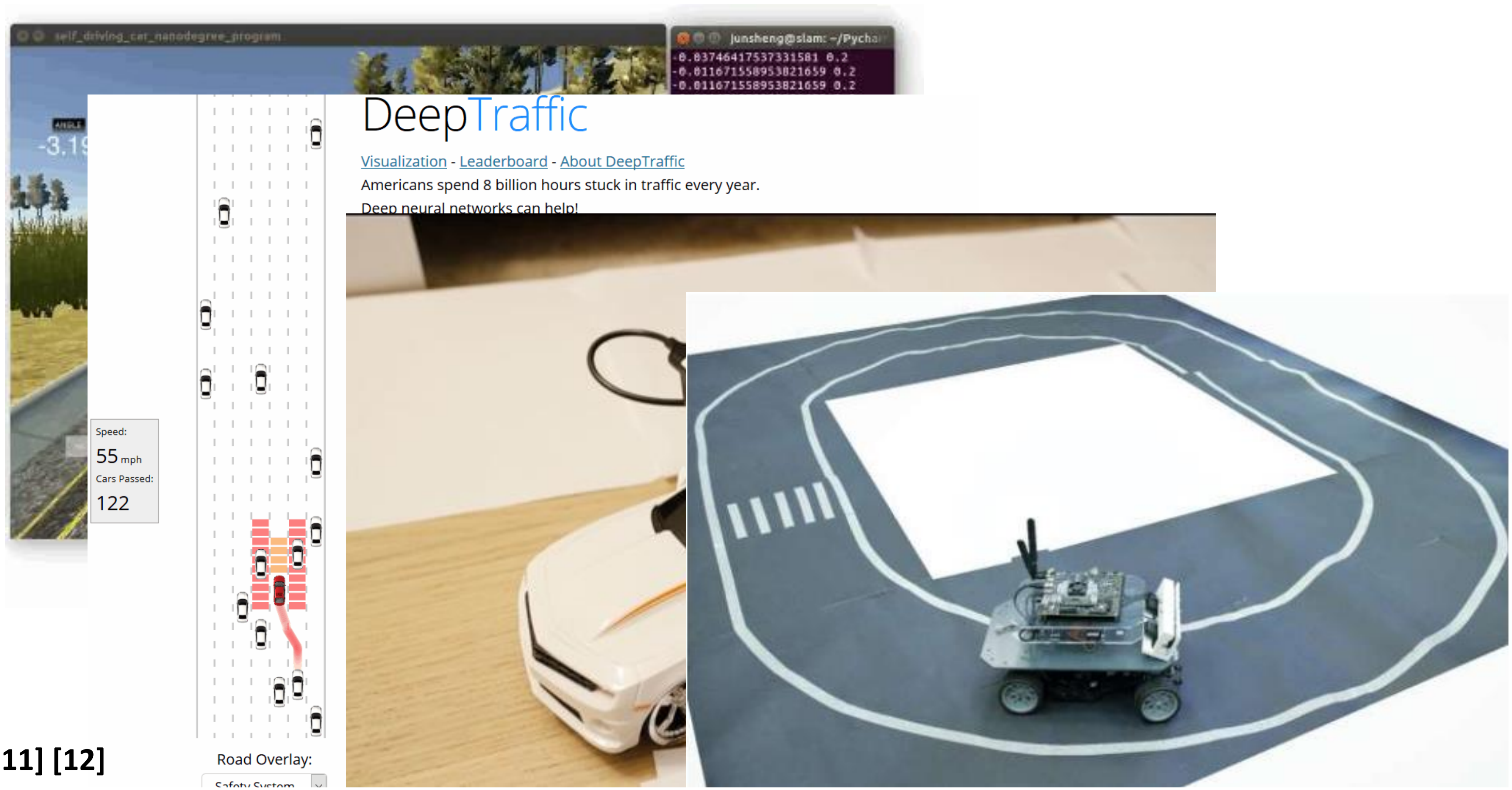
- Multiple behavioral modes (Direct Mode, Follow Mode, Furtive Mode)
- Multi-modal and multi-task learning



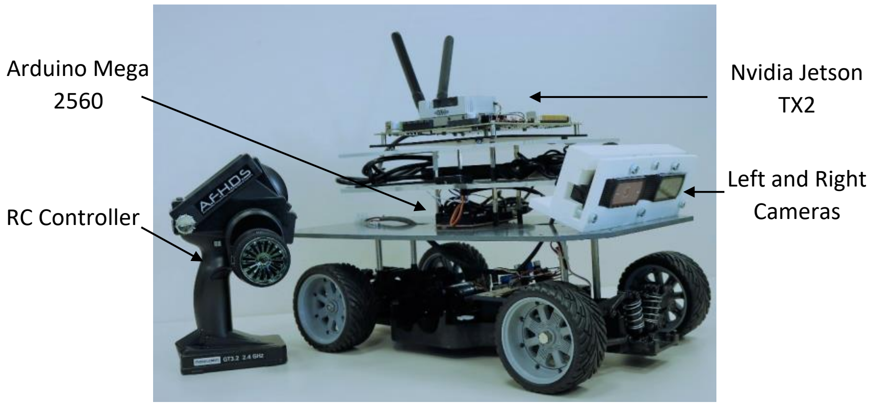

[9]

# Application Example: Autonomous Driving

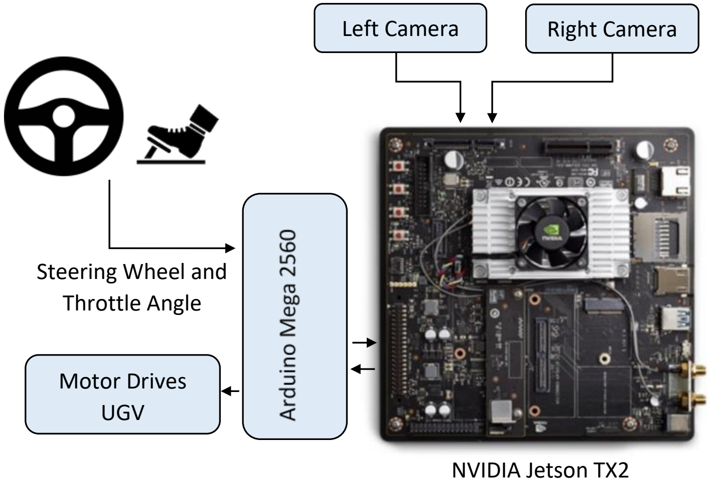



[10] [11] [12]

# Application Example: System Architecture




## Hardware Components

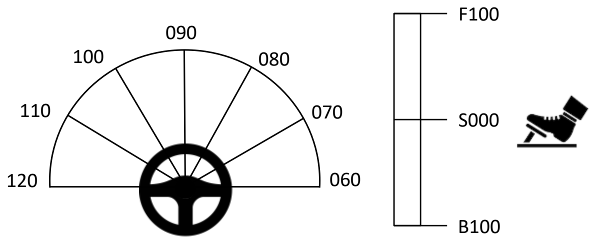


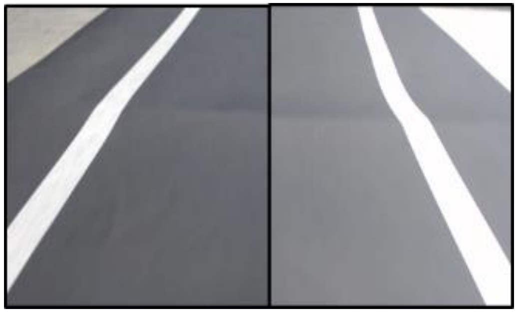

## System Architecture

| Onboard Processing Units | Power Consumption | Max. Clock |
|---|---|---|
| Nvidia TX2 (256-core) | 7.5W | 1302 MHz |
| Arduino Mega | 2.5W | 16 MHz |

| Motors | Power Consumption |
|---|---|
| DC Motor | 7.2W |
| Servo Motor | 4.2W |

