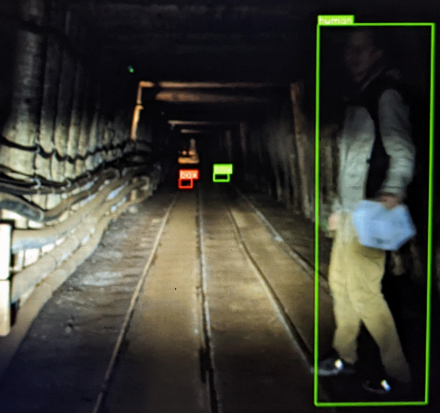
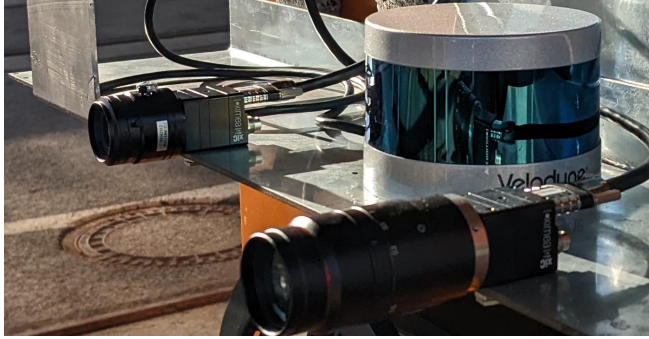




