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Tool for detecting deepfakes based on biological factors

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Abstract

Our bachelor's thesis focuses on video deepfake detection using physiological patterns, specifically on breathing signals extracted from photoplethysmographic (PPG) data. Two main detection approaches were proposed: a sequence-based approach that models breathing signals over time using recurrent neural networks such as long short-term memory (LSTM) or gated recurrent unit (GRU), and an image-based approach that analyzes the consistency of breathing signals across different facial regions using PPG maps and convolutional neural networks (CNN). The evaluation was provided on the FaceForensics++ [1] and Celeb-DF [2] datasets. The results show that the method based on breathing patterns does not achieve the expected level of accuracy. Better results were achieved when filtering was not applied, which may indicate a lack of information in the filtered signal. Nevertheless, the thesis made a contribution to the study of physiological signals and highlighted potential directions for further research.

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1. Introduction

The advancement of deepfake generation technologies makes it increasingly difficult to detect synthetic content using traditional methods. Models like Sora from OpenAI [3] demonstrate how realistic such generated videos can become. This raises serious concerns about misinformation, identity fraud, and public trust, making developing more reliable detection methods crucial.

A robust detection system must rely on signals that are hard to replicate artificially and remain consistent across videos. One of the proposals for this problem is using biological signals.

Previous studies have explored deepfake detection using biological signals such as heart rate via photoplethysmography (PPG), eye blinking patterns, gaze tracking, and subtle head motion. However, further progress is essential both in developing new methods and gaining a deeper understanding of the limitations and challenges in this area.

Our thesis proposes a novel approach for detecting deepfakes by analyzing respiratory patterns extracted from facial regions in video. The method is primarily based on PPG signals, which are widely used in medicine and already serve as the core for some detection techniques. This method introduces an additional layer of signal analyzing that is subtle, difficult to fake, and biologically grounded.

The work contributes by exploring the use of PPG and biological signals for deepfake detection and identifying their strengths and weaknesses. Although the proposed method based on breathing patterns did not yield high accuracy, this result and its discussion are key findings. The thesis focuses on analyzing the reasons for the limited effectiveness of the method, providing a detailed discussion of its weaknesses and future directions.

2. Method overview

The detection process is based on the assumption that a deepfake video will either not contain any breathing patterns or that such patterns will not correspond to those of a real person, as simulating them is difficult due to the complexity and subtlety of physiological processes. The overall architecture of the proposed method is illustrated in Figure 1. The PPG signal is extracted from the facial region in the video and subsequently filtered to isolate the breathing component. The thesis proposes two main approaches for detection: a sequence-based approach, in which breathing signals are modeled over time using recurrent neural networks such as long short-term memory (LSTM) or gated recurrent unit (GRU), and an image-based approach, which analyzes the consistency of breathing signals across different facial regions using PPG maps and convolutional neural networks (CNNs), which is based on the FakeCatcher papers [4].

3. Evaluation and limitations

The proposed approaches were evaluated using widely known datasets such as FaceForensics++ and Celeb-DF. The results in Table 1 show that the detection method based on breathing signals did not reach the expected level of accuracy. The main limitations include the low frequency of breathing patterns, the generation of false (hallucinated) signals caused by supervised PPG extraction methods, as shown in Figure 4, and the high sensitivity of breathing signal estimation to video noise and quality. Although the proposed approaches are unreliable enough for practical deepfake detection, during testing with various configurations, the image-based approach showed good results without signal filtering, as shown in Table 3, which may indicate a lack of information in the filtered signal.

4. Future directions

Based on the conducted analysis and experimental results, several promising directions for future research in deepfake detection using biological signals can be identified:

1. **Frequency-domain analysis**: It can be suggested that removing the breathing-frequency filtering step led to improved model performance. This means that valuable information may exist in the higher-frequency components of the signal. Future research could explore spectral characteristics and leverage frequency-domain approaches for deepfake detection. A notable difference can be observed in Figure 5, which compares the power spectral density of a real video and a deepfake video.
2. **Use of advanced architectures**: One of the possible directions in frequency-domain analysis could involve using techniques such as graph attention networks (GAT), which have been successfully applied to detect speech-based deepfakes [5] and could potentially be adapted to analyze PPG signal spectrums. These architectures may more effectively capture temporal-spatial patterns and subtle physiological inconsistencies.
3. **Improvement of PPG signal extraction**: The sensitivity of the models to noise and video quality, along with the hallucination effects observed in existing supervised methods, highlights the limitations of current PPG extraction techniques. Future work could focus on enhancing the preprocessing pipeline using adaptive filtering that preserves useful information in the signal or developing a more effective method for extracting the PPG signal.
4. **Fusion of multiple biological indicators**: While the thesis focused specifically on physiological signals, other studies have shown promising results using heart rate, eye blinking, or facial micro-movements. Combining multiple physiological factors may increase the robustness and reliability of detection.

5. Conclusions

Our thesis explored physiological signals, specifically breathing patterns extracted from PPG data, for detecting deepfake videos. Two detection strategies were proposed: a sequence-based model using LSTM or GRU networks and an image-based model using PPG maps and CNNs. While the breathing patterns methods did not achieve the expected accuracy, the work provided valuable analysis of the limitations of such approaches, including signal quality, noise sensitivity, and generalization challenges. Despite the weak accuracy of the methods, it can be concluded that physiological signals are a promising direction for deepfake detection, with further improvements such as frequency domain analysis and more advanced architectures.

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