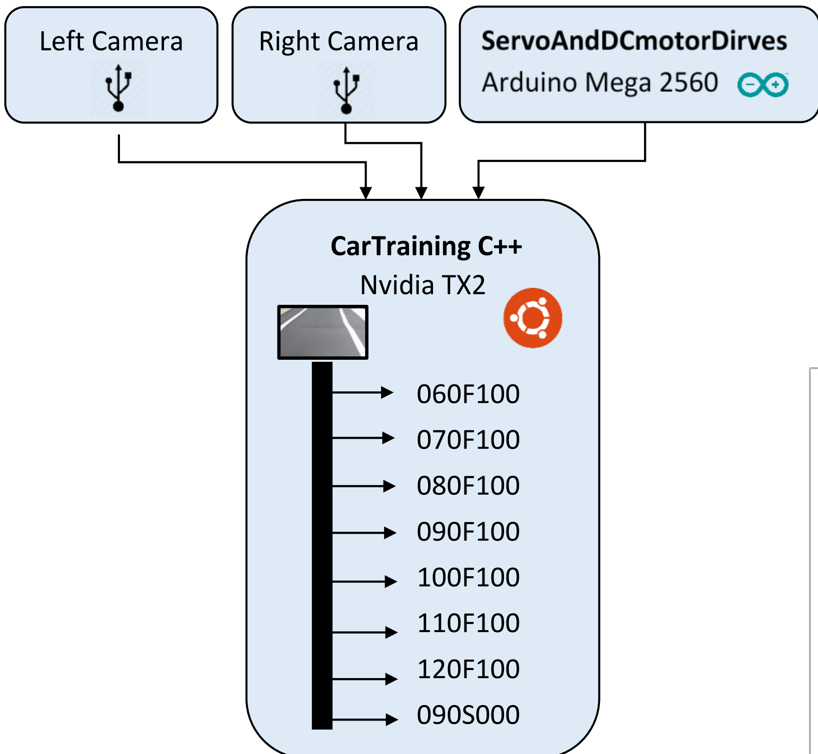
# Application Example: Deep Learning Algorithm

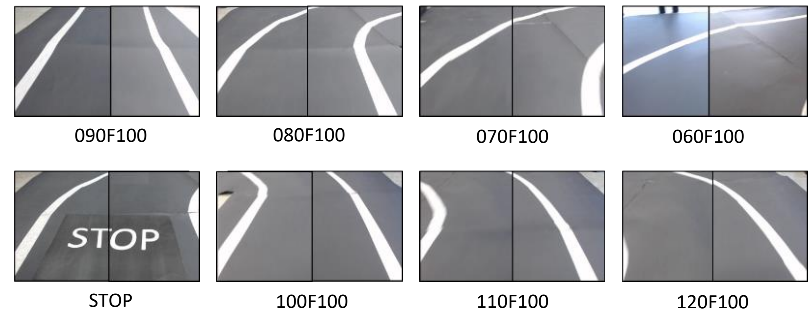


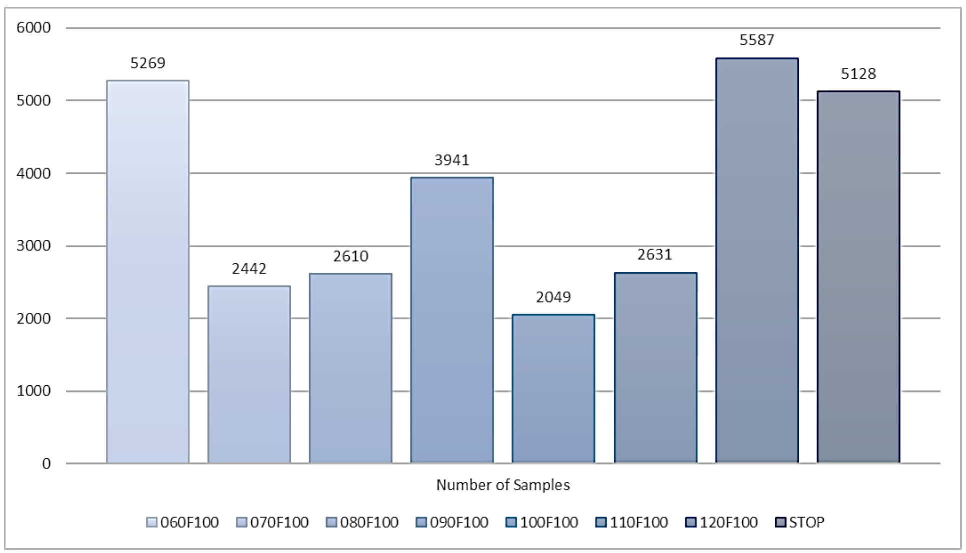



| Movement Command | Turning Radius | Throttle Position |
|---|---|---|
| **060F100** | 60 Degrees (Right) | Forward 100% |
| **070F100** | 70 Degrees (Right) | Forward 100% |
| **080F100** | 80 Degrees (Right) | Forward 100% |
| **090F100** | 90 Degrees (Straight) | Forward 100% |
| **100F100** | 100 Degrees (Left) | Forward 100% |
| **110F100** | 110 Degrees (Left) | Forward 100% |
| **120F100** | 120 Degrees (Left) | Forward 100% |
| **090S000** | Straight | STOP |

