TunnelEye

Autonomous inspection of road tunnels based on Artificial Intelligence

Why TunnelEye?

Critical situation of road tunnels in Italy and Europe

Visual inspection is slow (1 m/min) and costly (labour and equipment)

Great inconvenience are caused to traffic

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TunnelEye – objectives

Tunnel inspection

- High-resolution camera
- Custom lights
- Geo-reference positioning system
- Data acquisition system
- Can inspect tunnels up to 80km/h
- No need to close roads

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TunnelEye – objectives

Tunnel inspection

Machine learning

- Data sent to external PC
- Machine learning algorithms for defects identification, measurement and classification
- Cracks severity assessment
- Cracks map generation

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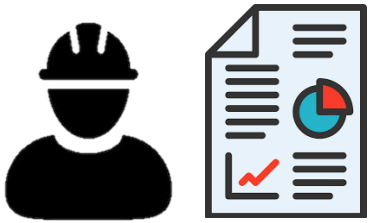
TunnelEye – objectives

Tunnel inspection

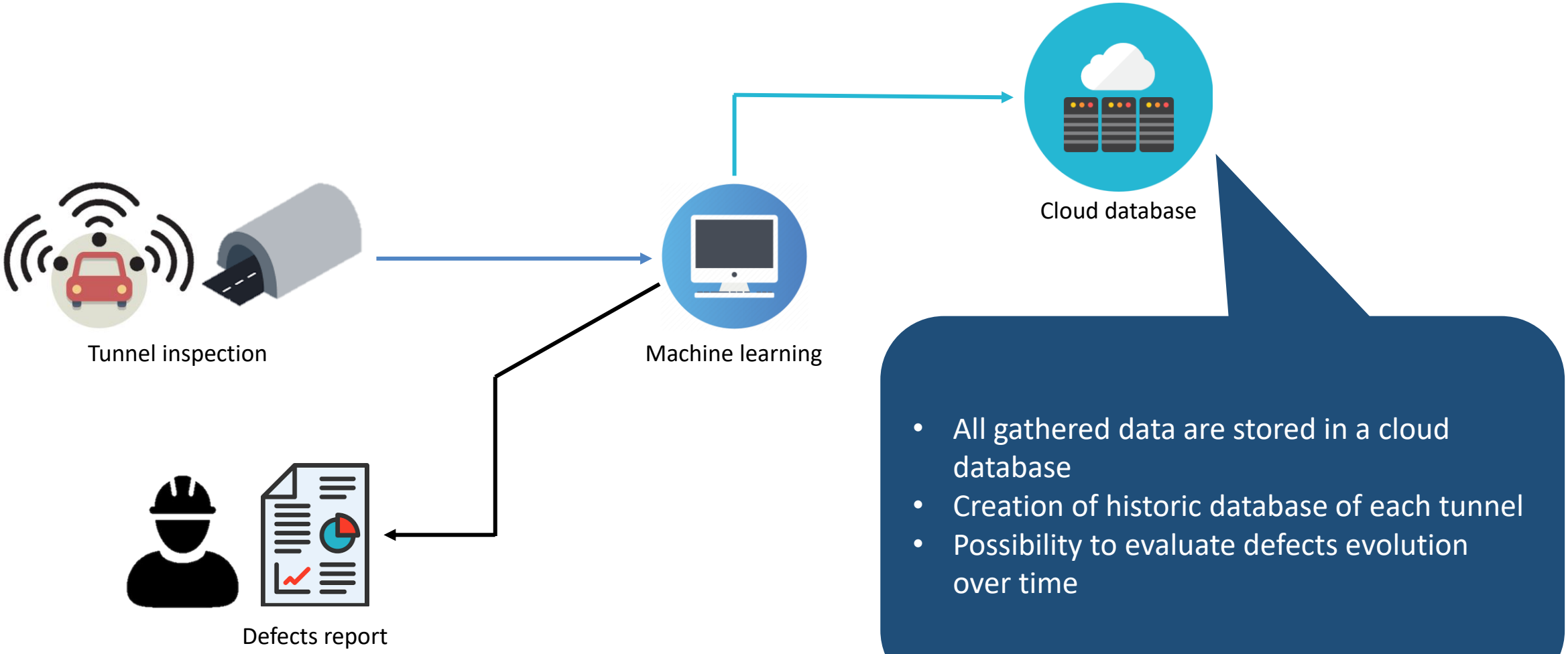
Machine learning



Defects report

- Tunnel status report automatically generated
- Directly accessible to the inspector
- Elaborated defects map
- Engineers only need to validate the report

