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Repairing is Caring - An Approach to an AI-Supported Product-Service-System for Bicycle Lifecycle Prolonging

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Outline

- Motivation
- Problem Scenario: Bicycle Owner and Repairer Perspective
- Data Collection Process for Lifecycle Decision
- Bicycle dataset: Acquisition, Overview, and Distribution
- AI-based Methodology: Architecture and Modeling Process
- Results: Defect Detection and Repairability Assessment use case
- Bicycle Repair Ecosystem
- Limitation and Future Outlook

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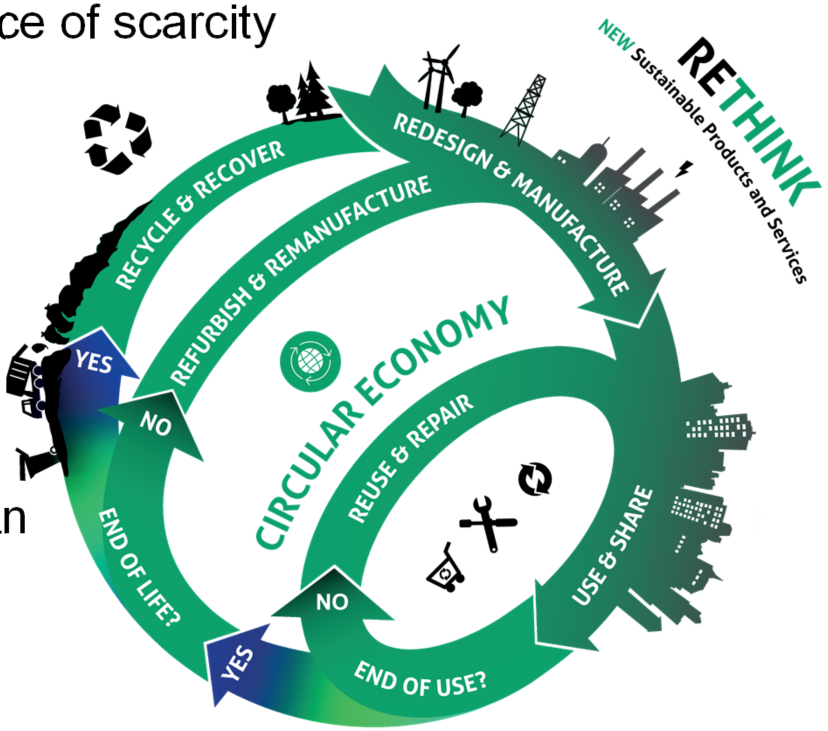
Motivation

- Earth has finite resources, resulting in an increasing prevalence of scarcity
- Therefore, transforming to a circular economy helps:
  - reduces waste
  - Increases the lifespan of products
  - Create a sustainable ecosystem on a large scale
- Repairing is a sustainable option to extend a product's lifespan
- Bicycles are good examples for reuse:
  - It plays an essential role in today's mobility ecosystems
  - Reduce the rate of emissions
  - Requires less space compared to other mobility solutions



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Problem Scenario

Owner

- Wants to get rid of an old bike
- with the lowest effort and time feasible

Repairer

- Wants to repair bikes quickly and in an economically feasible way
- Need to know the defect or missing component
- Resell the repaired bikes