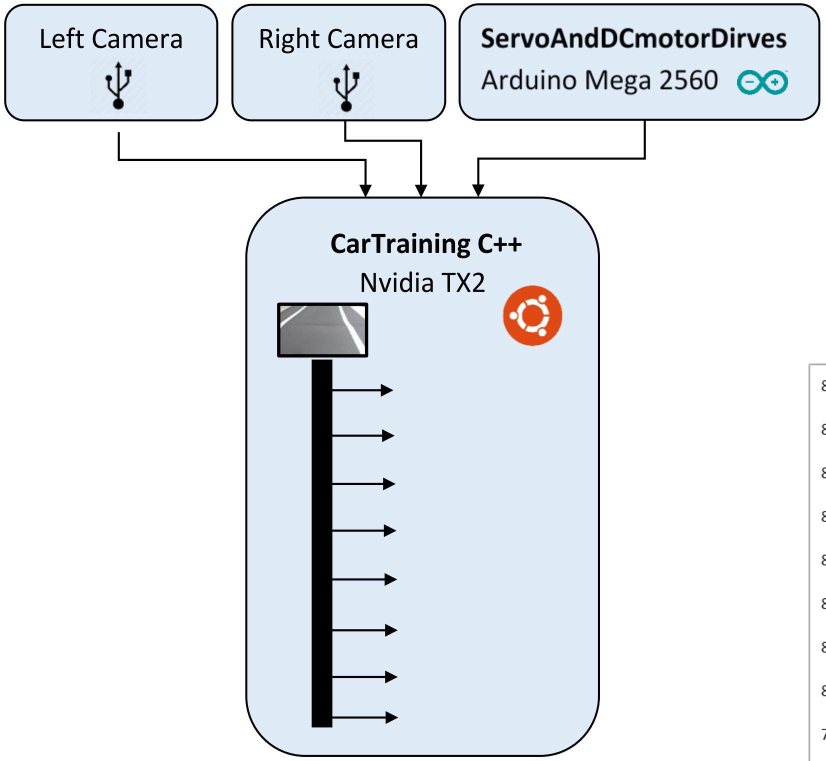
# Application Example: Data Collection

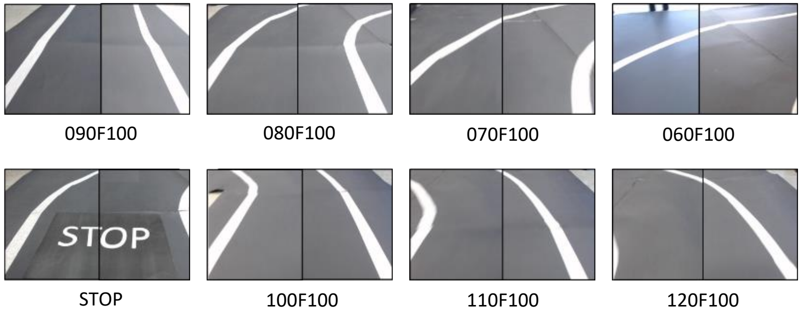


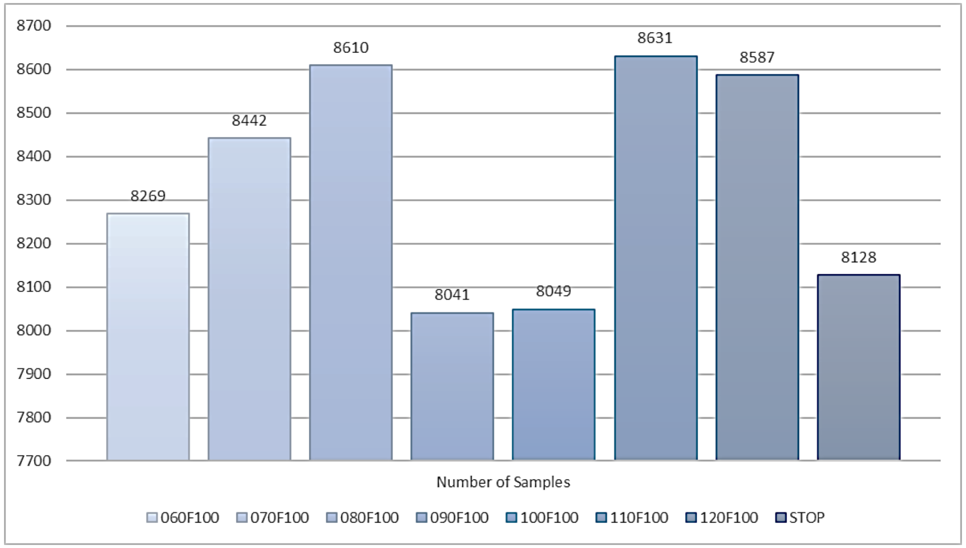



# Application Example: Data Augmentation

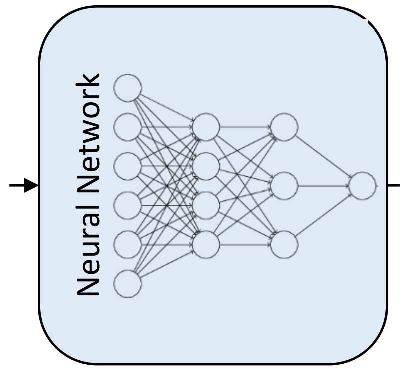


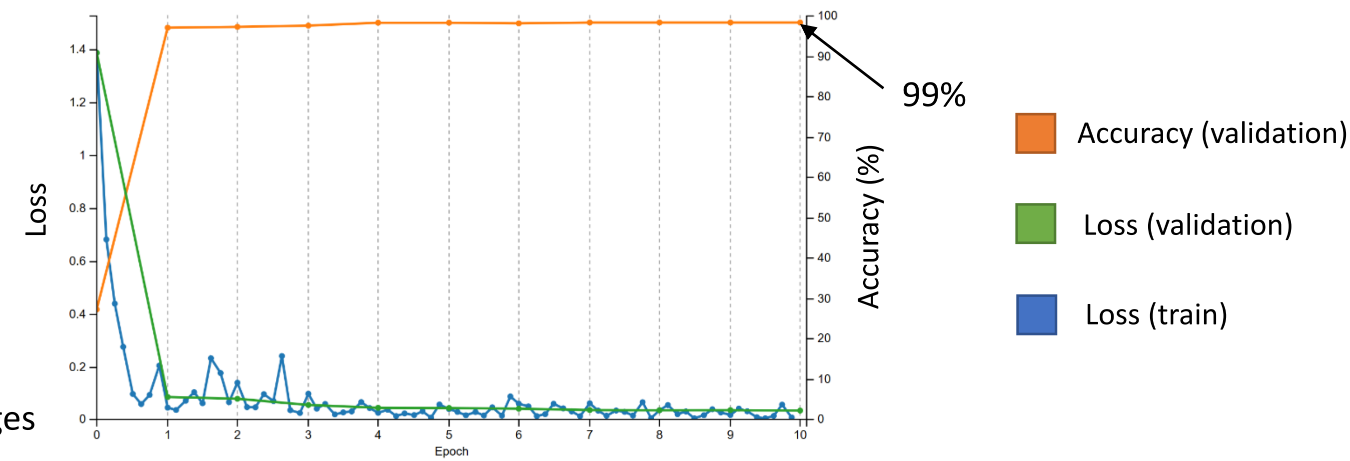
# Application Example: Neural Network Training