autoBAHN4mining

(semi-)autonomous mining trains—
pilot project@Salzwelten-Hallein, Salzburg

Felix Hörbinger, Wolfgang Pree
CS@PLUS

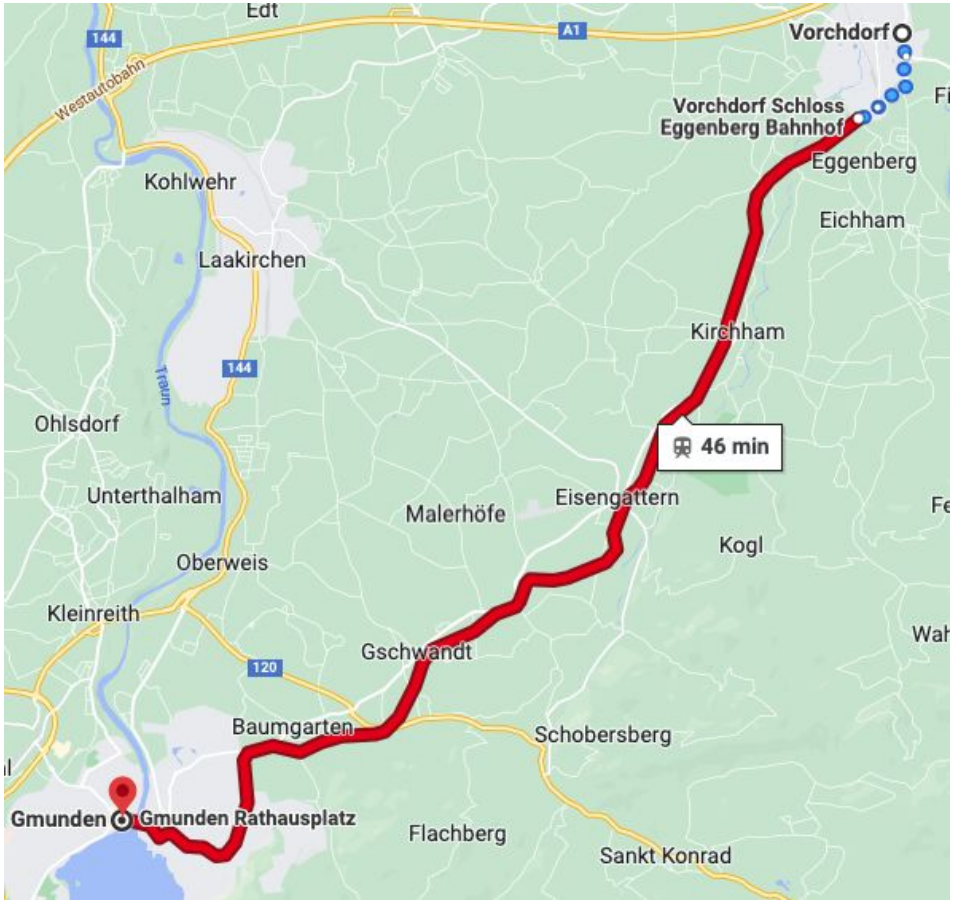
PARIS LODRON UNIVERSITÄT SALZBURG

benefits for mines

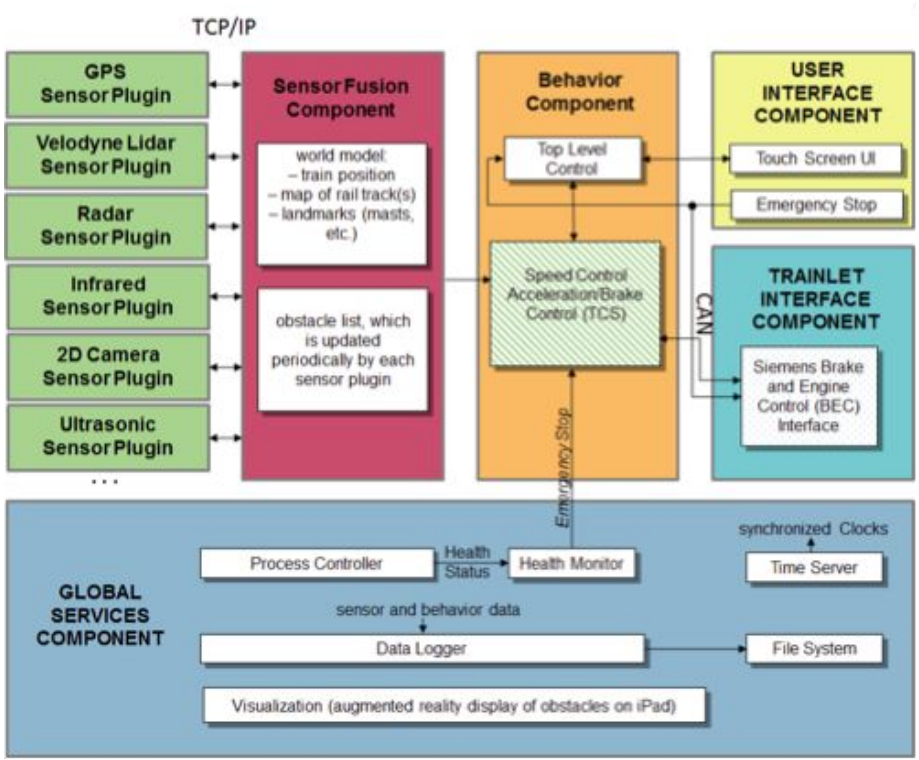
- improves safety
- reduces train driver costs by a factor of 20 or more (one human operator for 20-30 trains)
  + counteracts potential/actual train driver shortages
- reduces infrastructure costs (maintenance of signals, etc.)
- can increase train utilization, potentially towards 24/7

- straight-forward and thus inexpensive to upgrade existing trains

how it all began ... (2008)



'conventional' implementation (NO deep learning)



mining trains—THE low-hanging fruit of autonomous driving

- **rails define path where a train can move**
- **constant weather/climate—in all underground mines, all over the world**
- **train speed typically < 20 km/h**
  => requires obstacle detection only up to 50-70 meters

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- **liability can be significantly reduced by putting a human in the loop**
- low probability of encountering an obstacle
  => one human operator might monitor/control 20-30 trains, maybe many more

