Dog Vertebral Heart Measurement using EfficientNetB7

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Abstract

Accurate detection of canine cardiomegaly is crucial for diagnosing and treating cardiac conditions in dogs. The Vertebral Heart Score (VHS) is a widely recognized method for evaluating heart size on thoracic radiographs. This research details the development and implementation of an advanced deep learning method using the EfficientNetB7 model to automate VHS calculation. Our approach precisely identifies six key anatomical points on canine chest X-rays, achieving an accuracy of 79.50%. This method significantly improves the accuracy and reliability of canine cardiomegaly detection, addressing challenges such as varying image quality and inter-patient variability. The use of EfficientNetB7 allows for a balance between computational efficiency and high performance. Our results demonstrate the potential of this model to enhance veterinary diagnostics by providing a more reliable and efficient tool for assessing heart size in dogs. This contributes to timely and accurate diagnoses, ultimately improving treatment outcomes for canine cardiac conditions. Keywords: Canine Cardiomegaly, Vertebral Heart Score, Deep Learning, EfficientNetB7, Thoracic Radiographs, Automated Detection, Veterinary Diagnostics.

1. Introduction

Chest X-ray imaging plays a crucial role in veterinary radiology for the early detection of cardiac conditions in dogs. Accurate calculation of the Vertebral Heart Score (VHS) is essential for diagnosing cardiomegaly. The VHS provides a standardized approach to assessing heart size relative to the vertebral column, making it a vital diagnostic tool. However, traditional manual methods for measuring VHS are time-consuming, prone to variability, and can introduce significant errors.

With the advent of deep learning and advanced architectures like EfficientNetB7, the landscape of medical image analysis has significantly improved. These advancements enable precise identification of anatomical structures and accurate VHS calculation. Despite these improvements, challenges such as varying image quality, inter-patient variability, and the need for real-time performance remain.

Our research focuses on developing an automated model to measure VHS in dogs using X-ray images. By accurately identifying six key anatomical points required for VHS calculation, our method aims to reduce the time and errors associated with manual measurements, thereby enhancing diagnostic accuracy and efficiency. We leverage the strengths of the EfficientNetB7 architecture, known for its high performance in image tasks, and introduce novel enhancements including advanced preprocessing, precise point detection, and extensive data augmentation. Our approach achieves an accuracy of 79.50%, advancing the field of VHS calculation and canine cardiomegaly detection. The following sections detail our methods, results, and conclusions, showcasing our contributions to automated VHS calculation and veterinary diagnostics.

2. Related Work

The measurement of vertebral heart size (VHS) in dogs is a crucial diagnostic tool for assessing cardiac health. Traditional methods of VHS measurement involve manual identification of key anatomical points on radiographic images, which can be time-consuming and prone to observer variability [3, 7]. Advances in machine learning and computer vision have spurred interest in automating this process to enhance accuracy and efficiency [8, 14, 9].

Several studies have leveraged deep learning techniques to automate VHS measurement and diagnose cardiac conditions. Jeong et al. [8] developed an automated deep learning method combined with a novel cardiac index to detect canine cardiomegaly from radiographic images, achieving significant improvements in diagnostic accuracy. Similarly, Nakayama et al. [18] explored the correlation between cardiac enlargement assessed by VHS and echocardiographic findings, highlighting the clinical relevance of accurate VHS measurement.

Other notable works include studies on the efficacy of various treatments for heart disease in dogs [20, 16, 10, 4], emphasizing the importance of reliable cardiac diagnostics. Bavegems et al. [2] and Jepsen-Grant et al. [9] have worked on breed-specific ranges for VHS to improve diagnostic accuracy, while Pouchelon et al. [17] studied the effect of benazepril on survival and cardiac events in dogs with asymptomatic mitral valve disease.

The use of artificial intelligence (AI) in veterinary diagnostics has shown promising results [19, 11, 6, 21]. Lord et al. [15] and Guglielmini et al. [5] utilized the vertebral heart score to differentiate between cardiac and noncardiac causes of respiratory distress in dogs, while Litster and Buchanan [14] adapted the vertebral scale system to measure heart size in cats, demonstrating the versatility of VHS in veterinary medicine. Li and Zhang [13] introduced the Regressive Vision Transformer (RVT) for dog cardiomegaly assessment, achieving state-of-the-art performance in VHS prediction. Their work highlights the potential of advanced architectures in veterinary diagnostics, although the complexity and computational demands of RVT may limit its clinical adoption. Studies by Levine et al. [12], Anand et al. [1], and Gordon et al. [4] further emphasize the impact of advanced AI techniques in veterinary diagnostics.