70000
Training Images

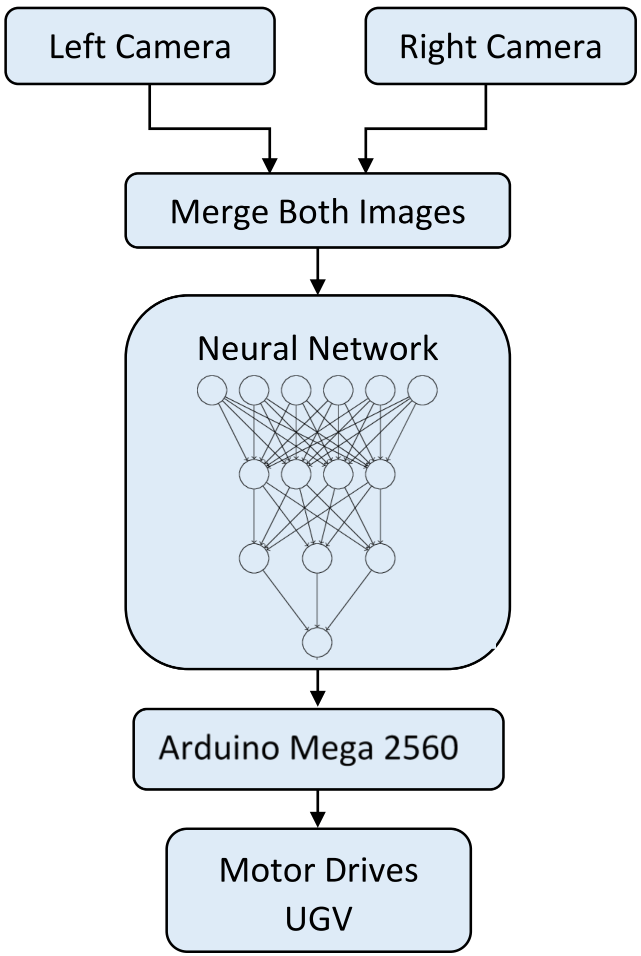


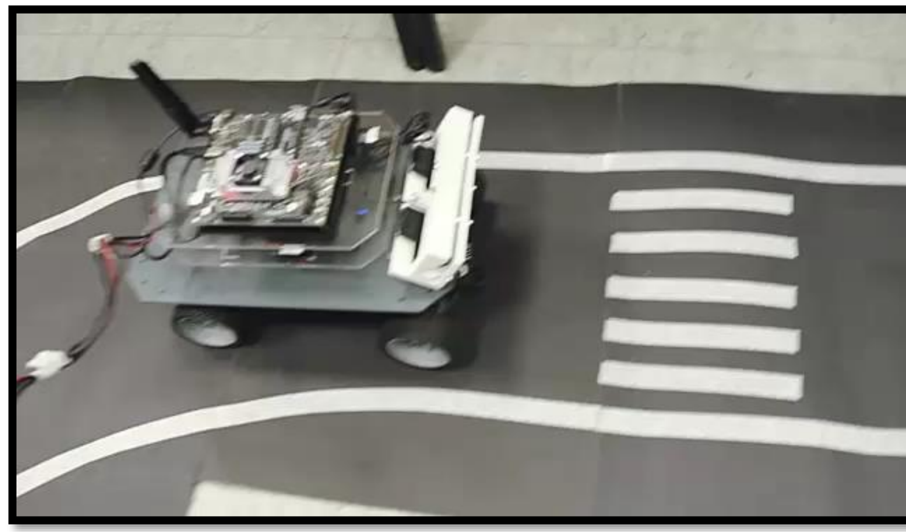

060F100
070F100
080F100
090F100
100F100
110F100
120F100
090S000

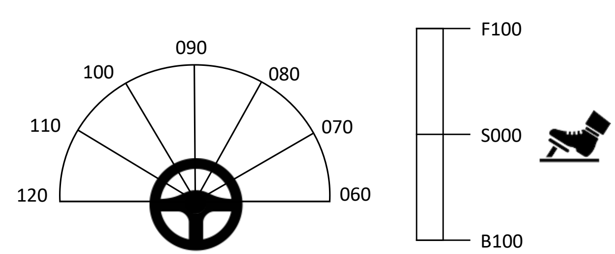
16000
Cross-Validation Images



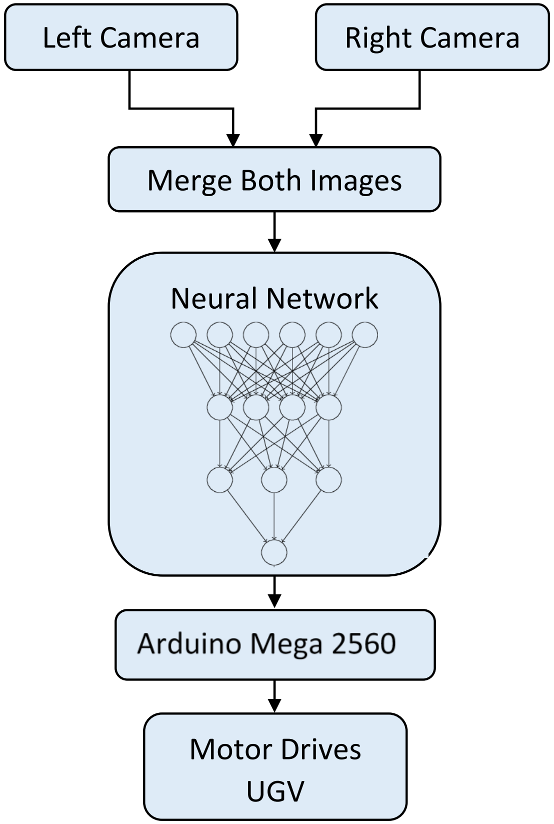
# Application Example: Neural Network Deployment

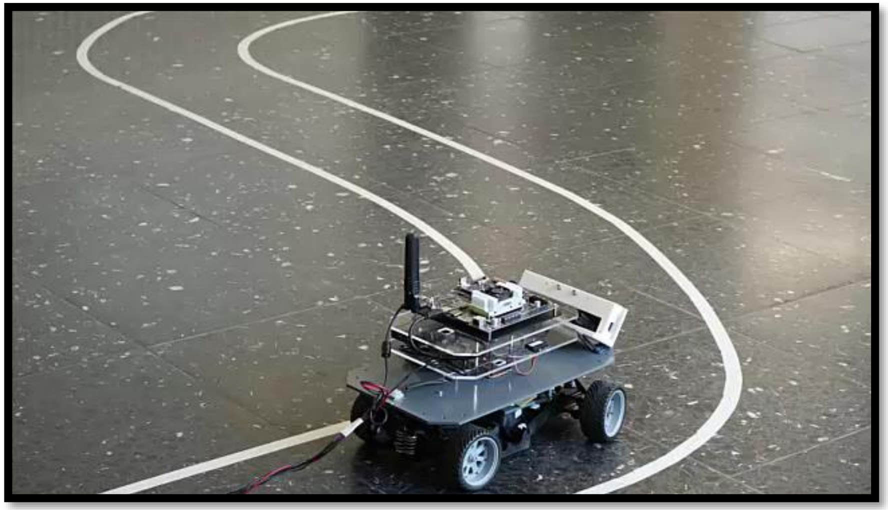


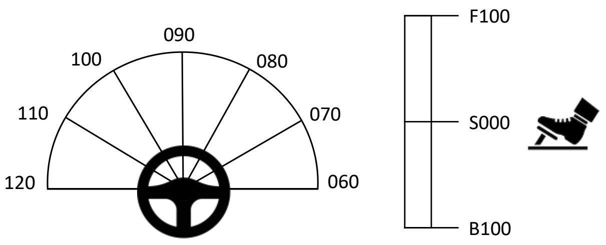





# Application Example: Generalization Test

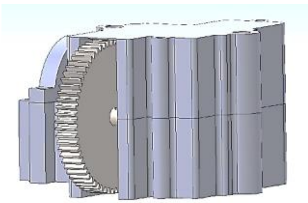


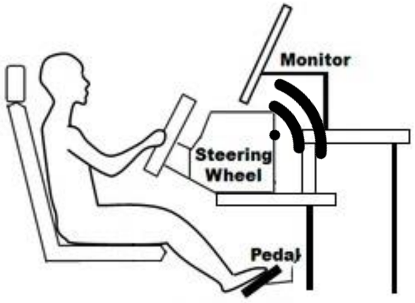





# Ongoing Projects

- Vehicle drive mechanism enhancement and sensor integration
- Lane center following and dataset collection
- Autonomous forward parking
- Traffic light and traffic sign detection