- **controlled environment** (only employees are in the mines)

self-driving mining train :: self-driving truck/car

2 cameras +
1 basic lidar

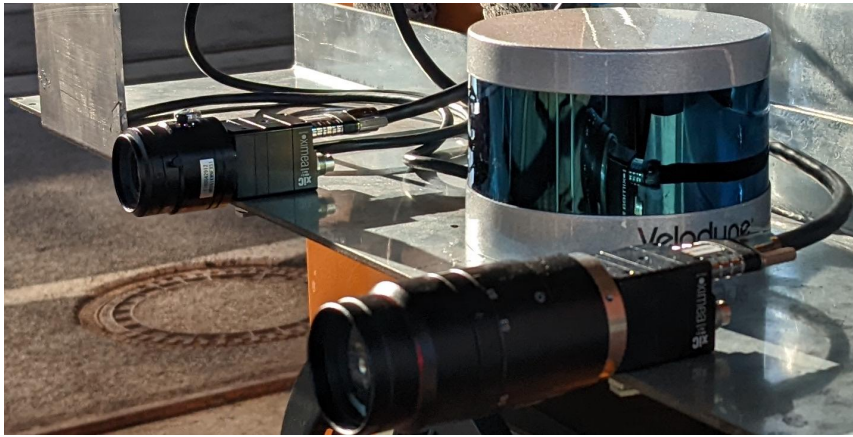
6 high-end lidars +
camera(s) + radar +
(GPS + IMU)

+ sensors at rear

autoBAHN4mining@Salzwelten Hallein

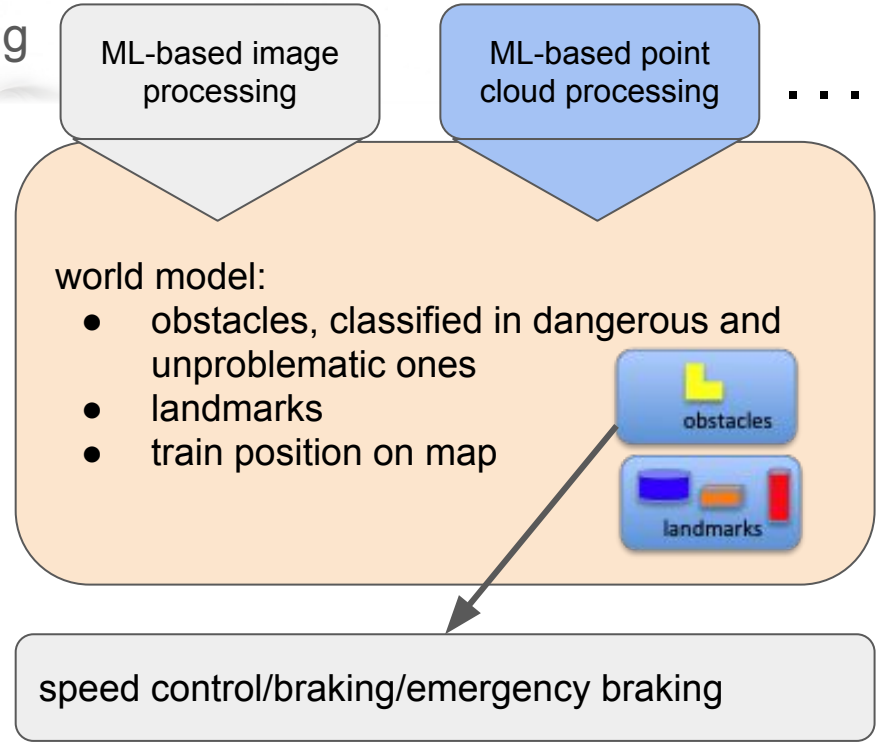
state-of-the-art, off-the-shelve hardware

- Ximea high-resolution cameras
- Velodyne lidar (100 m range Puck)
- nVidia GPU (Jetson Nano Kit)

