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ODD monitoring in Autonomous Vehicles

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Operational Design Domain

- Necessity for ODD:
  - An AV must be proven safe before it is allowed to operate on public roads.
  - ODD outlines the specifications and conditions for which an AV is designed.
  - ODD helps in restricting the area in which an AV can safely operate.

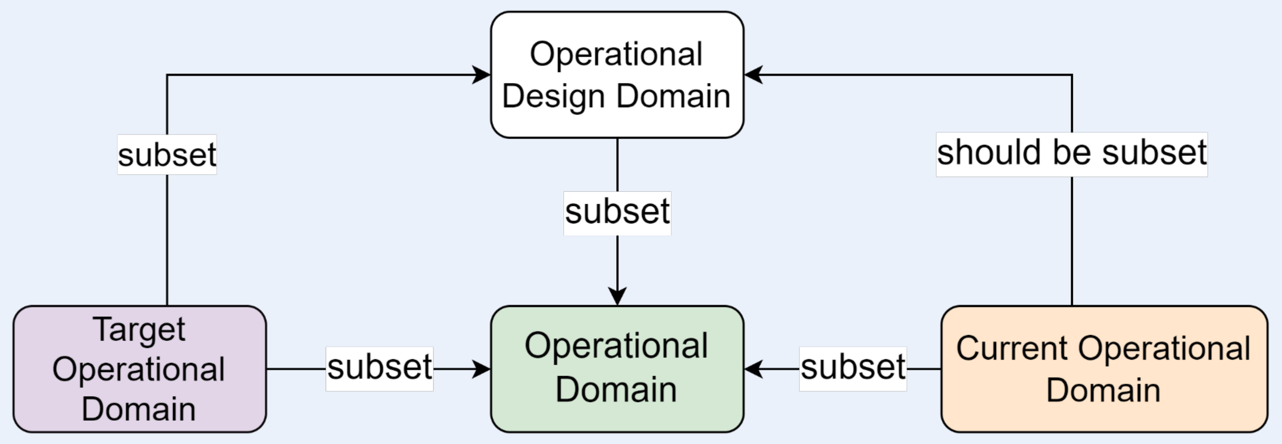


Fig 1: Relationship between ODD, OD, COD and TOD.

- ODD exits:
  - ODD boundaries cannot be enforced at all times.
  - An ODD exit in an AV happens, when its COD ⊈ ODD.
  - The ODD boundaries have to be monitored in real-time to detect these exits.
  - ODD exits from perspective of ISO 34503 can be seen in Figure 2.