TunnelEye – objectives



- All gathered data are stored in a cloud database
- Creation of historic database of each tunnel
- Possibility to evaluate defects evolution over time

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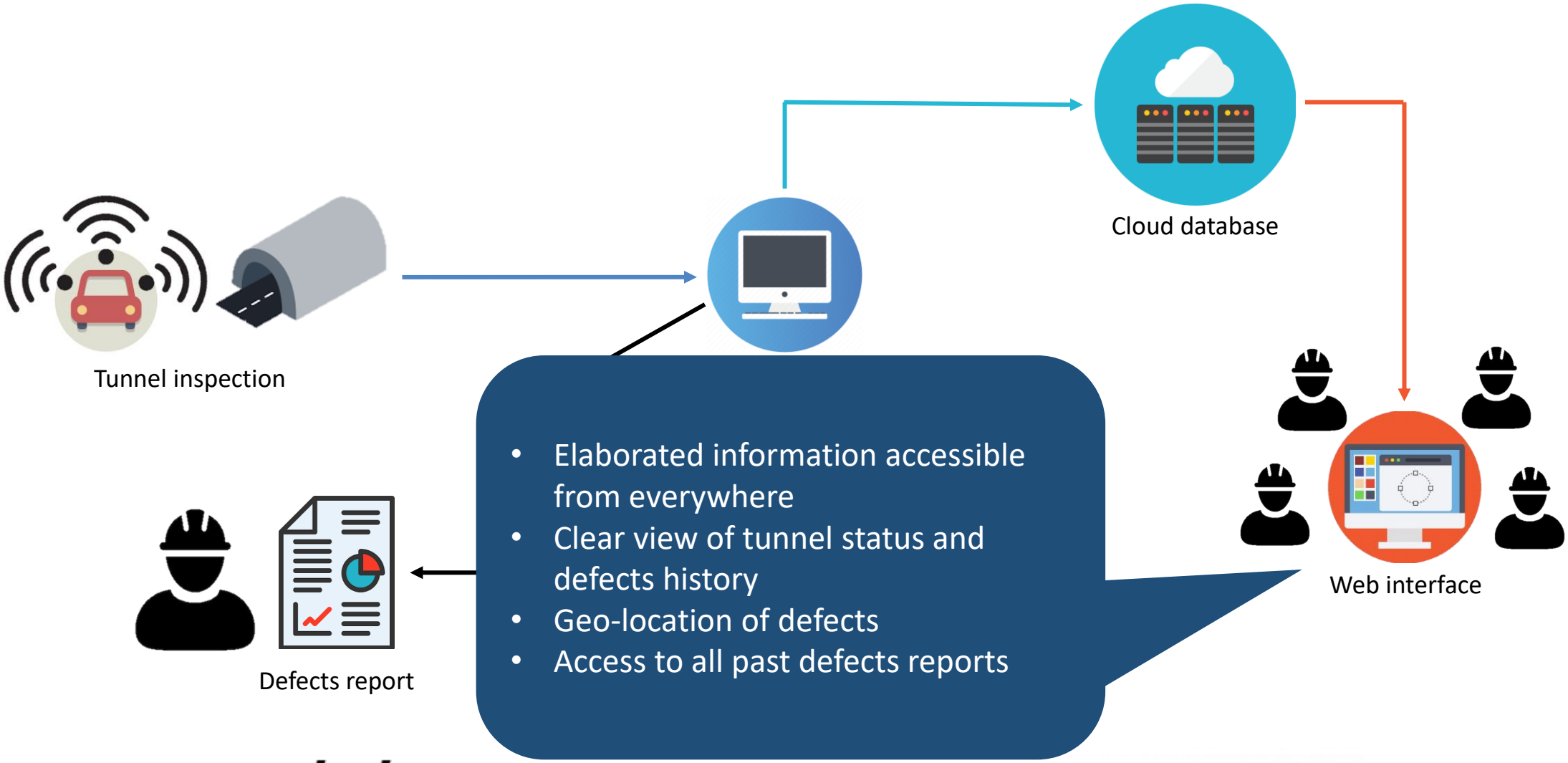
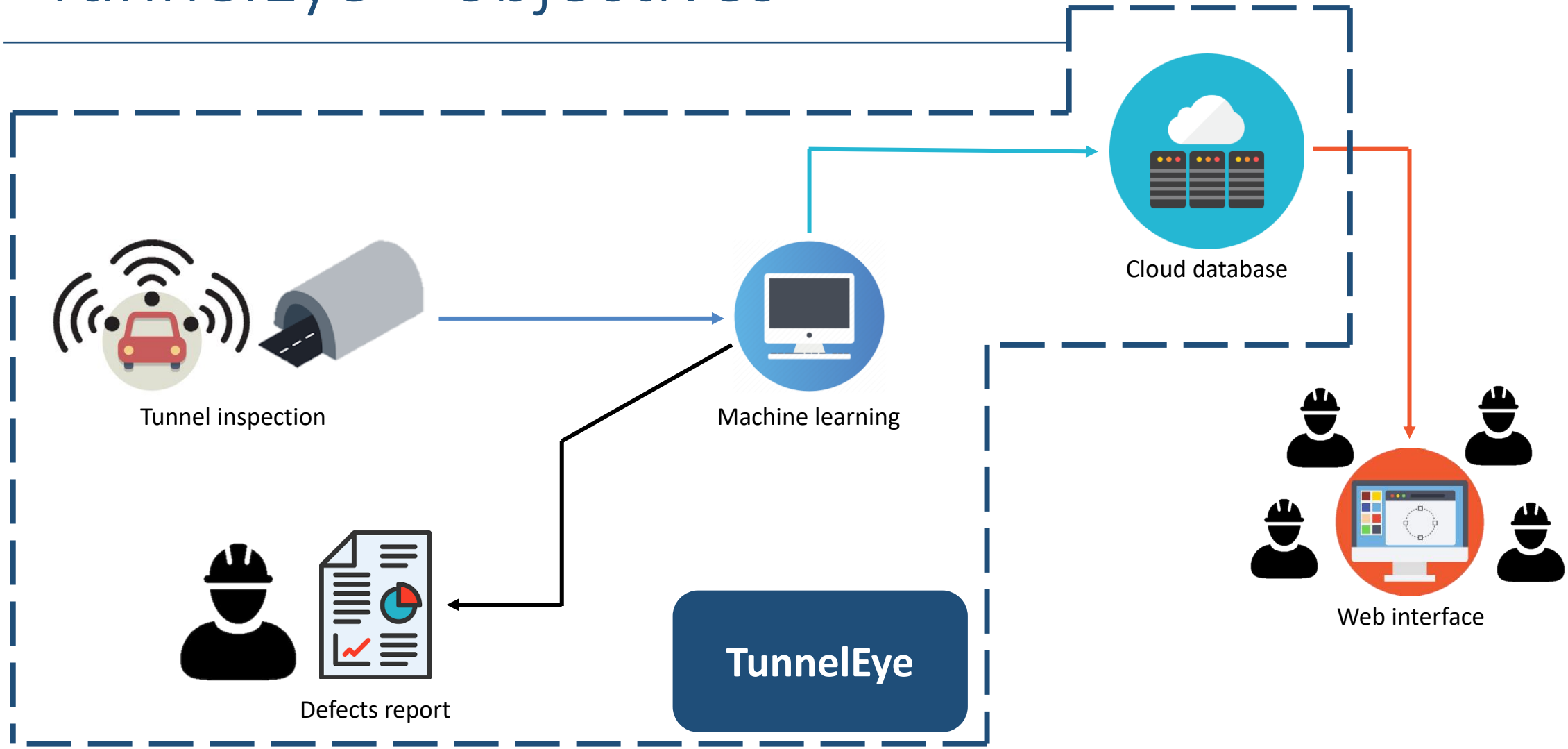
TunnelEye – objectives



