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Identification of Heart Sounds for the Analysis of Cardiac Pathology Using Machine Learning

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Cardiovascular diseases (CVDs), including chronic heart failure (CHF), represent a major global health challenge. Early detection is essential but often limited by data scarcity. This paper explores two key contributions to address this issue: detection of CHF decompensation using phonocardiogram (PCG) recordings and machine learning, and PCGmix, a novel data-augmentation technique tailored to heart sounds. In a study with 37 CHF patients, our models classified decompensated vs. recompensated states with up to 72% accuracy. PCGmix further improves diagnostic performance in scenarios with limited training data, achieving comparable accuracy to models trained on datasets up to 50% larger without augmentation.

Povzetek: Študija preuči zaznavanje dekompenzacije kroničnega srčnega popuščanja iz PCG posnetkov z ML ter predstavi PCGmix kot augmentacijo srčnih zvokov, ki izboljša učenje pri omejenih podatkih.

1 Introduction

Cardiovascular diseases (CVDs) remain the leading cause of mortality worldwide, with chronic heart failure (CHF) representing a major contributor [1, 2]. As incidence rates rise, there is a growing need for early, accurate diagnosis to reduce hospitalizations and improve outcomes. Advances in artificial intelligence (AI), particularly deep learning (DL), have enabled automated analysis of phonocardiogram (PCG) recordings. However, the effectiveness of such models depends heavily on access to large, labeled datasets, which remains an ongoing challenge in clinical practice.

This study addresses two key limitations of current research: detecting heart failure decompensation accurately from PCGs, and overcoming data scarcity through a heart-sound-specific augmentation method. We demonstrate that PCGs contain predictive signals of decompensation and introduce a novel augmentation technique, PCGmix, to support learning in data-scarce scenarios.

2 Chronic heart failure decompensation detection

The decompensated phase in CHF represents acute worsening of symptoms often requiring hospitalization, while recompensation marks clinical stabilization. Detecting this transition from PCG data could aid timely interventions.

Using a dataset of 37 CHF patients with recordings from both phases, we applied a combination of machine learning techniques to classify the two states. Features were extracted primarily from diastole, in both time and frequency domains. Our best-performing model achieved a classification accuracy of 72%. Cardiologists, who were given a subset of our data for classification based solely on sound, achieved an average accuracy of 50%. This result highlights the potential of automated PCG analysis in clinical decision support for CHF monitoring. Study details can be found in [3].

3 Heart sound data augmentation

To address data scarcity, we developed PCGmix, a heart-sound-specific data-augmentation method. Unlike generic approaches, which use single-instance transforms to generate a new instance, PCGmix generates synthetic PCG recordings by interpolating between two real instances to create a new one while preserving diagnostically relevant features. In this way, it also differs from existing data-augmentation methods, which are general and not specialised for heart sounds.

Empirical assessments using a publicly available database of 851 normal and abnormal heart-sound recordings [4] demonstrated that PCGmix outperforms state-of-the-art augmentation techniques when data availability is limited. The results for one of the DL models is shown in Figure 1. The black line represents the no-augmentation baseline. Our method is shown in orange and brown. ADSI indicates how much larger the original dataset would need to be for the no-augmentation approach to reach the same level of performance as the augmentation method.

At 10, 30, 56, 112, and 168 PCG recordings, our method

achieves the same performance as the no-augmentation approach trained on datasets 1.35–1.46, 1.34–1.69, 1.46–1.69, 1.08–2.25, and 1.01–1.65 times larger, respectively. Study details, including results from other DL models, can be found in [5, 6].

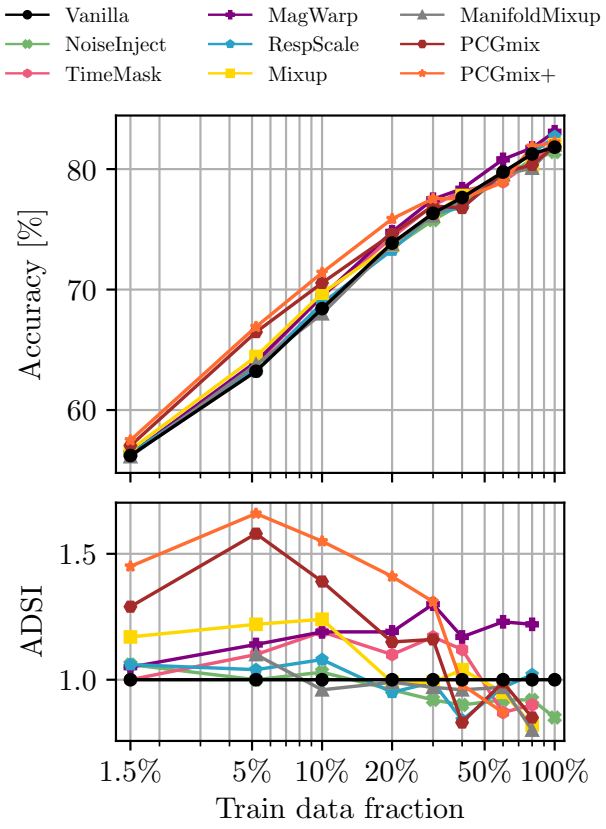

Figure 1: (top) Accuracy and (bottom) ADSI vs. training-data fraction in spectrogram domain experiments using a ResNet DL model. 100% training-data represents 554 PCGs. The x-axis scale is logarithmic.

4 Conclusion

Our work contributes to the knowledge at the intersection of AI and medicine, offering novel insights and methodologies to advance cardiovascular health monitoring and diagnosis. It demonstrates the performance achievable in detecting CHF decompensation using PCGs alone, and introduces and thoroughly validates PCGmix, a novel heart-sound-specific data-augmentation method.

References

[1] Martin, S. S., Aday, A. W., Almarzooq, Z. I., Anderson, et al. (2024) 2024 Heart Disease and stroke statistics: A report of US and global data from the American Heart Association, *Circulation*, 149(8), e347–e913. doi: 10.1161/CIR.0000000000001209.

[2] McDonagh, T. A., Metra, M., Adamo, M., et al. (2021) 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure, *European Heart Journal*, 42(36), 3599–3726. doi: 10.1093/eurheartj/ehab368.

[3] Susič, D., Poglajen, G., and Gradišek, A. (2022) Identification of decompensation episodes in chronic heart failure patients based solely on heart sounds, *Frontiers in Cardiovascular Medicine*, 9, 1009821. doi: 10.3389/fcvm.2022.1009821.

[4] Liu, C., Springer, D., Li, Q., et al. (2016) An open access database for the evaluation of heart sound algorithms, *Physiological Measurement*, 37(12), 2181–2213. doi: 10.1088/0967-3334/37/12/2181.

[5] Susič, D., Gradišek, A., and Gams, M. (2024). PCGmix: A data-augmentation method for heart-sound classification, *IEEE Journal of Biomedical and Health Informatics*, 28(11), 6874–6885. doi:10.1109/JBHI.2024.3458430

[6] Susič, D.(2024). Identification of heart sounds for the analysis of cardiac pathology using machine learning [Doctoral dissertation, Jožef Stefan International Postgraduate School]