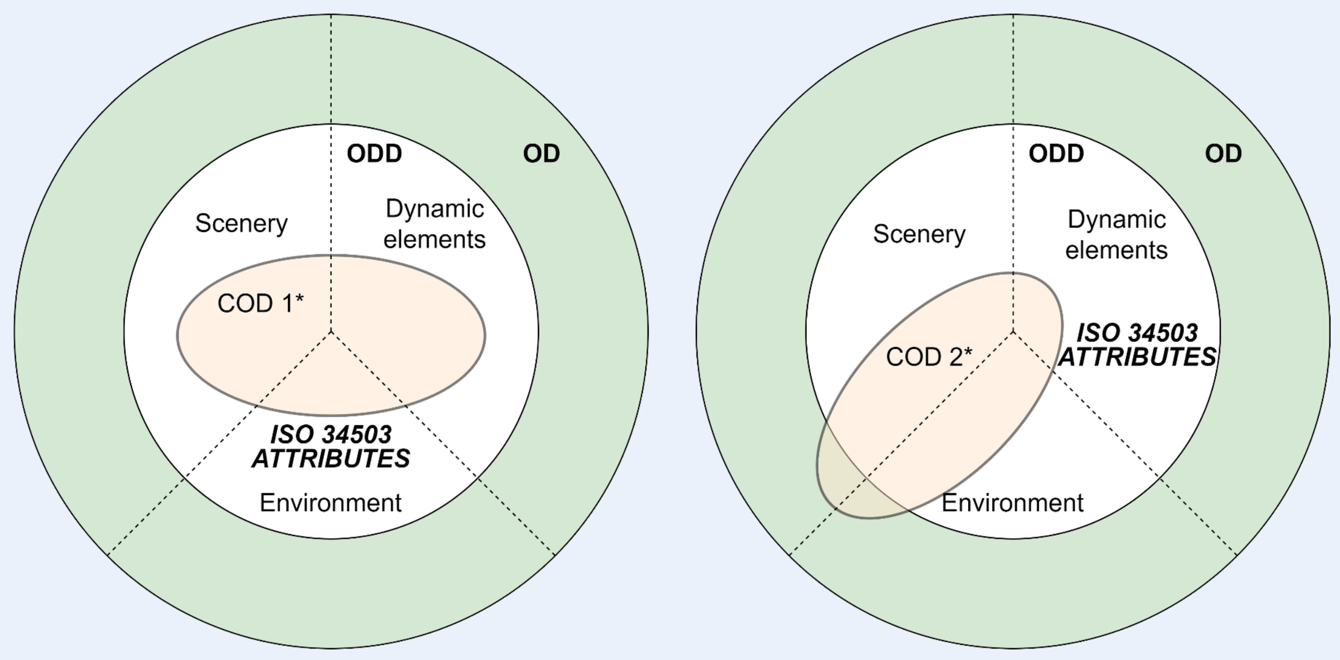
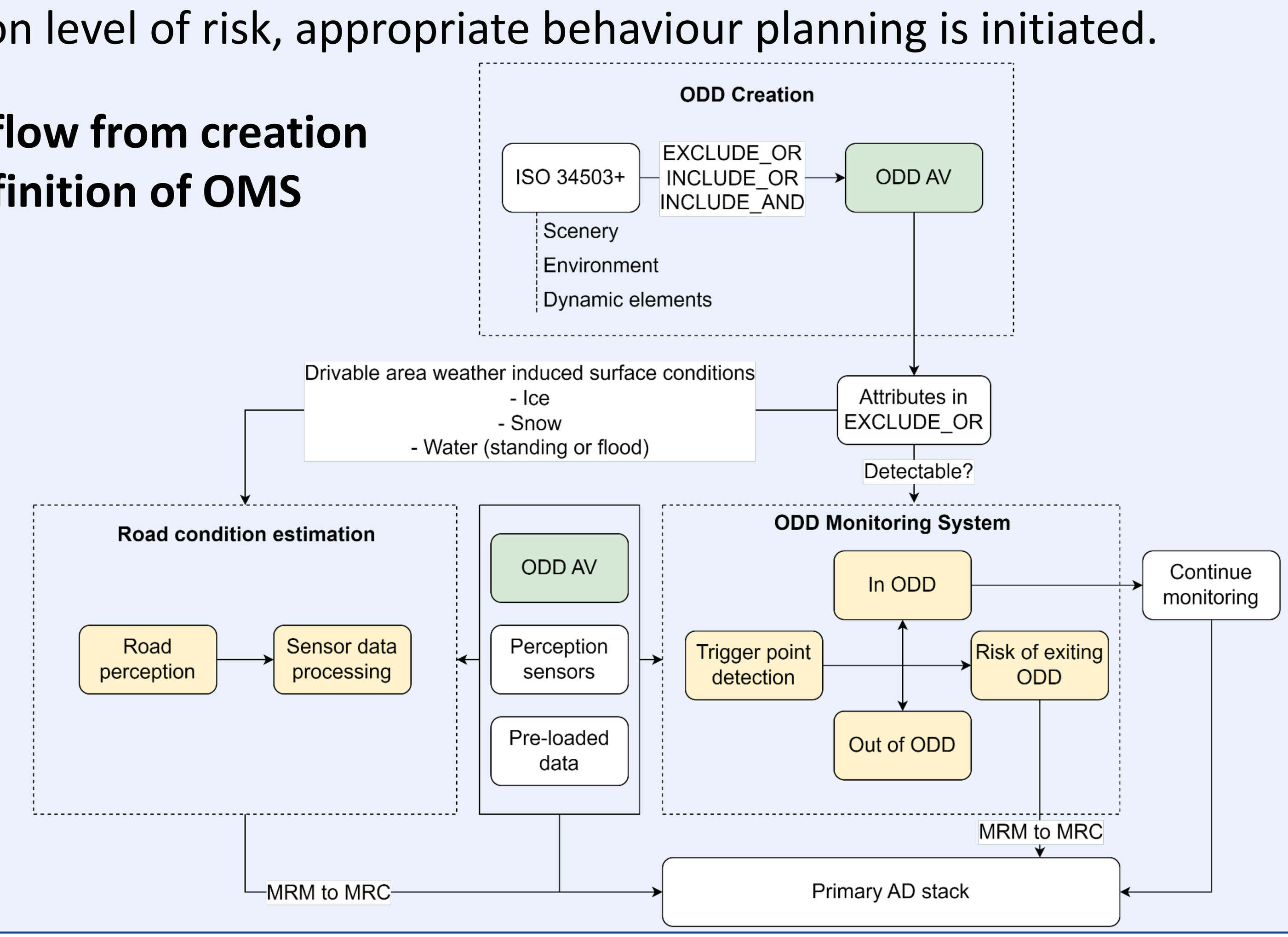