TunnelEye – objectives



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What we have achieved at M8

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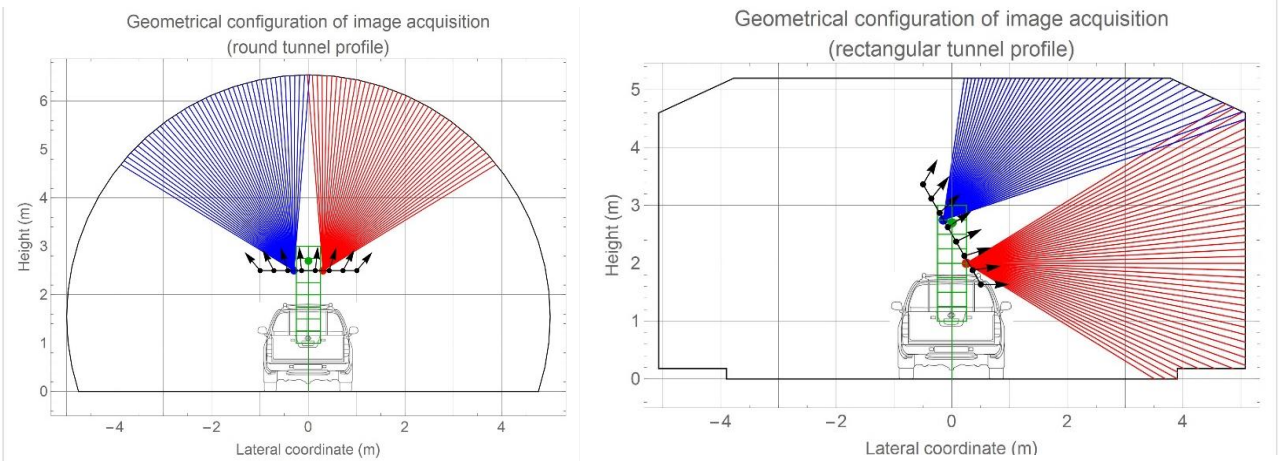
Kinematic imaging capturing system

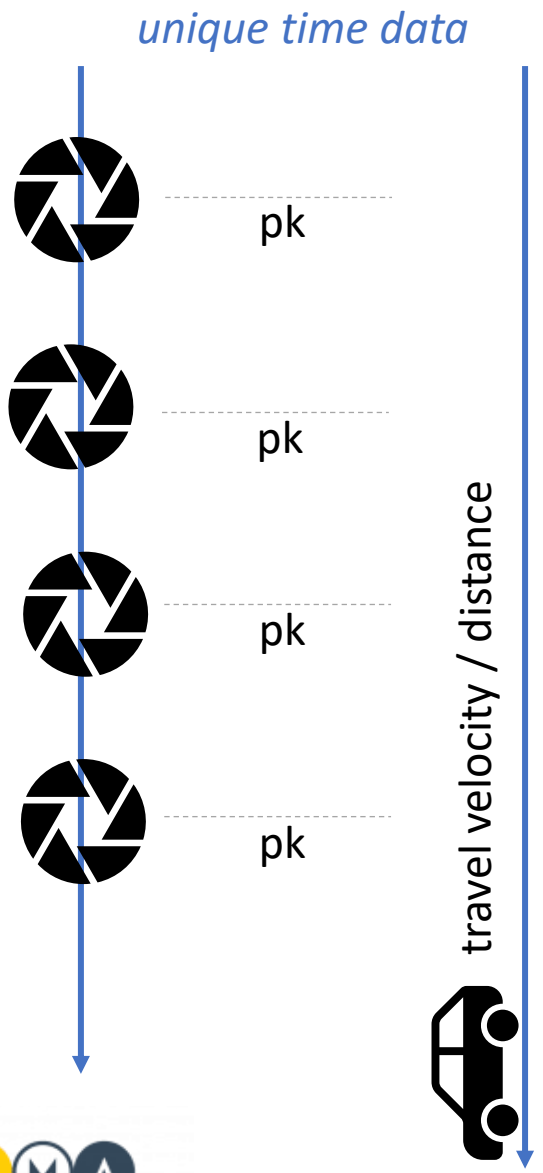
The kinematic imaging capturing system presents:

- **2 basic modules:**
  - 2 line-cameras for image acquisition,
  - 8 lights to correctly illuminate the caption area
- power supply unit
- positioning system
- a vehicle that travels into the tunnel



Acquisition process

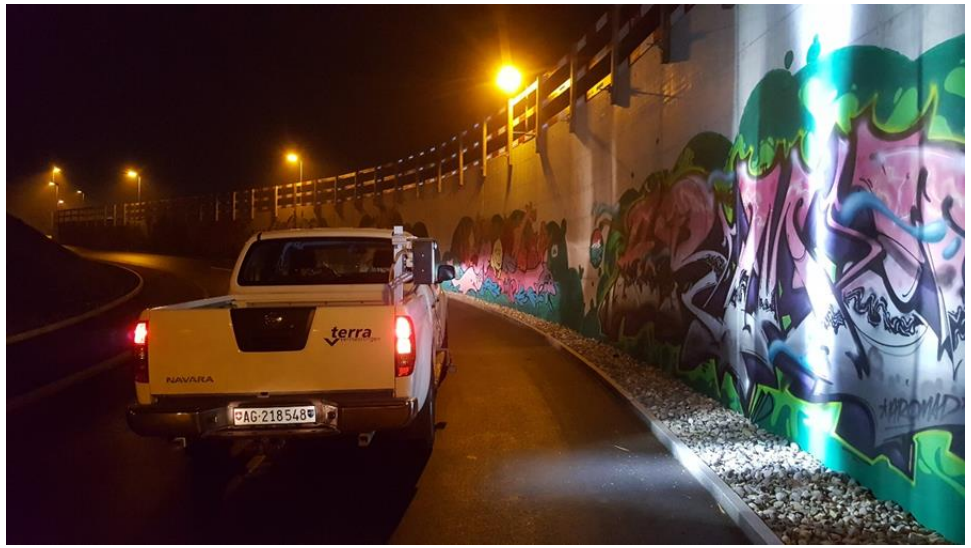
- The acquisition process is guided by an **ad-hoc program** developed to configure and control the system components as well as to record sensors and image data.
- Time synchronisation and triggering of the measurement components is provided by means of a PC board
- The output of the acquisition process consists in **high-resolution pictures**
- A second acquisition software is used to correlate recorded data with spatial position information, based on unique timer information



Test planning and parameters to control

The kinematic imaging system functional layout (hw + acquisition sw) development is **complete**.

Tests are planned in real application cases aiming to **adjusting camera settings** (sensors, exposure, image line rate, etc.) **to ensure resulting image resolution with high speed of execution (up to 80 km/h)**



<u>Fundamental acquisition parameters under testing:</u>

1) optimal choice of camera (image sensor) and lens
2) optimisation of geometrical parameters (view-angles of cameras and distances between cameras, lighting for different tunnel profiles)
3) optimisation of measurement parameters (measurement speed and image acquisition parameters)
4) improvement of lighting system (if needed)