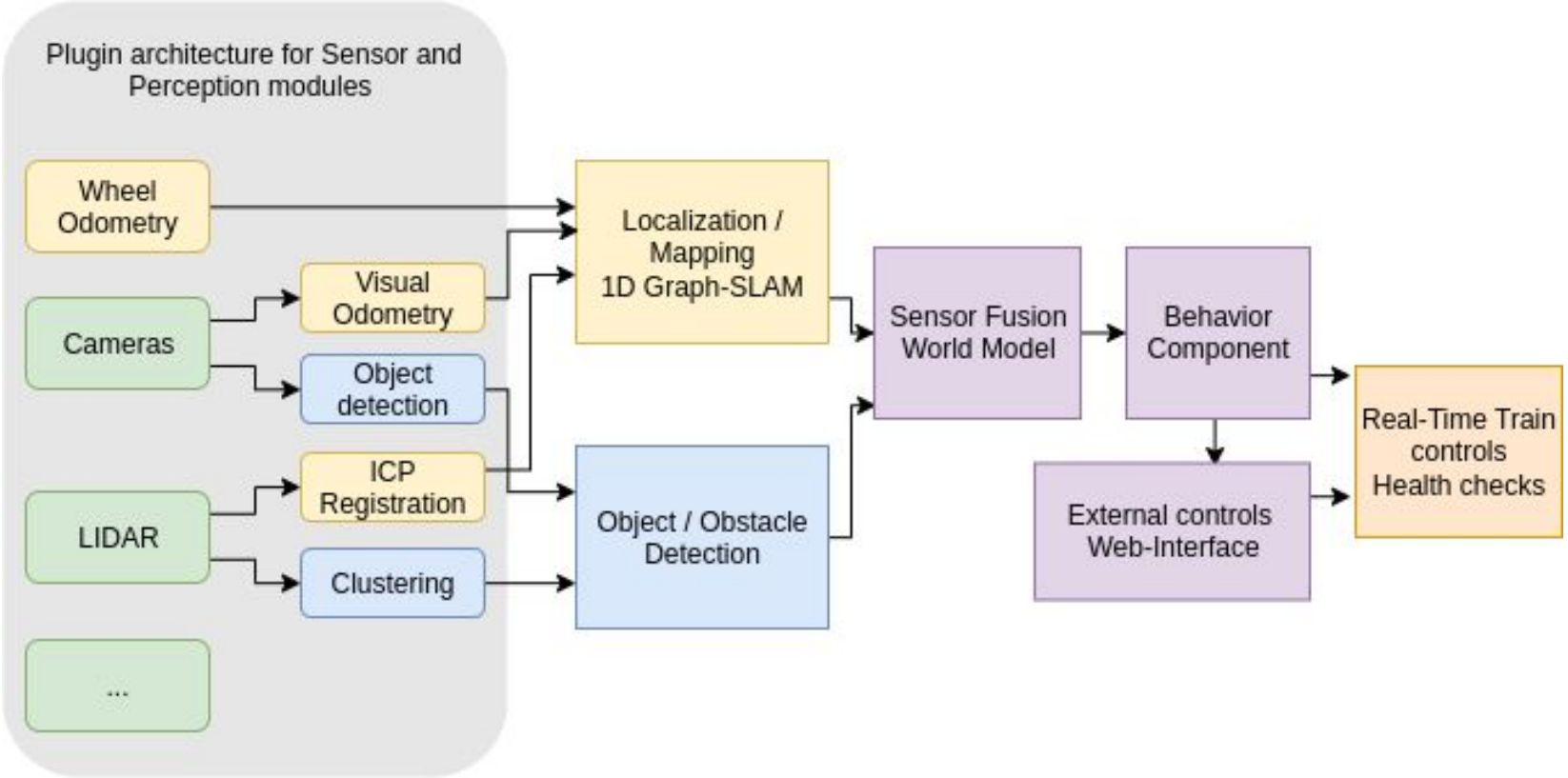


lean, cutting-edge software

- deep learning for sensor data processing
  - obstacle recognition
  - rail detection
- plug-in sensor fusion framework
  - core data structure: a list of objects classified according to 'obstacleness', forming the basis of a world model
  - allows any degree of sensor redundance
  - implemented with imperative programming language Java
    => can be formally verified
- behavior component