Fig 2: ODD exits from perspective of ISO 34503.

ODD monitoring framework

- Trigger points:
  - To detect an ODD exit, it should have a detectable *trigger point*.
  - Trigger points can be defined using ISO 34503 attributes that are excluded from ODD.
- ODD monitoring framework:
  - An AV can exist in three possible states: in ODD, at risk of exiting ODD, and out of ODD.
  - Depending on level of risk, appropriate behaviour planning is initiated.

Fig 3: A workflow from creation of ODD to definition of OMS framework.



Use case: Contactless Road Condition Estimation

- Preliminary findings:
  - Between 2019-2022, 43% accidents involving personal injury in Germany were due to slippery roads from weather and winter-induced conditions.
  - Ramifications of failing to detect a slippery road before ego vehicle comes in contact could be disastrous.
  - Camera-based RCE is now an upcoming and significant topic of research.

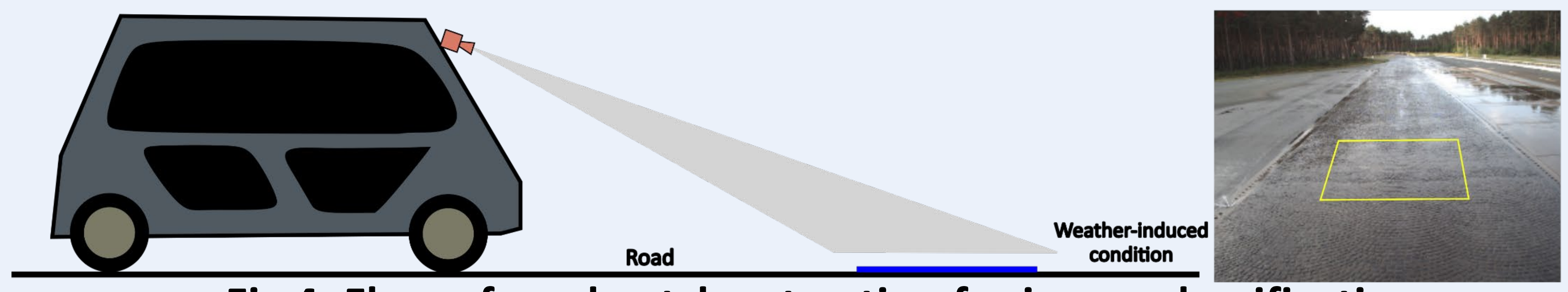


Fig 4: Flow of road patch extraction for image classification.

- Conclusions on RCE:
  - Standard approaches: Image classification or segmentation to weather-induced conditions as classes.
  - Special approaches: Drivable area detection, friction coefficient estimation
  - Image classification using CNNs is one of the most prominent techniques.

