

SoloAudio: Target Sound Extraction with Language-oriented Audio Diffusion Transformer

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Abstract—In this paper, we introduce SoloAudio, a novel diffusion-based generative model for target sound extraction (TSE). Our approach trains latent diffusion models on audio, replacing the previous U-Net backbone with a skip-connected Transformer that operates on latent features. SoloAudio supports both audio-oriented and language-oriented TSE by utilizing a CLAP model as the feature extractor for target sounds. Furthermore, SoloAudio leverages synthetic audio generated by state-of-the-art text-to-audio models for training, demonstrating strong generalization to out-of-domain data and unseen sound events. We evaluate this approach on the PSD Kaggle 2018 mixture dataset and real data from AudioSet, where SoloAudio achieves the state-of-the-art results on both in-domain and out-of-domain data, and exhibits impressive zero-shot and few-shot capabilities. Source code¹ and demos² are released.

Index Terms—target sound extraction, transformer, language-oriented, text-to-audio, zero-shot, few-shot.

I. INTRODUCTION

Human beings possess the remarkable ability to focus on a specific sound within a complex acoustic scene composed of various overlapping sound events [1]. Recent works that aim to replicate this human capability computationally have framed the task as target sound extraction (TSE) [1]–[4]. The objective of TSE is to extract sounds of interest from mixtures of overlapping audio, guided by clues that provide information about the target sound class. These clues can take the form of one-hot labels [2], [5], audio clips [6], or images [7], [8].

Most prior methods are based on discriminative models, which aim to minimize the difference between the estimated and target audio [3], [9]. While these models often produce good separation in non-overlapping regions, they tend to suffer significant performance degradation in overlapping areas. This is especially problematic in real-world scenarios where sound overlaps are common, making it a critical issue to address in TSE. With the advent of denoising diffusion probabilistic models (DDPMs) [10], [11], generative models have recently been applied successfully to TSE and source separation tasks [12]–[15]. DPM-TSE [13], a generative approach based on DDPM, achieves both cleaner target renderings and improved separability from unwanted sounds compared to discriminative models. However, DPM-TSE operates on log-mel spectrograms, where the diffusion process is applied, inherently limiting the reconstruction quality. Additionally, DPM-TSE relies solely on in-domain one-hot labels, which restricts its ability to generalize to out-of-domain data and unseen sound events.

Another challenge in the TSE task is the scarcity of training data, particularly clean, single-label audio, which is often used as the ground truth for target sounds. AudioSep [16] trains open-domain audio source separation models using natural language queries, with mixtures of large-scale multi-label audios. However, it struggles to

produce clean sound isolations for a single target sound, which is critical for real-world applications.

To address these issues, we propose SoloAudio, an audio- and/or language-oriented diffusion Transformer model for TSE. Our main contributions are summarized as follows:

- (i) We introduce a novel Transformer backbone with skip connections, applying the diffusion process in the latent space of an audio variational autoencoder (VAE). SoloAudio supports both audio clues and text clues, by utilizing a CLAP model [17].
- (ii) We leverage synthetic audio from a text-to-audio (T2A) generation model [18] as additional training data. Thanks to advancements in T2A, we can generate high-quality, clean audio to improve the training of TSE models.
- (iii) Experimental results on mixtures from the PSD Kaggle 2018 dataset [19] demonstrate that SoloAudio significantly outperforms state-of-the-art methods. Moreover, SoloAudio exhibits strong zero-shot and few-shot capabilities on out-of-domain data and unseen sound events.
- (iv) Subjective evaluations on real-world data consistently demonstrate a clear preference among listeners for the audio extracted by SoloAudio, highlighting its superior ability to isolate target sounds while effectively eliminating irrelevant noise.

II. METHODOLOGY

A. Denoising Diffusion Probabilistic Model (DDPM)

DDPMs consist of a forward and backward process. The forward process incrementally adds Gaussian noise to the data, following a variance schedule β_1, \dots, β_T :

$$q(x_t | x_{t-1}) := \mathcal{N}(x_t; \sqrt{1 - \beta_t}x_{t-1}, \beta_t \mathbf{I}) \quad (1)$$

The forward process enables sampling x_t at any timestep t in a closed form (x_0 is the clean signal):

$$x_t = \sqrt{\alpha_t}x_0 + \sqrt{1 - \alpha_t}\epsilon, \quad (2)$$

where $\alpha_t = 1 - \beta_t$, $\bar{\alpha}_t := \prod_{s=1}^t \alpha_s$, and $\epsilon \sim \mathcal{N}(0, \mathbf{I})$.

Following [13], we use a modified diffusion scheduler and v prediction to improve the purity and overall performance of sound extraction. Additionally, we implement a diffusion noise schedule by keeping $\sqrt{\bar{\alpha}_t}$ unchanged, changing $\sqrt{\bar{\alpha}_T}$ to zero, and linearly rescaling $\sqrt{\bar{\alpha}_t}$ for intermediate $t \in [2, \dots, T-1]$ respectively. This adjustment resolves the mismatch between training and inference and prevents the introduction of additional noise during sampling. A neural network is applied to predict velocity v_t :

$$v_t = \sqrt{\bar{\alpha}_t}\epsilon - \sqrt{1 - \bar{\alpha}_t}x_0, \quad (3)$$

In the reverse process of diffusion models, the model gradually reconstructs the original data from a random Gaussian noise.

$$p_\theta(x_{t-1} | x_t) := \mathcal{N}(x_{t-1}; \hat{\mu}_t, \hat{\beta}_t \mathbf{I}), \quad (4)$$

[†] Indicates equal contribution.

¹<https://github.com/WangHelin1997/SoloAudio>

²<https://wanghelin1997.github.io/SoloAudio-Demo>

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