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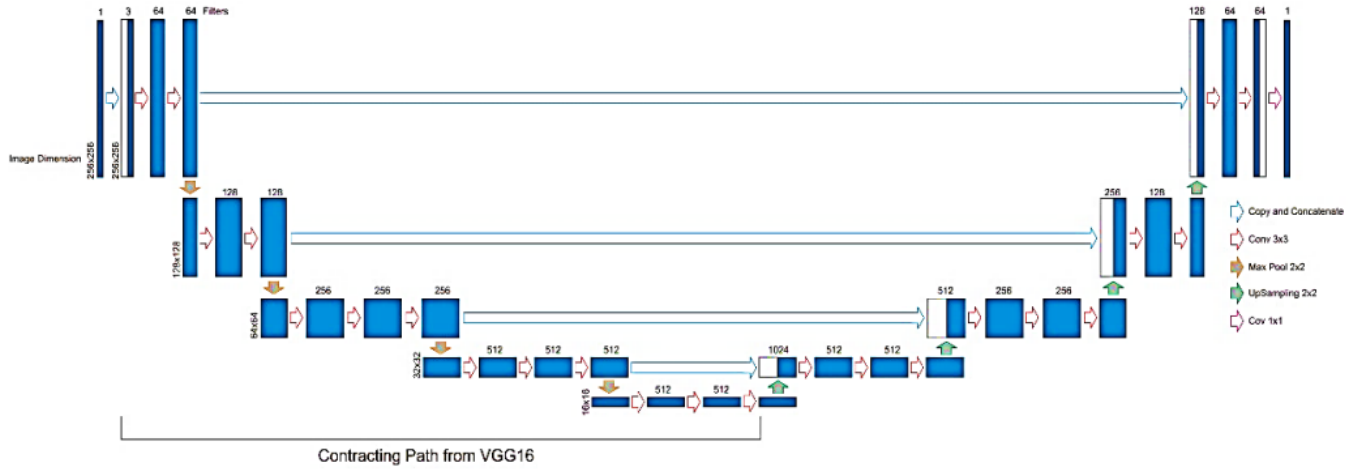
Image pre-processing and classifier

Image pre-processing is composed of three main steps:

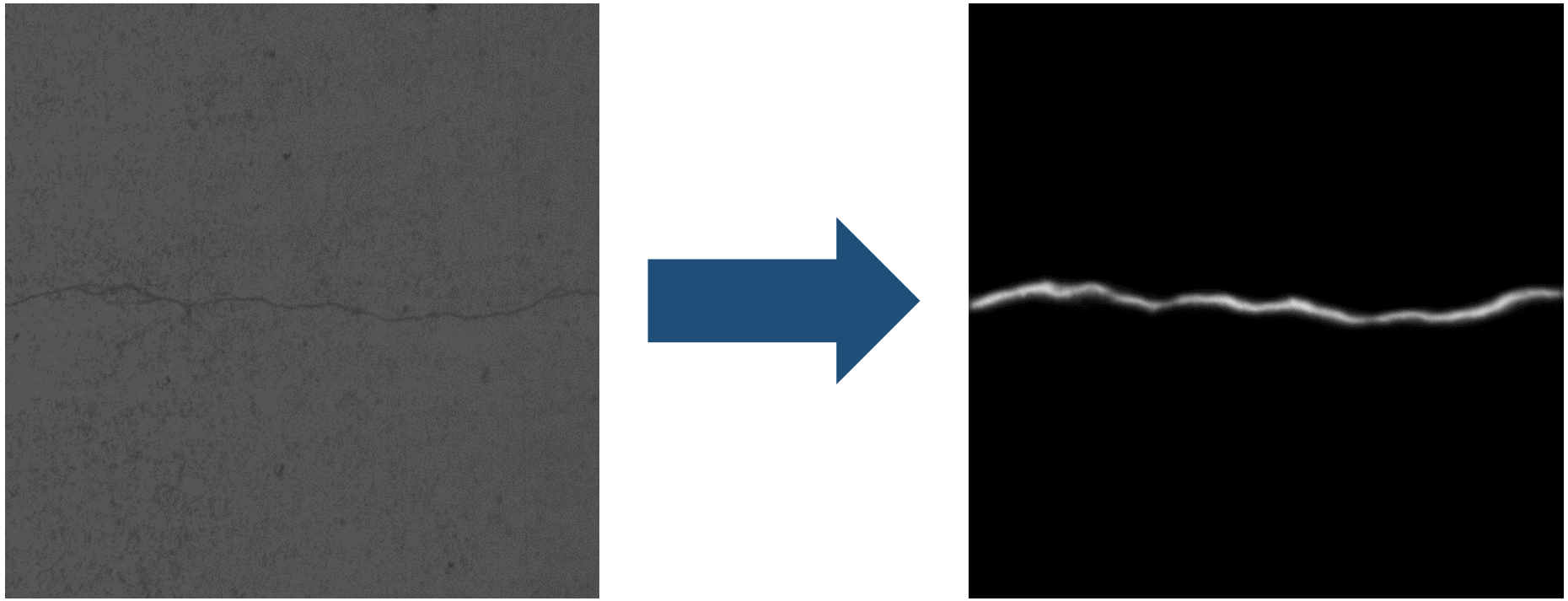
1. Data captured by line-cameras is correlated with spatial position information measured with an odometer, to obtain an undistorted complete 2D image of the tunnel.
2. The brightness of the images is adjusted by modifying each pixel value.
3. The images are cut into sub-images of known dimension so that they contain a reduced number of elements and details.