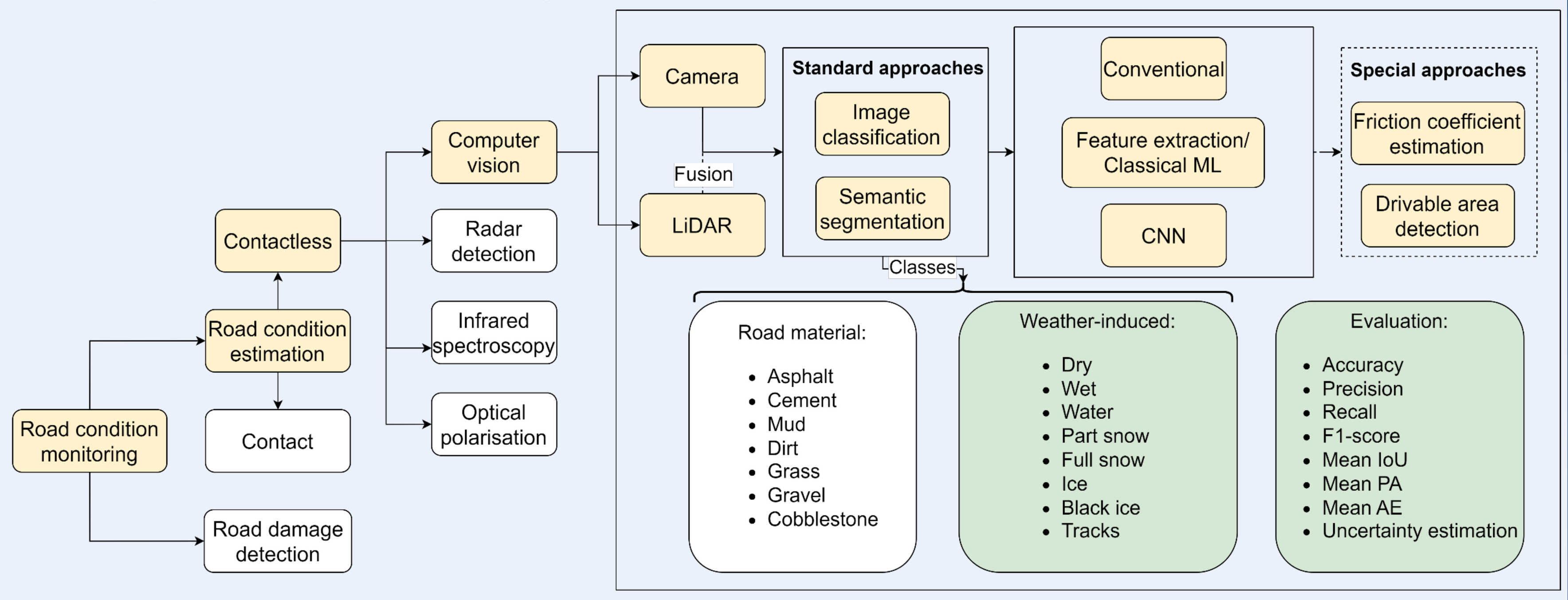


Fig 5: Summary of RCE study.

- Current challenges in contactless computer vision-based RCE:
  - Lack of algorithms to directly estimate road friction coefficient.
  - Lack of RCE datasets and class imbalance amongst the existing ones.
  - Appropriate evaluation techniques to evaluate the datasets‘ generalization capabilities.
- Outlook:
  - RCE algorithm development with:
    - real-time scalar friction coefficient estimation
    - a strategy to handle misclassifications.
  - Trajectory planning w.r.t friction coefficient,if required, a MRM to reach MRC.

