Hungarian University of Agriculture and Life Sciences

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Institute of Technology

Mechanical engineering master's

Development of a Part Recognition Tool for Physical Analysis of eAxles

Insider consultant: Tarr Bence
Associate professor

Insider consultant's Institute/Department: Department of Engineering Informatics

Outsider consultant: Lelkes János
Simulation engineer, Robert Bosch GmbH

Created by: **Tamim Deeb**

Robert Bosch GmbH (Budapest, Gyömrői út 104)

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Summary

In the landscape of automotive engineering, the emergence of electric vehicles (EVs) represents a significant technological and environmental milestone. Central to the advancement of EV technology is the development and optimization of electric axles (eAxles), which integrate key drivetrain components into compact, efficient units. This thesis presented the development of an advanced Part Recognition Tool designed to enhance the physical analysis of eAxles through the utilization of sophisticated image recognition technologies powered by artificial intelligence (AI). The tool automates the identification and categorization of eAxle components, facilitating more accurate and efficient developmental analyses.

The research included a detailed review which provides a comprehensive examination of the current state and advancements in image recognition technologies, focusing particularly on deep learning models like the ResNet architecture. It highlights the significant strides made in convolutional neural networks (CNNs) that leverage deep layers and skip connections to enhance learning from complex datasets, which are especially prevalent in applications involving mechanical components like eAxles. The review also delves into various machine learning algorithms and feature extraction techniques that are foundational to improving image classification tasks. These include methods for handling imbalanced datasets, optimizing model performance through advanced preprocessing techniques, and the integration of new data augmentation strategies. The scholarly discussion underscores the critical role of these technologies in advancing the precision and efficiency of part recognition tools.

A critical component of this thesis was the development and implementation of the "Linearoch" system, a sophisticated script designed to systematize and streamline the data preparation process for machine learning. Linearoch automates the organization, preprocessing, and management of complex data structures, significantly enhancing the efficiency of preparing large and heterogeneous datasets. By automating tasks such as reorganizing folder structures, renaming files while preserving hierarchical relationships, and handling various types of image files, Linearoch minimizes human error and reduces the time and effort typically associated with manual data preparation. Its core functionality transforms unstructured or semi-structured data repositories into well-organized formats that are readily accessible and optimized for further processing and analysis. This structured systematization is essential for improving the performance of machine learning models, ensuring that the data provided to these models is of high quality, well-annotated, and consistently formatted. The introduction of Linearoch in this research not only supported the effective training of the Part Recognition Tool but also set a precedent for future applications, offering a robust framework for data management in complex AI-driven projects.

The creation of a comprehensive dataset specifically designed for the training and testing of the AI model was detailed. This dataset included a wide array of eAxle images, meticulously annotated to ensure precise model learning. The complexity and variety embedded within this dataset aimed

to mirror real-world conditions, thus preparing the model to accurately identify and categorize eAxle parts across different makes and models of eAxles.

The core of the thesis involved the development of the AI model using the ResNet architectures. Modifications and optimizations were applied to these architectures to better suit the specific needs of eAxle analysis. The performance of the AI model was rigorously evaluated through a series of tests designed to assess its accuracy, reliability, and scalability, validating the effectiveness of the tool in practical applications.

In real-world applications, the Part Recognition Tool achieved an initial accuracy of 55%. Several strategies to enhance this accuracy were detailed, such as increasing the size of the training dataset, optimizing the number of augmentations, and continuously refining the AI model based on ongoing testing and feedback. These enhancements are expected to gradually improve the tool's accuracy, making it even more effective in practical settings.

Moreover, the thesis explored the practical implications of the Part Recognition Tool within the automotive industry. The integration of this tool into the eAxle development process is projected to significantly enhance the efficiency and accuracy of part analysis, which could lead to faster design iterations, reduced costs, and improved overall vehicle performance. The potential industry impact of such a tool underscores its value, not only as an academic endeavor but also as a significant technological advancement.

Based on the results presented in the thesis, several enhancements could be made to further improve the performance and accuracy of the Part Recognition Tool for eAxles. Firstly, increasing the diversity and volume of the training dataset could be beneficial. A more comprehensive dataset, including a wider variety of eAxle images from different models and under varying conditions, would likely enhance the model's ability to generalize and perform accurately in real-world scenarios. Secondly, experimenting with different levels of data augmentation could help determine the optimal balance that maximizes model robustness without introducing excessive noise. Exploring advanced augmentation techniques such as geometric transformations and synthetic data generation might provide further gains in model resilience. Additionally, adjusting the hyperparameters, such as learning rate and batch size, through a systematic grid search or automated hyperparameter optimization techniques could fine-tune the model's performance. Finally, integrating ensemble techniques, where multiple models or variations of the model are used to make collective decisions, could also enhance prediction accuracy and reliability, effectively leveraging the strengths of different model architectures and training strategies. These enhancements, supported by rigorous testing and validation, would likely lead to significant improvements in the tool's functionality and efficacy.

The Part Recognition Tool developed here promises greater accuracy and efficiency, highlighting the potential of AI to transform engineering analytical processes. The findings encourage ongoing refinement and application, aiming to meet the evolving technical demands of the automotive industry and ensure that these innovations lead to practical, scalable solutions.