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Repairer perspective

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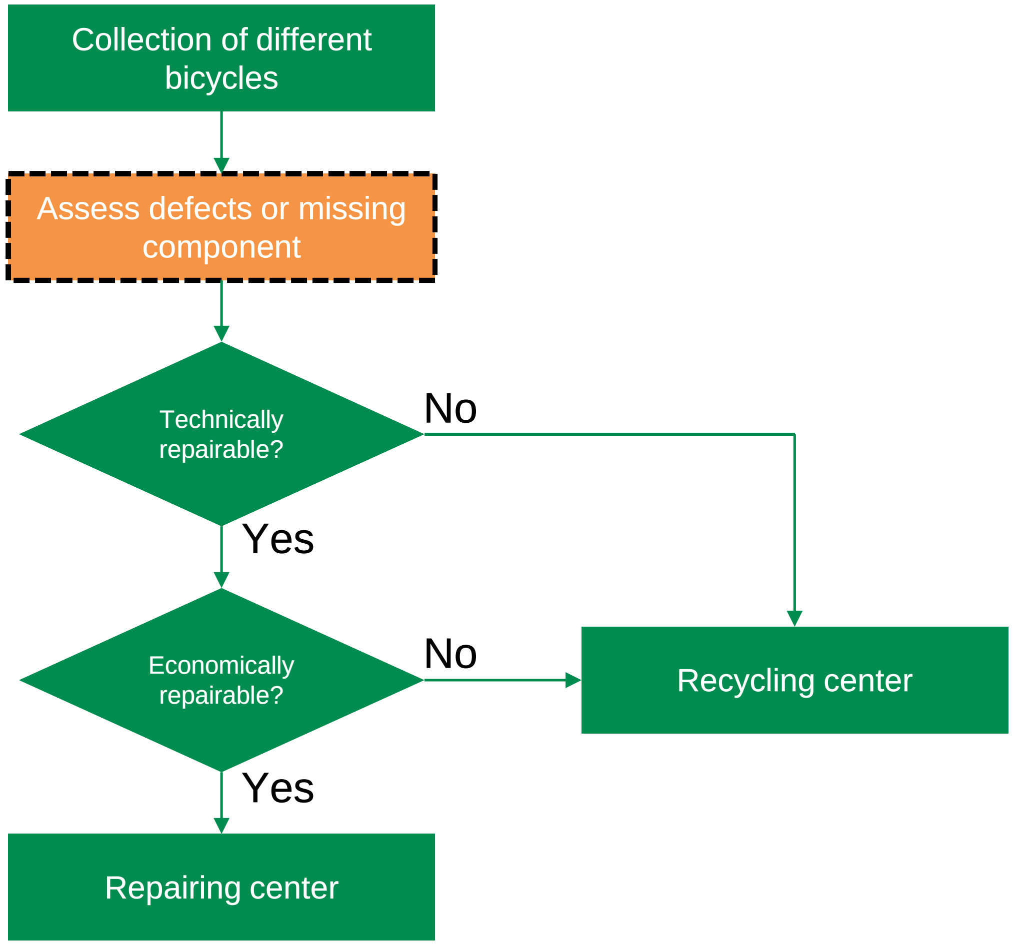
Data Collection Process for Lifecycle Decision

- Collection of 112 old bicycles during the phase of one month
- Identification of missing or defective components
- If the bicycle is repairable:
  - The defect is repaired
  - Missing components are replaced
- If the bicycle is not repairable, it directly goes to the recycling center



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Bicycle Data Acquisition

- Gather the details on each parts
- Guide to assess the overall condition of the bicycle
- Talking with the repairer
- Options for each component:
  - functional
  - defect
  - missing
- Classify the bike as repairable or not (for our repairer)

Bicycle
- Manufacturer
- Bike Type
- Wheel size
- Gearshift Type
- Number of Gears

- **Breaks** (Type)
  - Front wheel break assessment
  - Rear wheel break assessment
- **Drive Train**
  - Left pedal assessment
  - Right pedal assessment
  - Chainring assessment
  - Gear shift assessment
  - Pinion/Cassette assessment
- **Light** (Type)
  - Front light assessment
  - Rear light assessment
  - Dynamo assessment
- **Wheels**
  - Front wheel tire assessment
  - Rear wheel tire assessment
  - Front wheel impeller assessment
  - Rear wheel impeller assessment
- **Frame** (Condition)
- **Handlebar** (Condition)