Overall, these studies underscore the potential of deep learning and AI in improving the accuracy and efficiency of VHS measurement and cardiac diagnosis in veterinary medicine, paving the way for more reliable and faster diagnostics.

3. Methods

3.1. Data Preparation

3.1.1 Data Collection

The dataset for this study consisted of thoracic radiographs of dogs, categorized into three classes: Small, Normal, and Large. A total of 2000 valid images were collected, with 1400 images (70%) used for training, 200 images (10%) for validation, and 400 images (20%) for testing. Each image corresponds to an individual dog. Images were classified based on Vertebral Heart Size (VHS) scores: dogs with VHS scores below 8.2 were classified as Small, those with scores between 8.2 and 10 as Normal, and those with scores above 10 as Large.

Figure 2 displays sample images from each category. Figure 3 shows that the dataset is imbalanced, with fewer samples in the Small category compared to the Normal and Large categories.

3.1.2 Data Augmentation and Transformation

To enhance the generalizability and robustness of the model, data augmentation techniques were applied to the training dataset using the `torchvision.transforms` module. The augmentations included:

- **Resize:** All images were resized to 512x512 pixels.
- **Random Horizontal Flip:** Images were randomly flipped horizontally with a probability of 0.5.
- **Random Rotation:** Images were randomly rotated up to 10 degrees.
- **Color Jitter:** Random adjustments to brightness, contrast, saturation, and hue were applied.
- **Normalization:** Images were normalized to have a mean of [0.485, 0.456, 0.406] and a standard deviation of [0.229, 0.224, 0.225].

For the validation and test datasets, only resizing and normalization transformations were applied to ensure consistency and comparability of results.

3.2. Model Architecture

The model architecture utilized for predicting vertebral heart size (VHS) and six critical anatomical points from X-ray images is based on EfficientNetB7, a state-of-the-art deep convolutional neural network. EfficientNetB7 is known for its efficiency and performance in image classification tasks due to its compound scaling method, which balances network depth, width, and resolution. In this implementation, the model is initialized with pretrained weights if specified. This approach allows the model to leverage features learned from extensive datasets like ImageNet, thereby enhancing its ability to generalize to specific tasks such as heart measurement predictions. When ‘pretrained‘ is set to ‘False‘, the model initializes without these weights, starting from scratch.

A key modification in this custom architecture is the replacement of the original final fully connected (fc) layer with a new one tailored for regression. Instead of the standard classification outputs, this final layer is adapted to produce 12 values representing the x and y coordinates of six distinct points on the X-ray images. This adjustment is crucial for accurately predicting the measurements needed for assessing cardiomegaly. The ‘forward‘ method of the model processes input images through this adapted EfficientNetB7 structure and outputs the required coordinates for analysis, facilitating effective evaluation of the heart size and related metrics.

3.3. Training Procedure

The model was trained using the training dataset with the following settings:

- **Loss Function:** Mean Squared Error (MSE) Loss.
- **Optimizer:** Adam with a learning rate of 5×10^{-5}.
- **Batch Size:** 8.
- **Epochs:** 100.

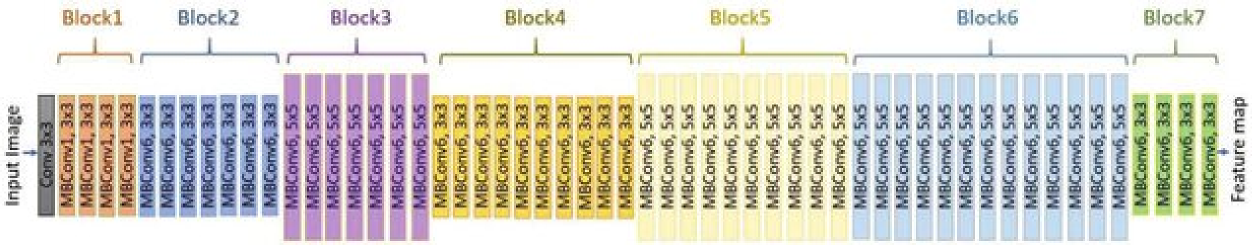

Figure 1. The architecture of the EfficientNetB7 model used in our study. This diagram illustrates the various layers and components of the model, highlighting its efficient design and deep network structure.