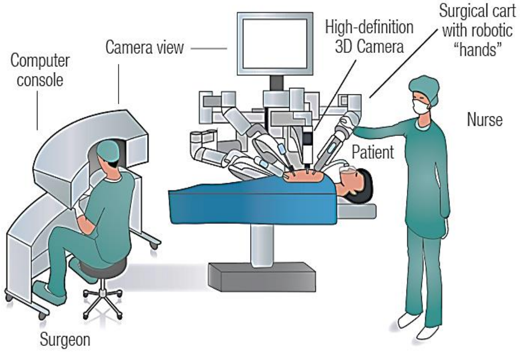




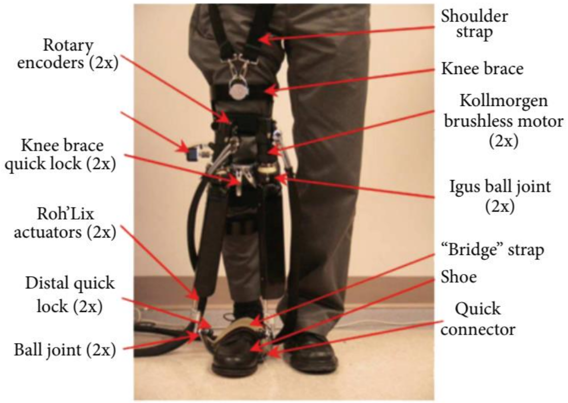

# Machine Learning In Medical Domain

## Surgical Robots, Challenges, and Ethical Concerns

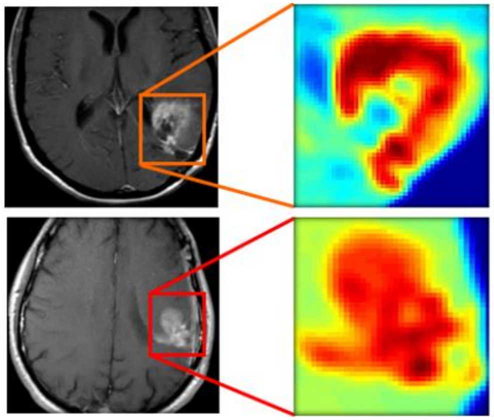
# Machine Learning In Medical Domain



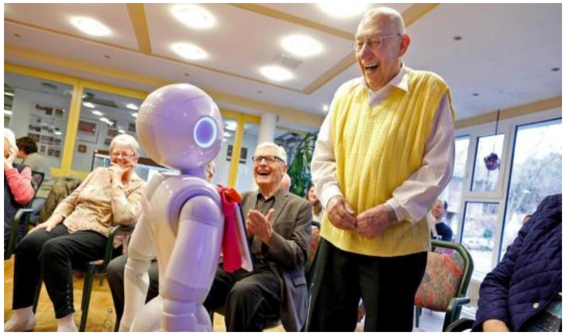

Robotic Surgery [13]




Rehabilitation Robots [14]



Diagnostics [15]



Care Robotics [16]

Medical Wearables [17]

Virtual Nursing Assistant [18]

# Surgery

1. Traditional open surgery
2. Minimally Invasive Surgery (MIS) / Conventional Laparoscopic surgery.
3. Robotic assisted surgery.

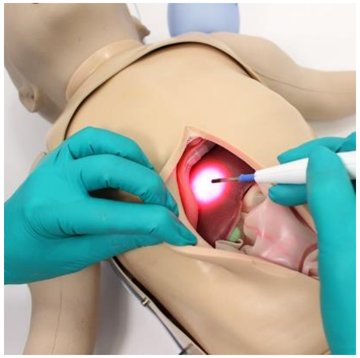
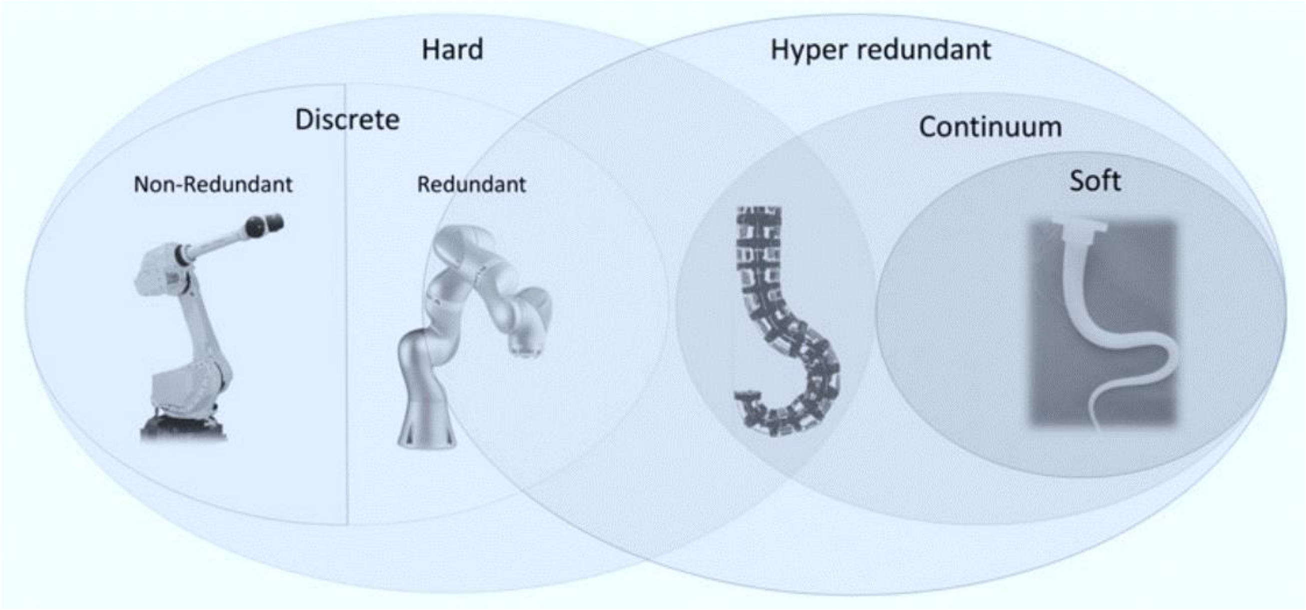


Fig. 1: Open Surgery Practice [19]

Fig. 2: Minimally Invasive Surgery [20]

Fig. 3: The da Vinci Si system [20]

# Robotic Manipulators In Robot-Assisted Surgery




- The ability to simplify a wide range of well-known complex tasks.
- The deformability of the soft material offers compliance, which facilitates safe human–robot interaction in comparison to the rigid counterparts.

[21]

# Rigid Link Versus Soft Robotic Manipulators

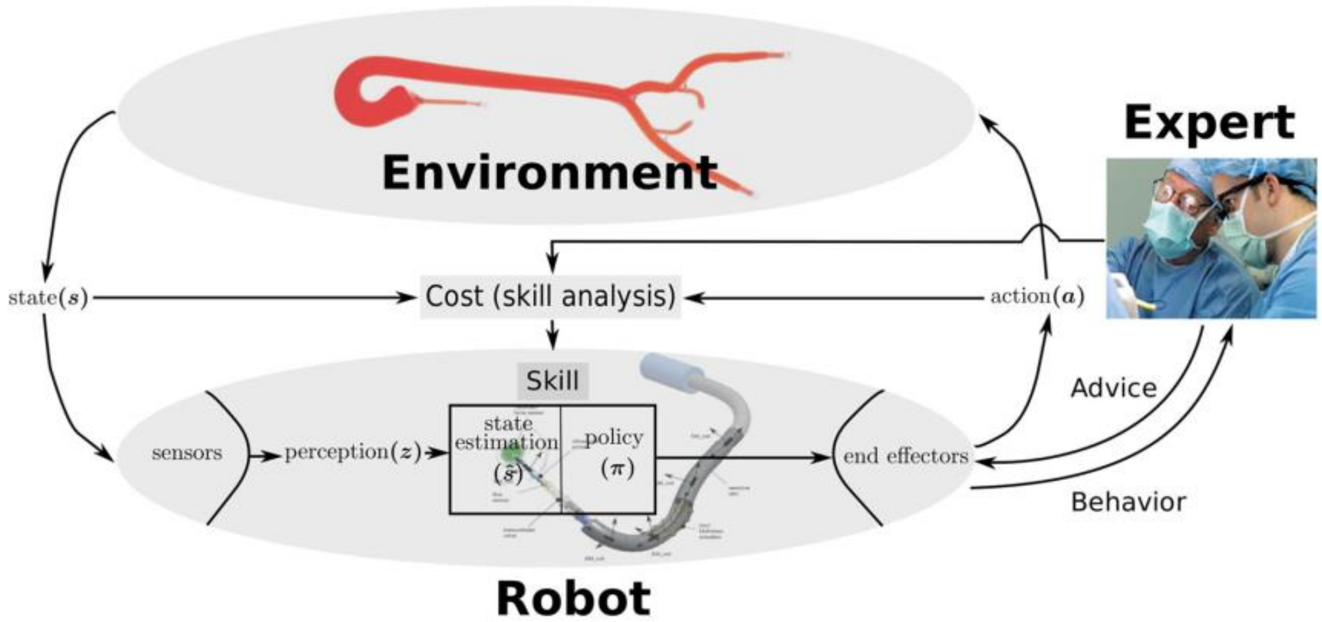
The da Vinci Si system: Rigid Manipulator [22]