As classifier The UNet-VGG16 fully convolutional network has been used. To train the model, a dataset containing around 11.500 images merged from 12 available crack segmentation dataset was used.



Crack classification

- For each image received as input the classifier returns a mask where crack pixels are highlighted in a grayscale image
- The higher the probability of each pixel being part of a crack, the whiter the pixel will be in the mask.



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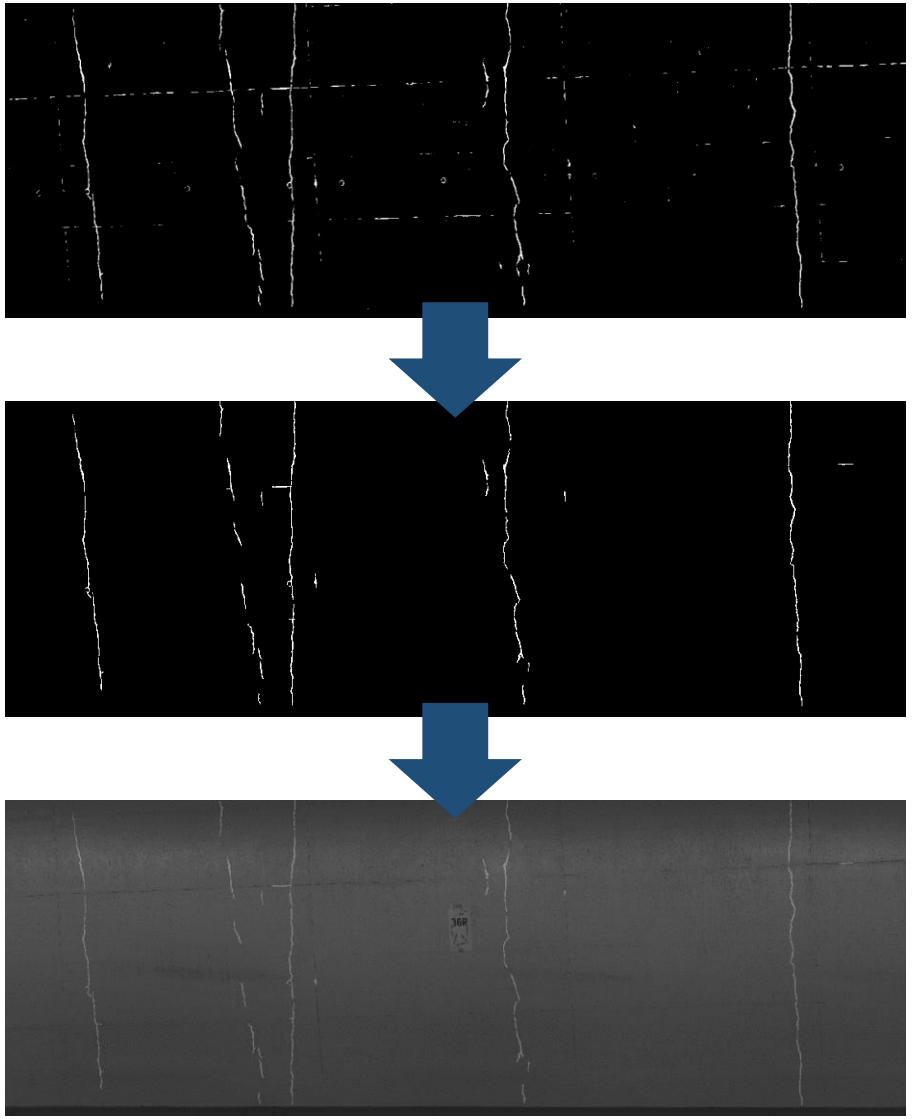
Post-processing