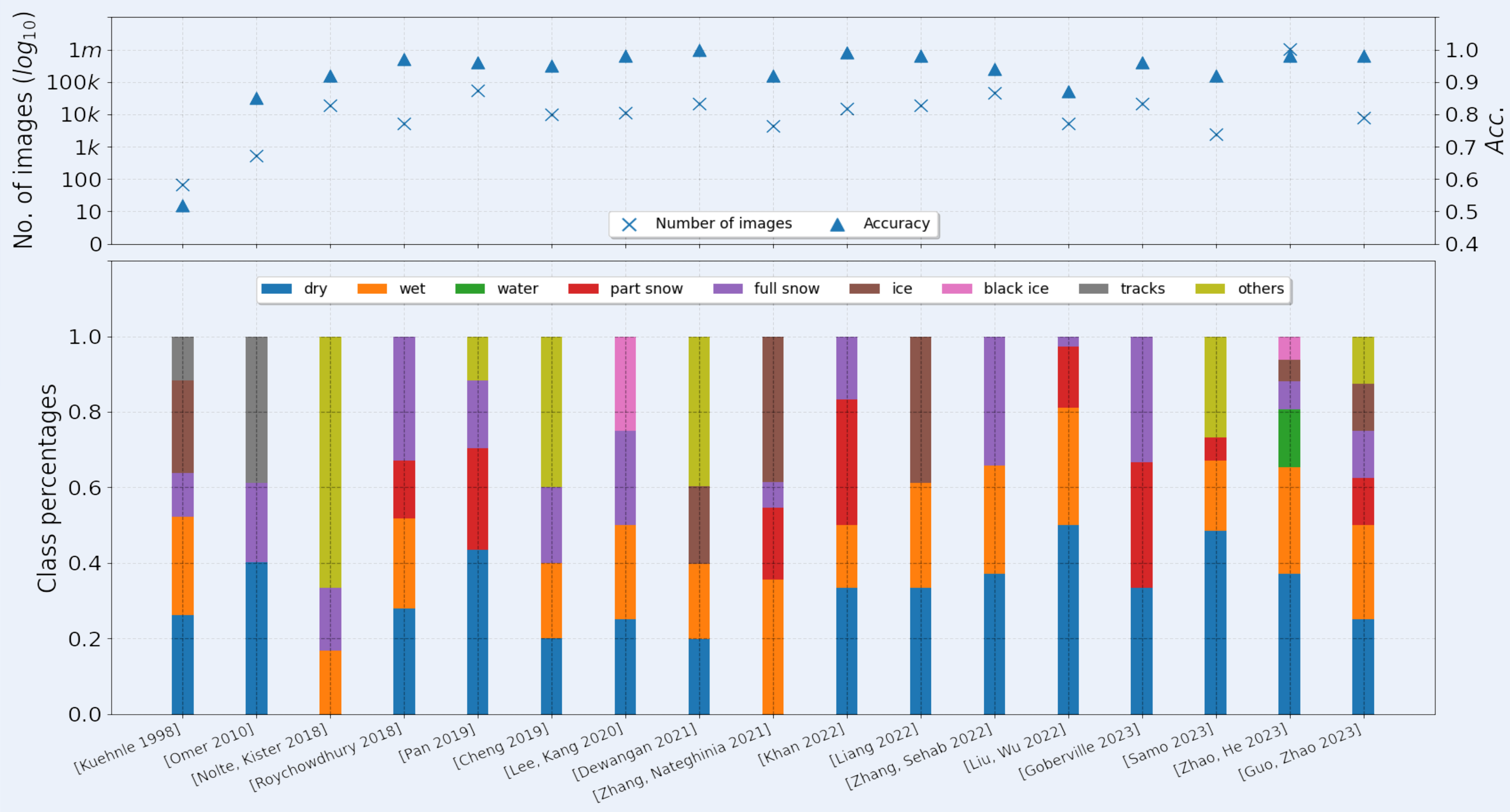


Fig 6: Dataset imbalance in RCE over the years.

NeMo.bil

The above-mentioned work is a part of an ongoing project NeMo.bil, in which an innovative last mile autonomous schwarm mobility concept is being investigated. As a part of it, autonomously driven NeMo.Cabs are being developed and the ODD monitoring system addresses the safety aspect in them.
Duration: 01.07.2023 – 30.06.2026
Partners: TH Augsburg, dSPACE, CADFEM, NeMo Paderborn along with others.
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Reference: The ODD monitoring system and the use case of RCE are analysed in detail in a pre-printed paper titled *„Study of Contactless Computer Vision-based Road Condition Estimation Methods within the Framework of Operational Design Domain Monitoring System“* and can be accessed through doi: 10.20944/preprints202407.2591.v1 or scanning the QR code.

Abbreviations: ODD: Operational Design Domain; AV: Autonomous Vehicle; OD: Operational Domain; COD: Current OD; TOD: Target OD; RCE: Road Condition Estimation; MRM: Minimum Risk Maneuver; MRC: Minimum Risk Condition

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