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Dataset Overview

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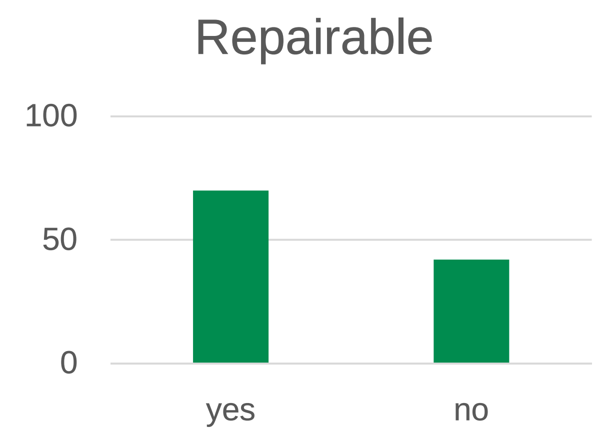
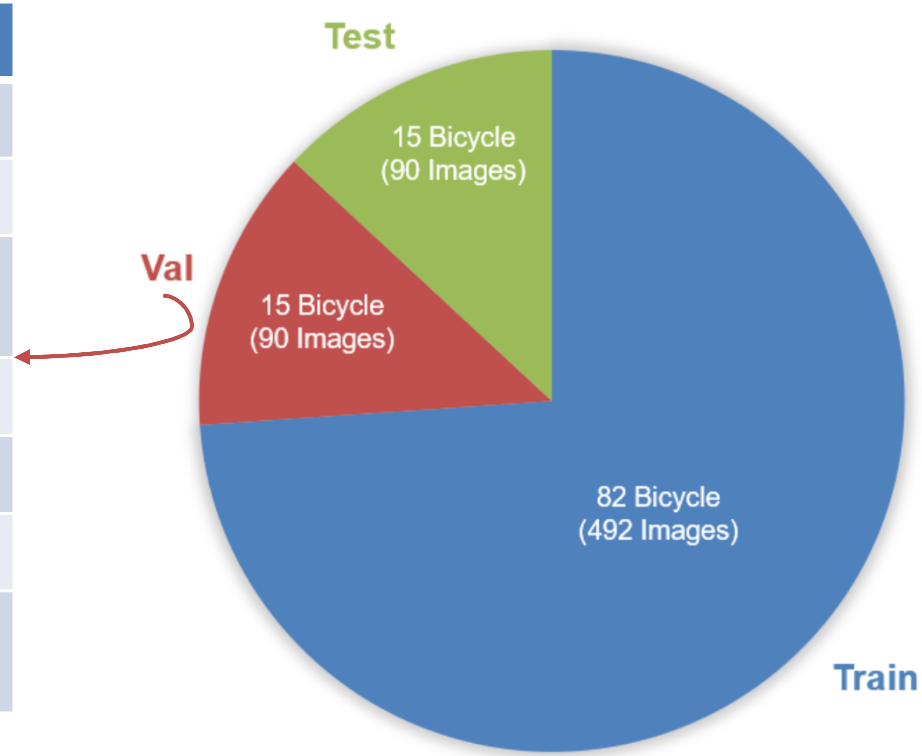
Dataset Distribution

- Total 112 bicycles:
  - Correspond to 672 images
- 70 bicycles are repairable:
  - Correspond to 420 images
- 42 bicycles are not repairable:
  - Correspond to 252 images



Hyperparameters
Optimizer
Learning rate
Learning rate scheduler
Dropout rate
Regularization rate
Batch size
Number of layers to freeze



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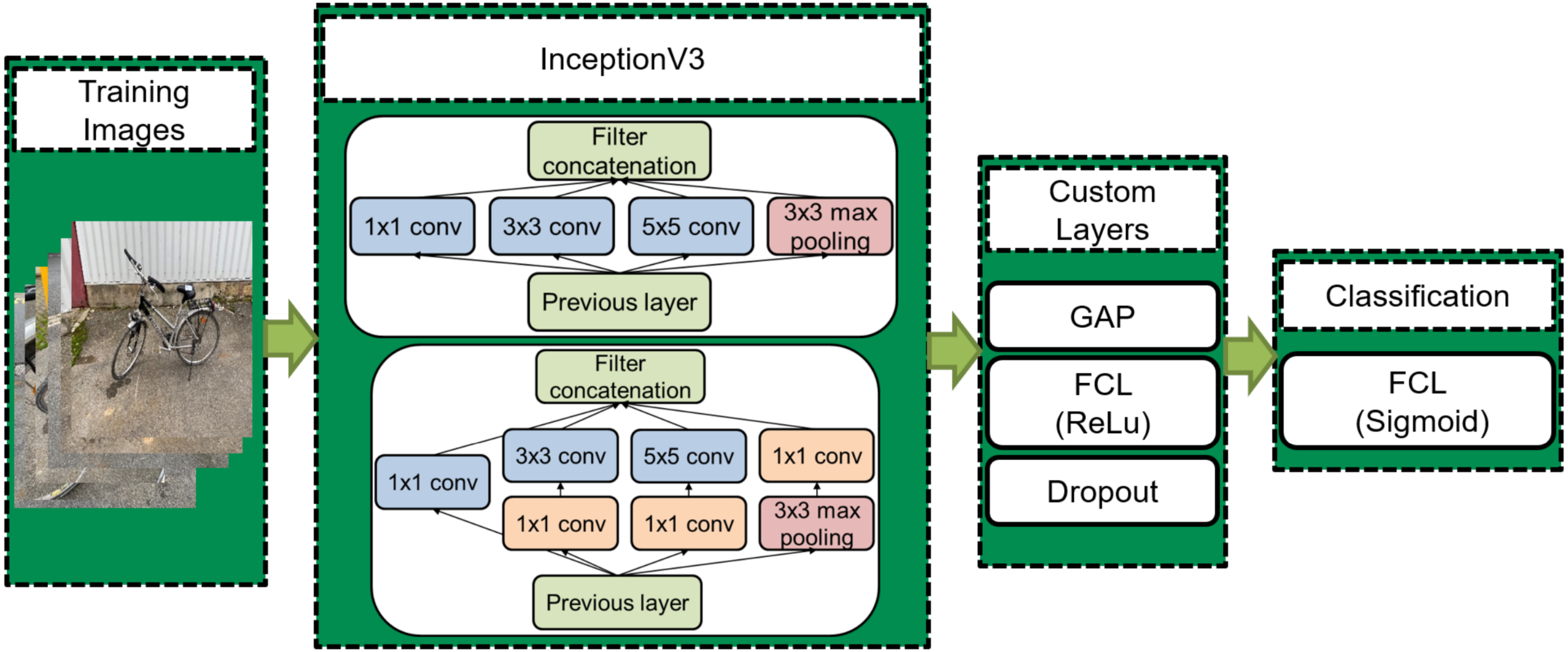
AI Architecture