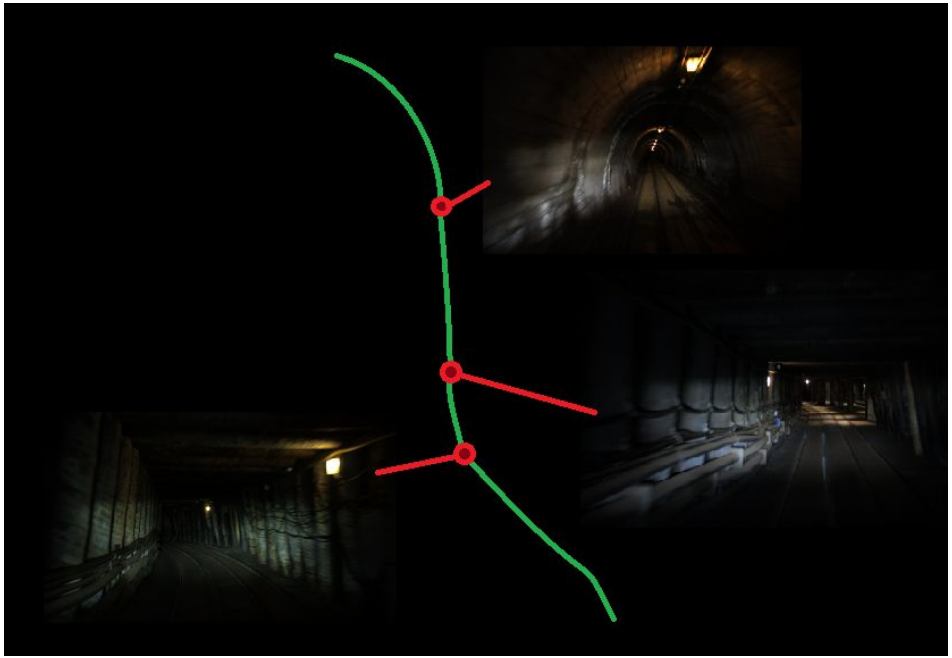
a closer look at the autoBAHN4mining architecture



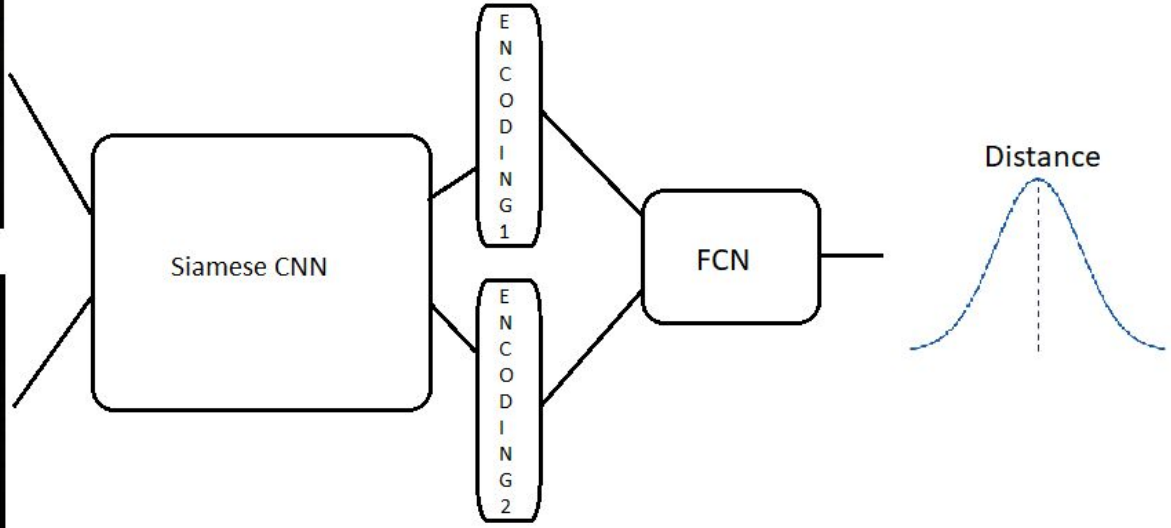
Mapping

Problems:

- no GPS/GNSS signals
- tracks can be slippery - odometer not accurate
- compass disturbed by mineral deposits and the train itself
- tunnels very uniform—visual or LIDAR odometry hard



Visual Odometry

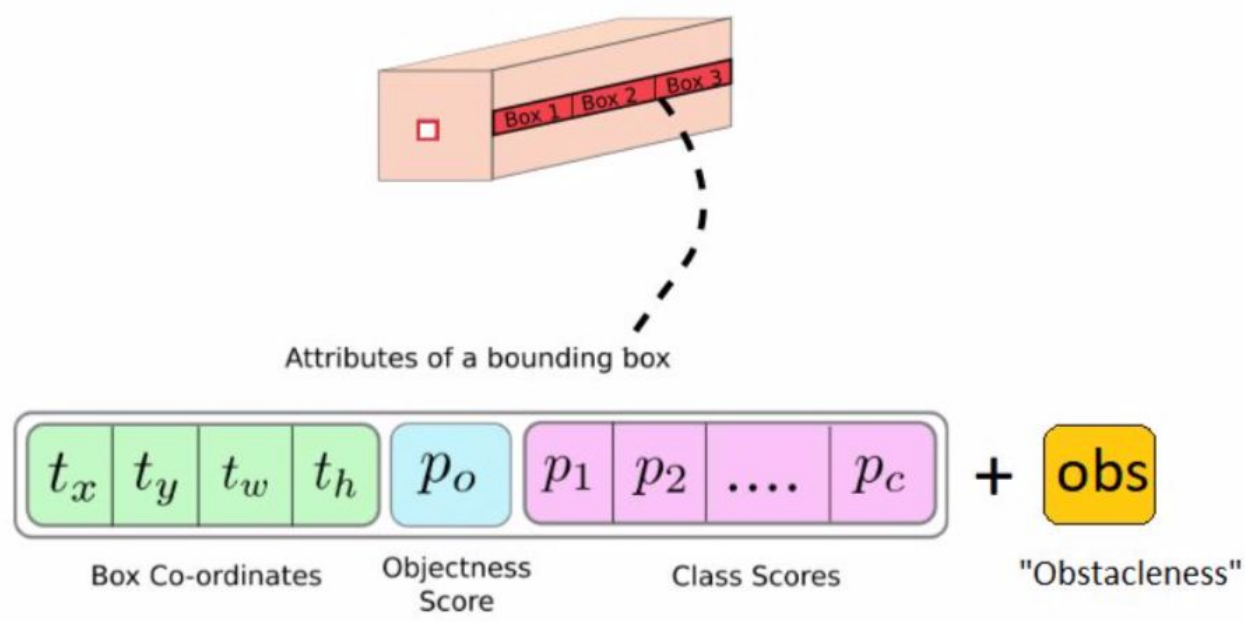


Deep Evidential Regression

Alexander Amini[1], **Wilko Schwarting**[1], **Ava Soleimany**[2], **Daniela Rus**[1]
[1] Computer Science and Artificial Intelligence Lab (CSAIL),
Massachusetts Institute of Technology (MIT)
[2] Harvard Graduate Program in Biophysics