STIFF-FlLOP: Soft Manipulator [23]

# Human based Surgery Versus Robot-Assisted Surgery

| | Human based Surgery | Robot-Assisted Surgery |
|---|---|---|
| Strengths | • Strong hand-eye coordination<br>• Flexibe and adaptable | • Improved dexterity<br>• Good geometric accuracy |
| | • Can integrate extensive and diverse information<br>• Able to use qualitative information<br>• Good judment | • Can use diverse sensors in control |
| | | • Stable and untiring<br>• Reproducibility |
| Limitations | • Limited dexterity outside natural scale<br>• Limited geometric accuracy | |
| | • Prone to tremor and fatigue | • Unable to use qualitative information<br>• No Judgement |
| | • Susceptible to radiation and infection | • Expensive + Technology in flux |

# Towards Cognitive Surgical Robots




- Implicit imitation learning (e.g. Reinforcement learning, Neural Network, Hybrid intelligent techniques, etc.)
- Robots cannot replace surgeons yet!.

**[24]**

# Machine (Medical) Ethics and Risks

Ethical Concerns

1. Replacement and its implications for labour
2. Privacy and data protection
3. Safety and avoidance of harm.
4. Confidence
5. Replacement and its implications for the quality of care: de-humanisation and ‘‘cold’’ care

# Machine (Medical) Ethics and Risks

Risks

1. Potential for infection, bleeding, etc.
2. Potential mechanical failure. Multiple components of the system can malfunction, including the camera, binocular lenses, robotic tower, robotic arms, software failure, and instruments
3. The energy source, which is prone to electric arcing, can cause unintended internal burn injuries from the cautery device.
4. There is a small risk of temporary, and even permanent, nerve palsies from the extreme body positioning needed to dock the robot

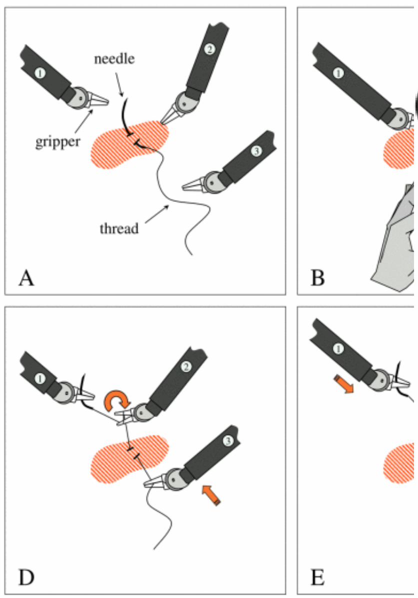
# Challenges In Surgical Robots

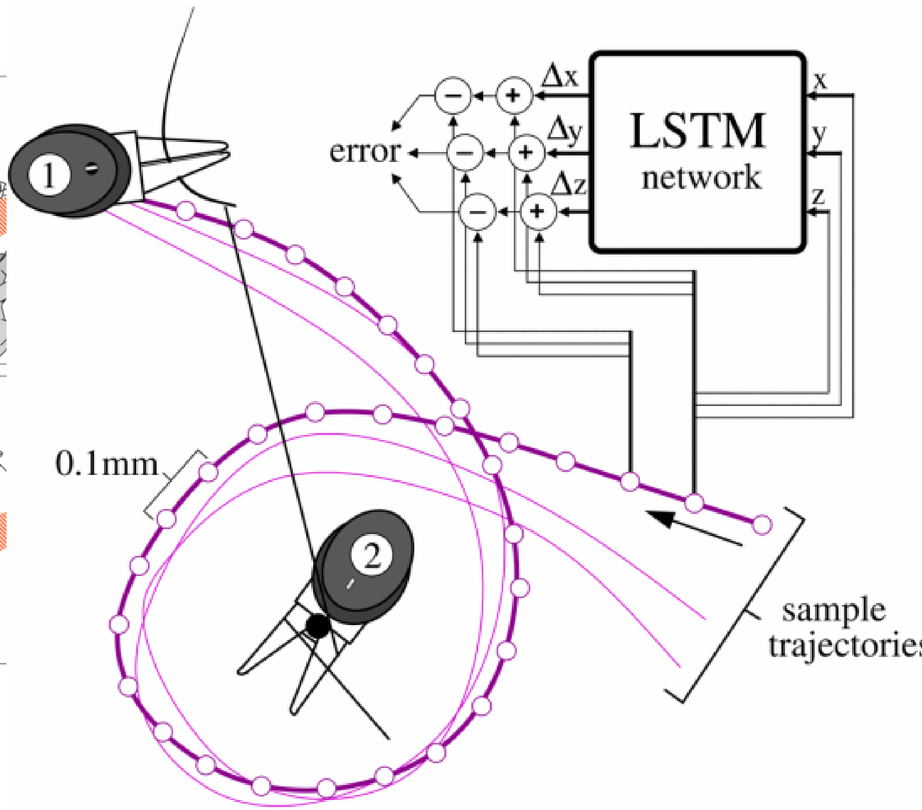
1. High-quality medical/surgical data: There is a need for large quantities of high-quality medical and surgical data to train ML techniques. Approval by an Ethical Commission might be required.

2. Learning and defining skill analysis metric: metrics that adequately capture the characteristics of best practice.

3. Adaptation to unknown or yet unobserved situations: Any system deployed in the OR and given decision-making power should be able to cope with uncertainty and unpredictable events and guarantee the safety of the patient just as expert surgeons have to adapt to such situations.

# A System for Robotic Heart Surgery that Learns to Tie Knots Using Recurrent Neural Networks



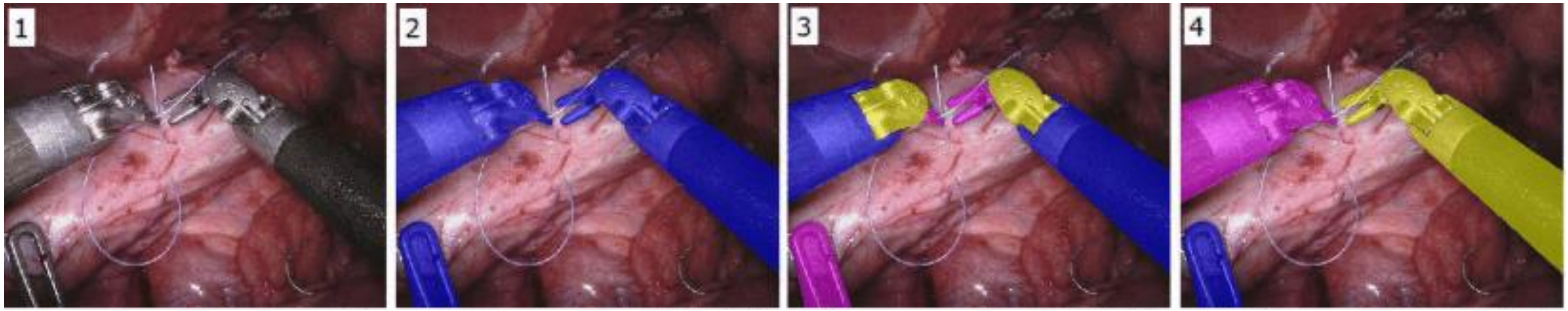

**[25]**

# Towards Cognitive Surgical Robots

- **Environment modeling:** Rigid and flexible registration, reconstruction of environment, recognition of anatomical features and landmarks, mechanical and physiological modeling
- **Localization:** Localization of instrument/robot w.r.t. environment
- **Robot control:** Low-level modeling and robot control
- **Skill analysis:** Analysis of surgical skill, derivation of performance metrics or cost functions for optimization
- **Critical event detection:** Detection of adverse events
- **Planning and control:** High-level trajectory and interaction planning, error handling