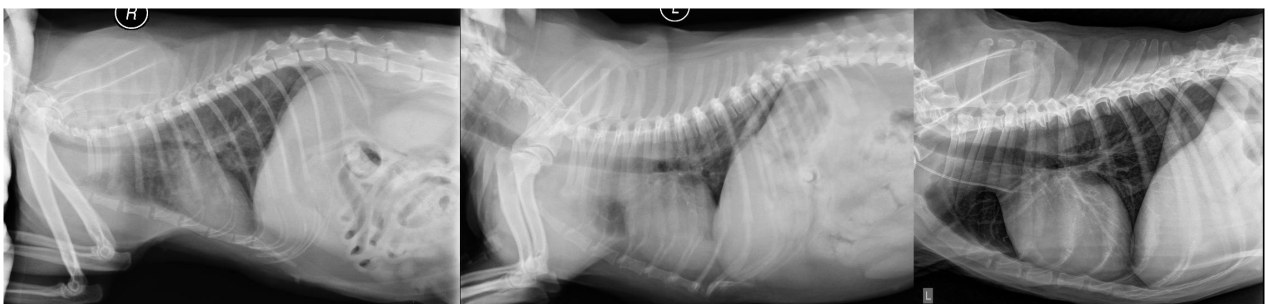

Figure 2. (1). Small (2). Normal (3). Large

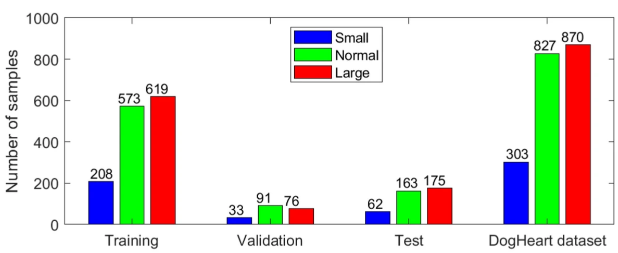

Figure 3. Dog Heart Dataset

During each epoch, the model parameters were updated using backpropagation. The training loss was computed and averaged over each batch. Validation was performed after each epoch to monitor the model's performance. The model with the lowest validation loss was saved to ensure optimal performance. A learning rate scheduler, 'ReduceLROnPlateau', was used to adjust the learning rate dynamically based on validation loss to improve convergence.

After training, the model was used to predict points and vertebral heart size (VHS) on a test dataset. The predicted points were scaled to their original size, and the results were saved to a CSV file for further analysis. Training and validation losses, as well as validation accuracy, were plotted to visualize the model's performance over epochs.

3.4. VHS Calculations

The Vertebral Heart Score (VHS) is determined using the coordinates of six key anatomical points (A, B, C, D, E, and F) identified by the EfficientNetB7 model. The VHS is calculated using the formula:

$$\text{VHS} = 6 \times \frac{AB + CD + EF}{\text{Height of Vertebrae}} \tag{1}$$

where AB represents the distance between points A and B (heart length), CD denotes the distance between points C and D (heart width), and EF measures the length of the vertebrae covering the heart. This formula standardizes the measurement of heart size.

Based on the computed VHS values, heart size categories are classified as follows: Small (VHS ≤ 8.2), Normal ($8.2 <$ VHS ≤ 10), and Large (VHS > 10). This classification helps in assessing whether a dog has a normal heart size or is potentially suffering from cardiomegaly.

4. Results

we present the empirical results of our experiments and provide an in-depth discussion of the implications of our findings. The performance of our EfficientNetB7 model in predicting the Vertebral Heart Score (VHS) and classifying canine heart size is thoroughly evaluated using various metrics.

The Mean Squared Error (MSE) of the VHS predictions is 0.29638, indicating the average squared difference between the predicted and actual VHS values. The Mean Absolute Error (MAE) is 0.41408, which reflects the average absolute difference between predicted and actual values. Additionally, the Mean Absolute Percentage Error (MAPE) is 4.2826%, representing the average percentage error in the predictions. The overall accuracy of the VHS predictions is