- A binary image is generated by setting each pixel to white if its value is above a specific threshold, to black otherwise.
- The full mask of the original raw image is reconstructed from the sub images.
- By analysing the geometrical properties of each element in the mask, most of the false positives are succesfully removed from the image.
- The first output of the system is generated by overlaying the raw image with its mask.



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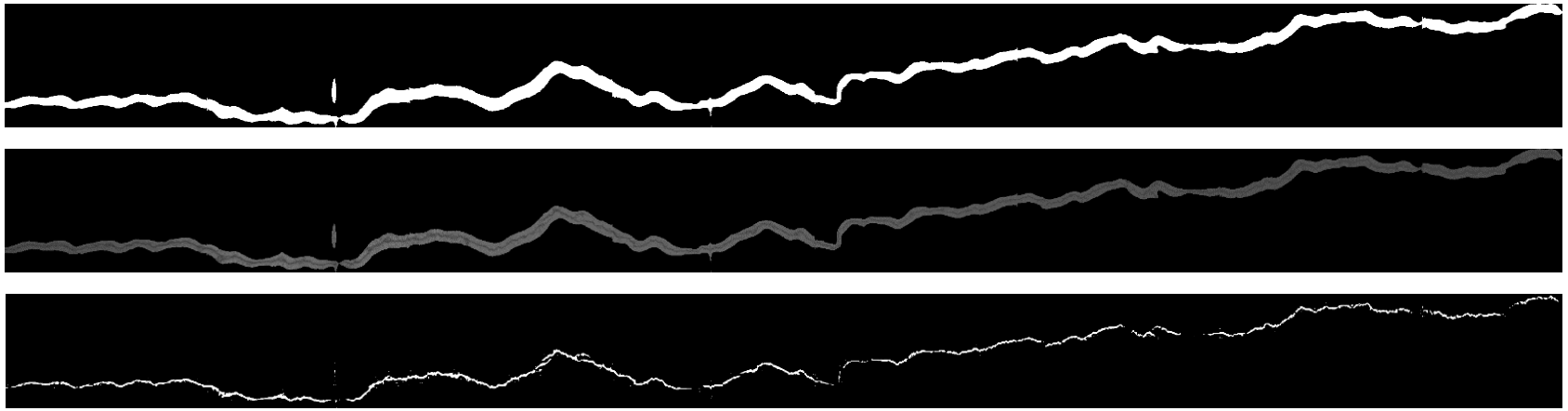
Post-processing

Three statistics parameters are calculated for each acquired image:

- Total cracks length in each tunnel section
- Total crack area (% of cracks area in the tunnel wall)
- Maximum crack thickness:
  - Each individual crack is first isolated in the mask image
  - White pixels are substituted with their original grayscale value in the raw image
  - An adaptive treshold method is used to highlight only crack pixels (original crack mask
  - An OpenCV function is used to calculate the maximum crack thickness



For more info:

www.stamtech.com
a.landini@stamtech.com

www.pizzi-terra.com
r.pizzi@pizzi-terra.com

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