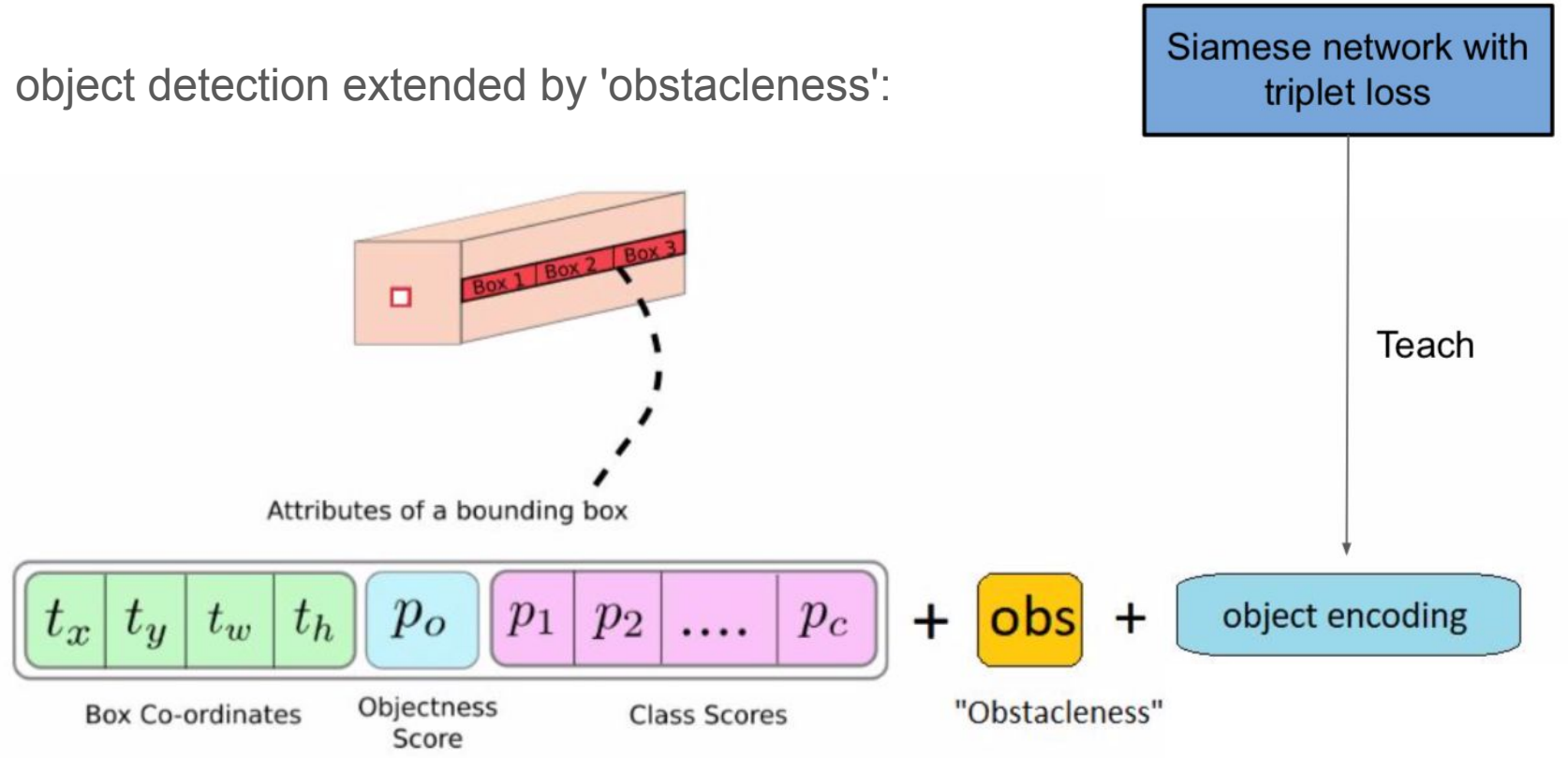
improved object detection

object detection extended by 'obstacleness':



improved object detection + similarity metric

object detection extended by 'obstacleness':



additional autoBAHN4mining tools/apps

virtual reality simulation (Unity 3)

remote monitoring & control by a human (Dart/Flutter app)

some future research tasks

- test the generalization to new object classes on the tracks
- adversarial attacks on “obstacleness” for better understanding of network data augmentation with Generative Adversarial Networks (GANs)
- comprehensive tests based on the simulator

Thanks for your attention!