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ConnRAD – Connectivity and Resilience for Automated Driving

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ConnRAD
Connectivity & Resilience for automated Driving Functions in Germany

Resilience Key Performance Indicators for Remote Driving

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A Step Further to Resilient Remote Driving

Performance degradation detection during run-time for complex system has been a challenging problem for a long time, as it is extremely difficult to pin-point the initial error that causes the system degradation. This is especially true for teleoperation system, since it splits itself into two spatially distributed subsystems that communicate via mobile network. In the project ConnRAD, we identify a potential set of Key Performance Indicators (KPIs) that assess and safeguard the performance of the remote driving subsystems during run-time.

Sub-System	Key Performance Indicators
Sensing	Camera information capacity
Video	Absolute image quality & Relative image quality
Network	Latency, data-rate, packet loss, packet reordering
Control	Time to complete, task completion rate, error rate

Method for Metric and KPI selection:

KPIs and metrics are selected from the literature based on a systematic approach. First, the remote driving system is split into multiple subtasks (e.g. video compression and streaming, collect sensor information). Then the approach starts with a literature research on metrics and KPIs for remote driving. The obtained KPIs and Metrics are afterwards compared against overall data degradation categories and assigned to the system subtasks. Based on the result, white spots along the potentially degraded data from subtasks were observed. These were closed with dedicated literature research regarding the specific data. Modes of potential data degradation considered:

- Correctness of the data (e.g. correct color schemes)
- Reliability of the data (e.g. constant frame rates
- Completeness of the data (e.g. full image is obtained at receiver)
- Accuracy of the data (e.g. the resolution of the image)
- Actuality of the data (e.g. the delay added by the compression)

Open at this stage is a complete sensitivity analysis of the degraded data and the individual metrics and KPIs. A metric is assumed to be suitable for a KPI if a threshold can be identified that splits the system into safe and unsafe behavior.

Reactive KPIs

The KPIs divide themselves into reactive and proactive KPIs. The reactive KPIs tracks the current states of the system performance and can only react to a system degradation when one has taken place. Idea of the underlying metrics is to enable both operator and vehicle to evaluate the data degradation with their own data. By sharing the metric results, then both subsystems can confirm their current evaluation and profit from additional data that they might not have access to, like the original images.

MSE:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(p_i^{compressed} - p_i^{original})$$

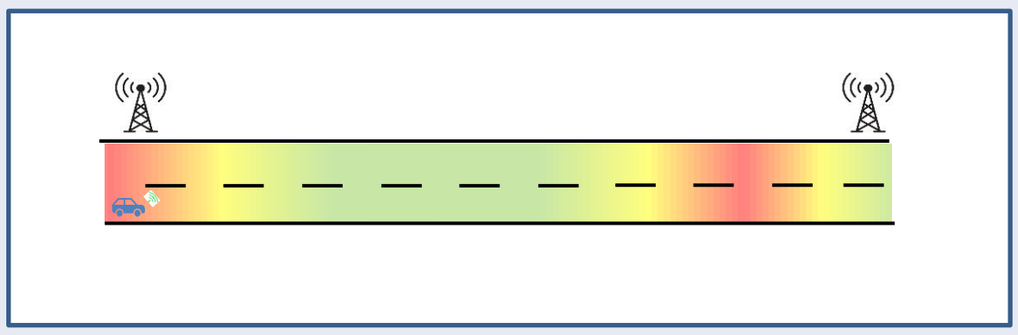
NIQE:

$$\mathrm{NIQE} = \sqrt{(\boldsymbol{\mu}_\mathrm{m} - \boldsymbol{\mu}_\mathrm{i})^T \left(\frac{\sum\_\mathrm{m} + \sum\_\mathrm{i}}{2}\right)^{-1} (\boldsymbol{\mu}_\mathrm{m} - \boldsymbol{\mu}_\mathrm{i})}$$

The sensitivity analysis shows additionally the **correlation** between the KPIs and possible **fail-cases** of remote driving system. This shows the **effectiveness** of corresponding KPIs in case of system failure.

Proactive KPIs

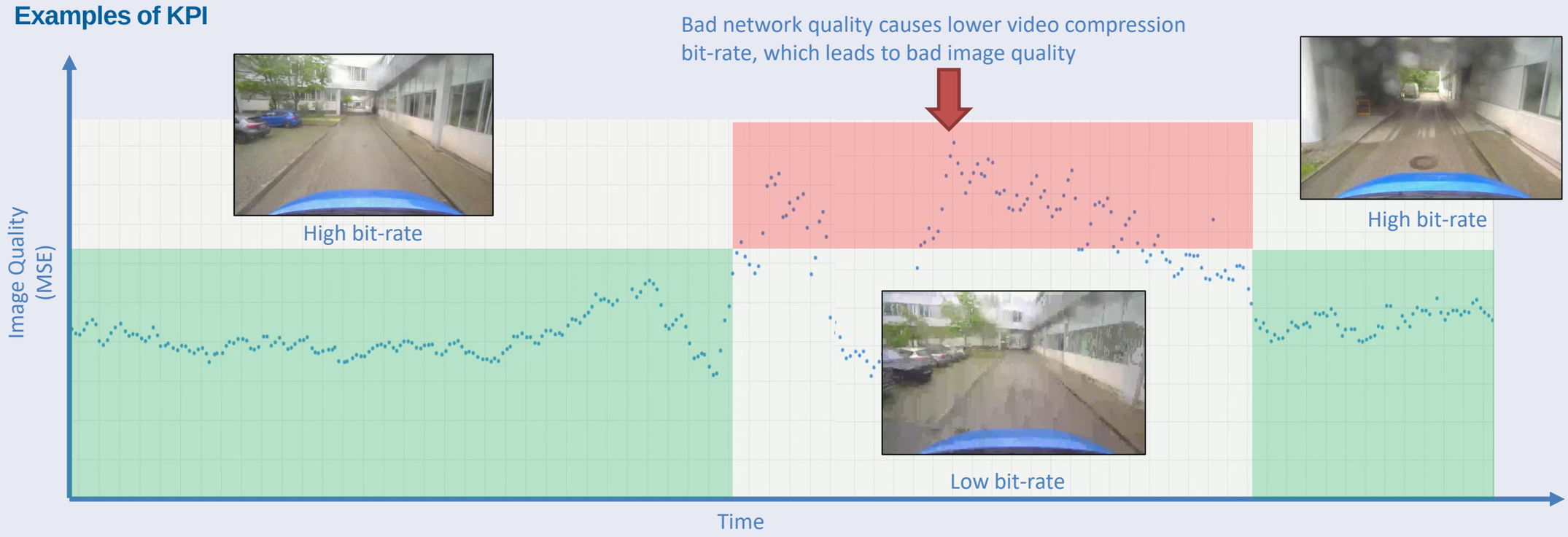
The proactive KPIs, such as **residual risk estimation** and **predictive quality of service** predict the possible imminent system degradation and try to prevent it or mitigate the risk if it is inevitable



Predictive Quality of Service

Predictive quality of service aims to predict future network states based on current and past observations. The applicability of a radio map for the prediction of the network quality was assessed in this project together with potential countermeasures. One of the most important aspects of data transmission for remote operation is a consistent video stream. PQoS can e.g. help with a congestion control.

Examples of KPI



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