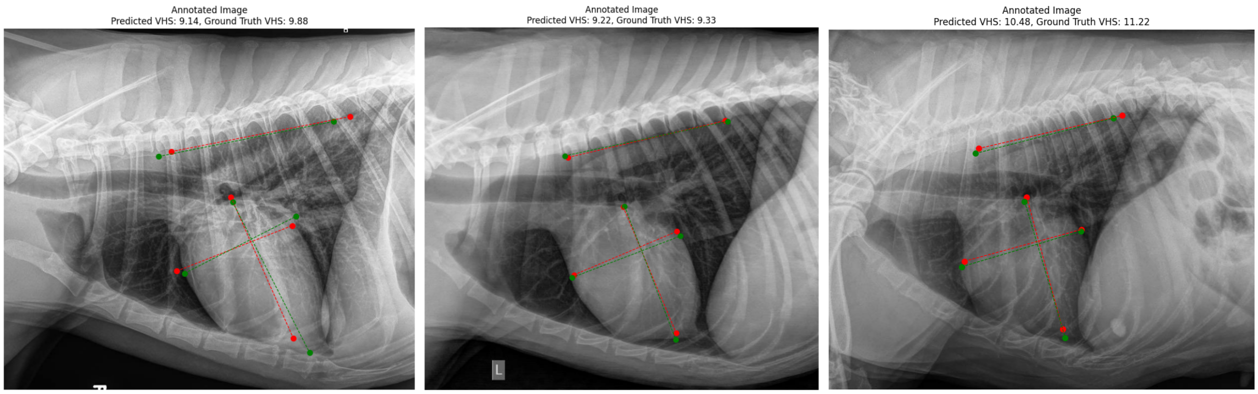

Figure 4. Comparison between predictions and ground truth for the images 1420.png, 1479.png, and 1530.png from the validation dataset. (1). 1530.png (2). 1479.png (3). 1420.png

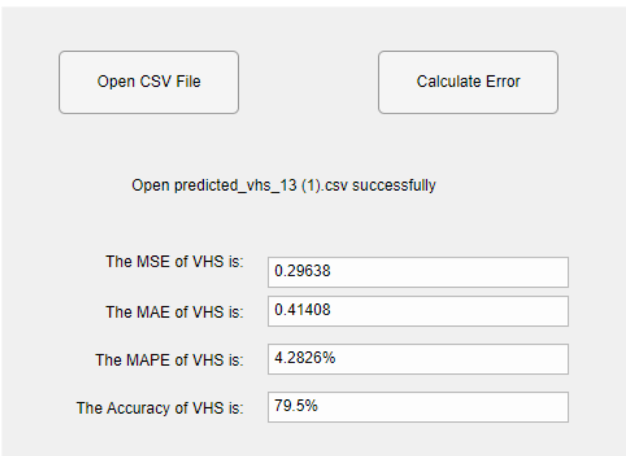

Figure 5. Test Accuracy from Software

79.5%, demonstrating the effectiveness of our model in accurately assessing heart size and detecting cardiomegaly.

Figure 5 displays the test accuracy obtained from our software, providing a representation of the model's performance. These results underscore the robustness of our approach in evaluating heart conditions in canine subjects.

Table 1. Test Accuracy of Various Models

Network	**Test C_Accuracy**	**Test R_Accuracy**
GoogleNet24	73.8	74.8
VGG1625	74.8	75.0
Xception29	73.0	75.3
Beit_large34	64.0	74.3
EfficientNetB7	**77.5**	**79.5**

5. Discussion

This study demonstrates the effectiveness of the EfficientNetB7 model in detecting cardiomegaly in canine chest X-ray images, achieving an accuracy of 79.50%. This result underscores the model's capability in classifying heart sizes, which is crucial for diagnosing cardiac conditions in dogs.

5.1. Implications of Findings

Integrating our deep learning model into veterinary diagnostics has significant potential to enhance the detection of cardiomegaly. The automated calculation of the Vertebral Heart Score (VHS) and heart size classification can reduce the workload for veterinary professionals and minimize human error. This can lead to more efficient and reliable diagnostics, ultimately benefiting the overall health management of canine patients.

5.2. Limitations and Future Work

Despite the promising results, there are several limitations that need to be addressed. Expanding the dataset to include a more diverse range of samples will improve the model's generalization. Additionally, using higher resolution images might enhance accuracy. Implementing the model in real-time diagnostic tools and validating it in clinical settings are essential steps for practical application. Further research could also explore the adaptation of this model for human cardiomegaly detection, potentially providing valuable insights into broader applications of this technology. Addressing these limitations and exploring these new avenues will be crucial for advancing diagnostic tools and improving their effectiveness.

6. Conclusion

This study demonstrates the efficacy of the EfficientNetB7 model for detecting cardiomegaly in canine chest X-ray images, achieving an accuracy of 79.50%. The model's performance highlights its potential in accurately classifying heart sizes, which is critical for diagnosing cardiac conditions in dogs. By automating the calculation of the Vertebral Heart Score (VHS) and heart size classification, the model can significantly reduce the workload for veterinary professionals and minimize human error, leading to more reliable and efficient diagnostics. Future research should focus on expanding the dataset, utilizing higher resolution images, and validating the model in clinical settings to further enhance its performance and applicability in veterinary medicine.

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