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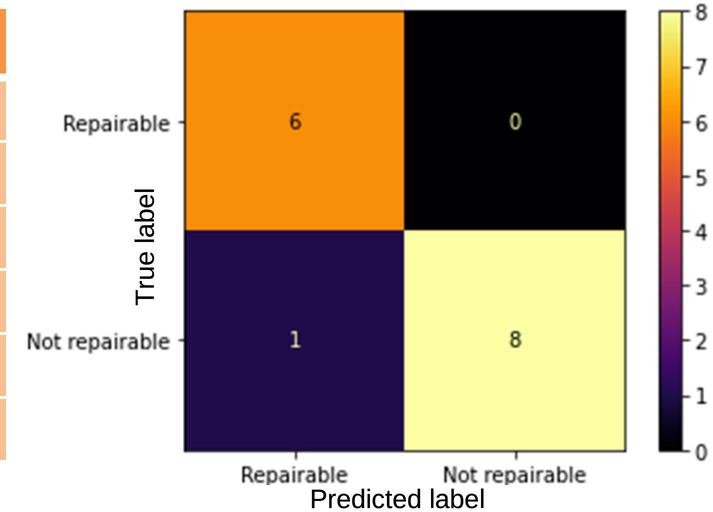
Achieved Results

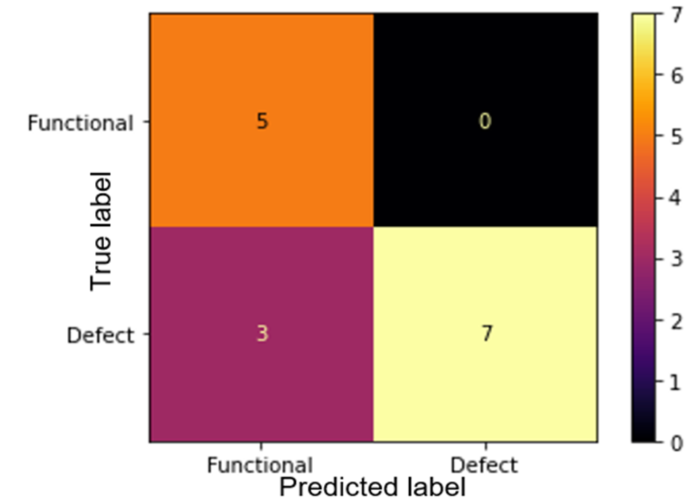
Repairability Assessment Use Case

	Precision	Recall	F1-score	Support
Repairable	0.86	1.00	0.92	6
Not repairable	1.00	0.89	0.94	9
accuracy			0.93	15
macro avg	0.93	0.94	0.93	15
weighted avg	0.94	0.93	0.94	15