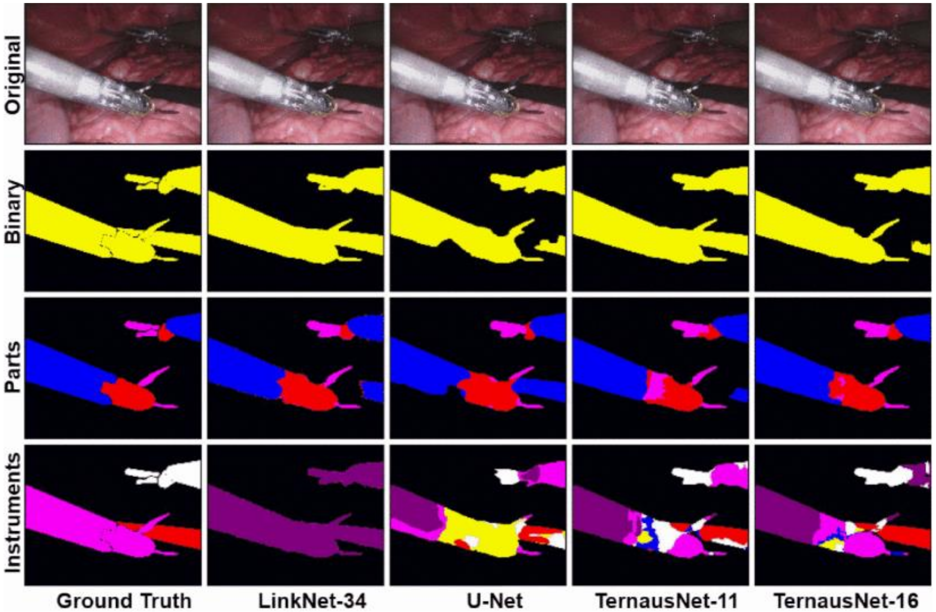
# Automatic Instrument Segmentation in Robot-Assisted Surgery using Deep Learning

- Information in a surgical console of a robot-assisted surgical system includes valuable details for intra-operative guidance that can help the decision making process.
- A critical component of this process is semantic segmentation of the instruments in the surgical console.




**[26]**

# Automatic Instrument Segmentation in Robot-Assisted Surgery using Deep Learning

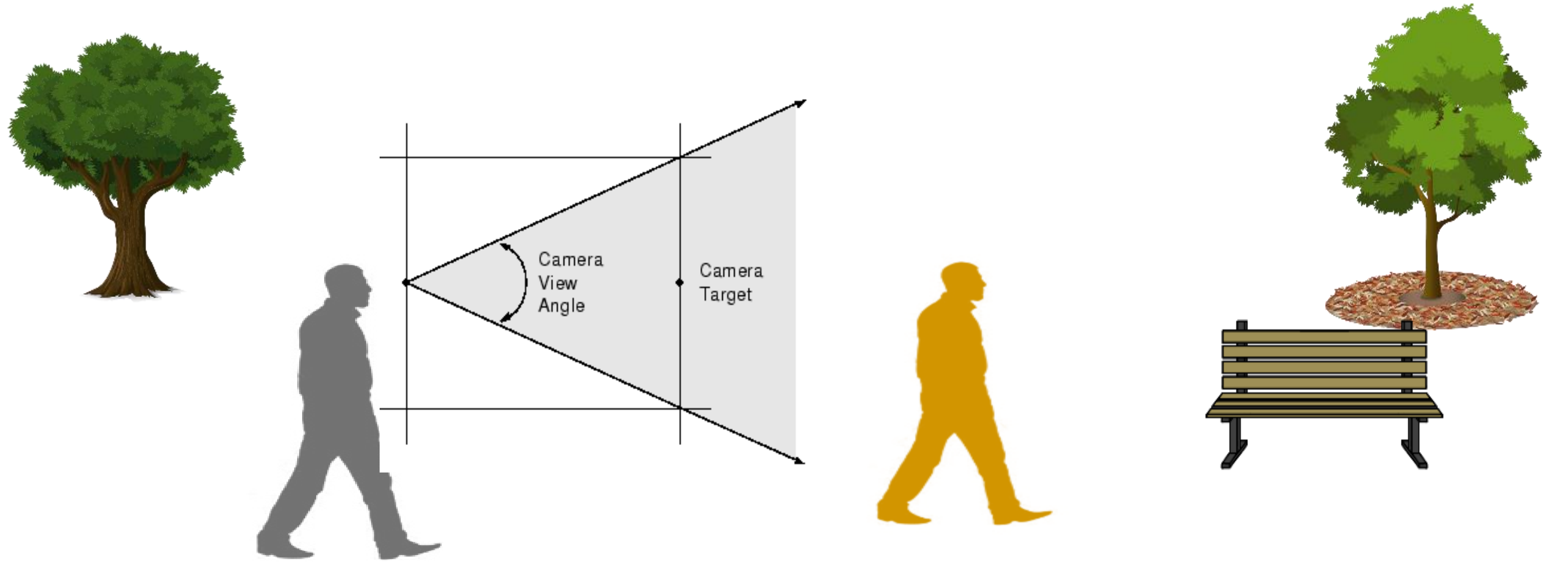



| | Binary segmentation | | | Parts segmentation | | | Instrument segmentation | | |
|---|---|---|---|---|---|---|---|---|---|
| Model | IOU | Dice | Time | IOU | Dice | Time | IOU | Dice | Time |
| U-Net | 75.44 | 84.37 | 93 | 48.41 | 60.75 | 106 | 15.80 | 23.59 | **122** |
| TernausNet-11 | 81.14 | 88.07 | 142 | 62.23 | 74.25 | 157 | **34.61** | **45.86** | 173 |
| TernausNet-16 | **83.60** | **90.01** | 184 | **65.50** | **75.97** | 202 | 33.78 | 44.95 | 275 |
| LinkNet-34 | 82.36 | 88.87 | **88** | 34.55 | 41.26 | **97** | 22.47 | 24.71 | 177 |
| | | | [ms] | | | [ms] | | | [ms] |

[26]