Defect Detection Use Case

	Precision	Recall	F1-score	Support
Repairable	0.62	1.00	0.77	5
Not repairable	1.00	0.70	0.82	10
accuracy			0.80	15
macro avg	0.81	0.85	0.80	15
weighted avg	0.88	0.80	0.81	15



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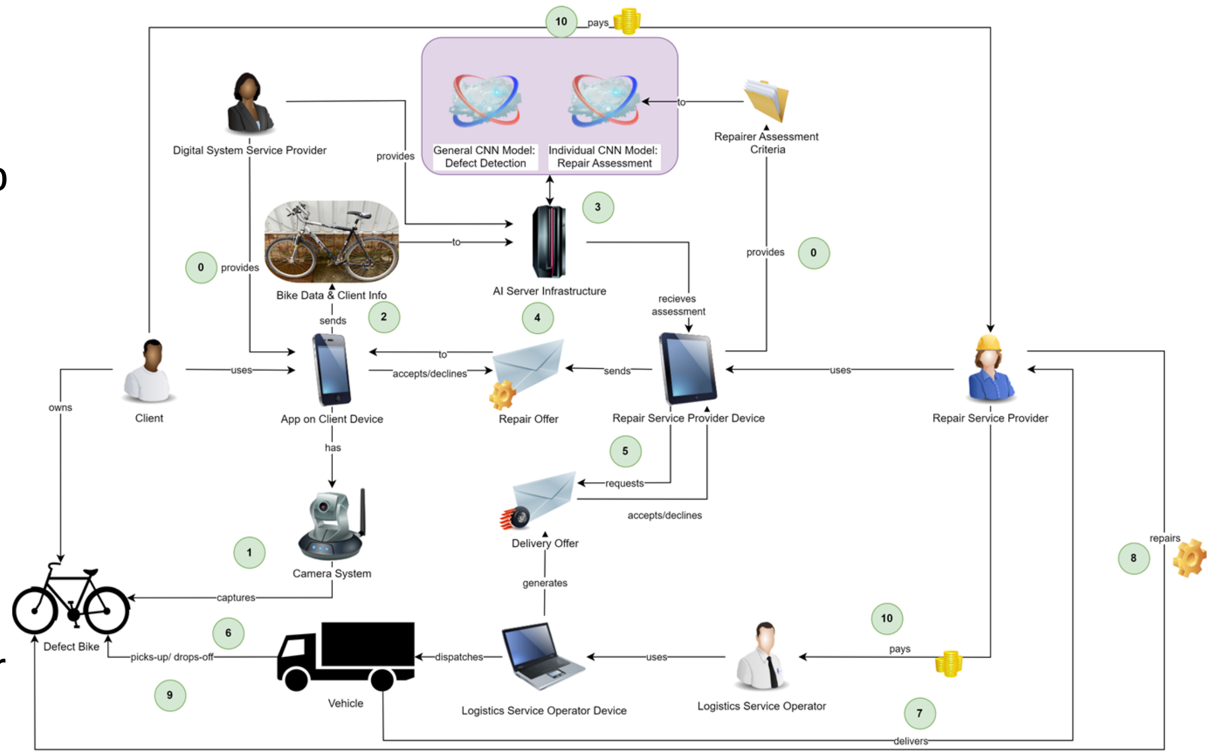
Product-Service-System for bicycle repairing

- Step 1: The client initiates the process
- Step 2: Processing of images and sending them to the AI Server Infrastructure
- Step 3: Repairability assessment by the model, trained on the assessment criteria of the repairer
- Step 4: The repairer submits an offer to the Client
- Step 5: The repairer contacts the logistics provider
- Steps 6 & 7: The logistics provider picks up the bicycle
- Steps 8 & 9: Repairing and returning the bicycle to the client



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Limitation and Future Outlook

- Examining the robustness of the model in the case of detecting defects for multiple components

- So far, the AI-based models are configured in line with the operational contexts and requirements of the specific repairer…

- Developing reconfigurable pipeline framework:
  - Human in the loop → Active learning
  - Receiving feedback from the system stakeholders to align with their unique operational contexts and respective needs
  - Customization of training processes according to specific requirements

Limitation and Future Outlook

- Adapting the hyperparameter optimization workflow to identify damages and thus guide repairability decisions
- Finding the right balance between generalizability and specificity
- What about the ecological impact?

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Thank you very much for your attention!