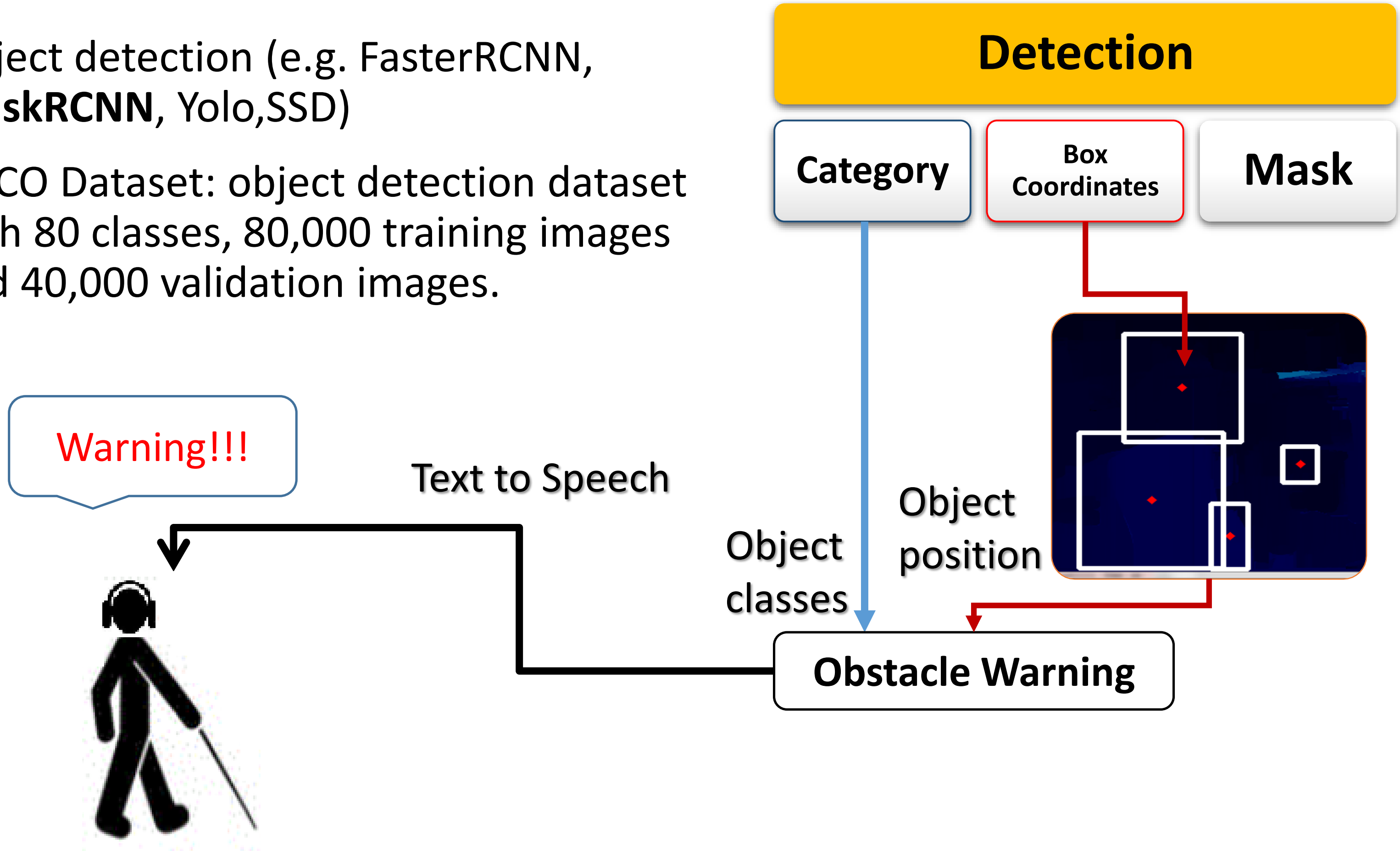
# Application Example: Intelligent Assistive System for the Visually impaired

- According to the World Health Organization (WHO) the global magnitude of visual impairments are 285 million people visually impaired, of which 39 million were blind
- Several electronic assisting devices have been developed for these persons where the majority is aids of mobility and obstacle detection



# Application Example: System Architecture

- Object detection (e.g. FasterRCNN, **MaskRCNN**, Yolo,SSD)
- COCO Dataset: object detection dataset with 80 classes, 80,000 training images and 40,000 validation images.

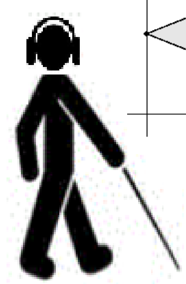


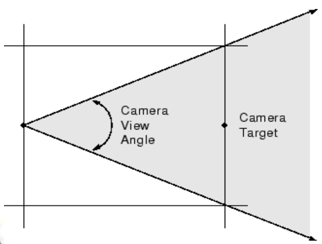
# Ongoing Projects

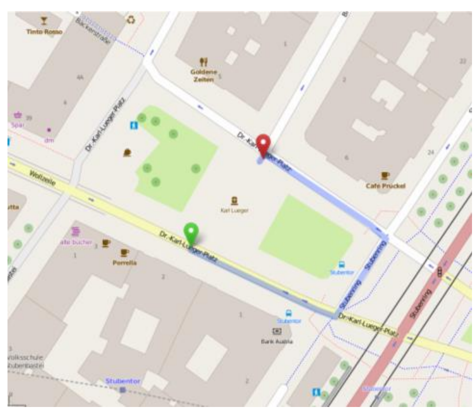
- A Semantic Scene Understanding Based Outdoor Navigation System
- Face Recognition

Stereo Camera

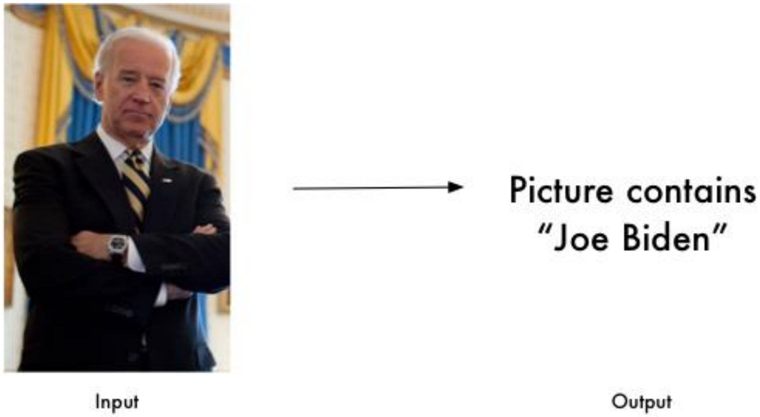
GPS

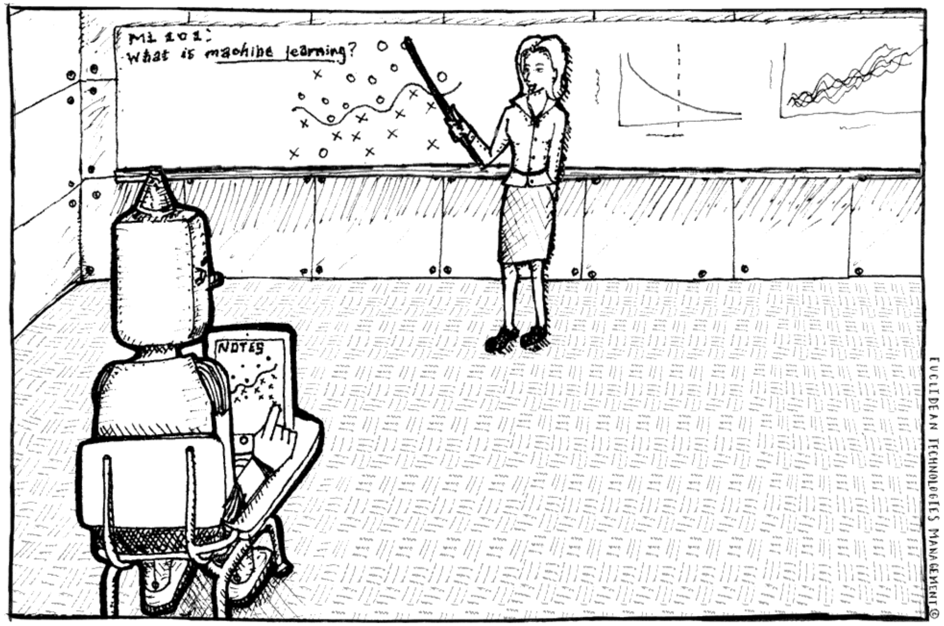




Open Street Maps




ML 101:
What is machine learning?
NOTES
EUCLIDEAN TECHNOLOGIES MANAGEMENT ©

# Questions!?

# References

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