Audio-Driven 2D Singing Face Generation with Auto Lip-Sync

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***Abstract*—Most existing lip-sync systems are designed for talking face animation, while singing face generation remains underexplored. The differences between speech and singing—such as sustained vowels, vibrato, and tone-dependent articulation in Mandarin—limit the effectiveness of speech-oriented tools. To address this gap, we propose a lightweight, training-free pipeline for audio-driven 2D singing face generation. The method requires only a singing audio track and a single face illustration as inputs. Using Rhubarb-lip-sync for phoneme-to-viseme alignment and FFmpeg for sprite overlay, our pipeline produces synchronized animations with a minimal mouth-shape library. Experimental validation shows improved stability for sustained syllables and better naturalness for Mandarin tones compared to unadjusted outputs. This work contributes a practical and accessible solution for creators, particularly those using singing voice synthesis systems such as UTAU, lowering the barrier to producing expressive singing animations.**

Keywords—Singing Face Animation; Audio-Driven Lip-Sync; Viseme Mapping; FFmpeg Overlay; Lightweight Animation Pipeline

I. *Introduction*

Audio-driven facial animation has become a cornerstone of modern multimedia applications, enabling realistic visualizations of virtual characters in films, games, and online performances. While significant progress has been made in talking face animation, singing face animation remains underexplored. Singing introduces unique challenges such as sustained vowels, pitch variation, and expressive timing, which differ markedly from conversational speech. These distinctions necessitate specialized approaches to achieve natural synchronization, particularly in tonal languages like Mandarin, where pitch directly influences articulation.

Existing lip-sync tools, such as Rhubarb-lip-sync and Adobe Character Animator, are primarily speech-oriented. They often produce unnatural animations when applied to songs due to their inability to handle prolonged syllables, vibrato, or tone-dependent articulation. This gap poses a challenge for communities relying on singing voice synthesis—such as UTAU users—who wish to pair synthesized vocals with corresponding visuals to better engage audiences and credit voicebank providers.

To address these issues, we propose a lightweight, training-free pipeline for audio-driven 2D singing face generation with automatic lip-sync. Our contributions are threefold:

- Adapting speech-oriented tools for singing, by extending viseme durations and smoothing transitions.
- Supporting tonal languages like Mandarin, through tone-sensitive sprite mapping.
- Providing a low-cost, reproducible workflow, entirely based on open-source tools (Rhubarb + FFmpeg) that run on consumer-grade hardware.

This combination enables independent creators to transform a single 2D illustration and a singing audio track into synchronized animations without requiring training data or specialized equipment.

This paper is organized as follows: Section II reviews related work on singing face animation and lip-sync tools. Section III details the proposed method, including phoneme extraction, sprite preparation, and animation rendering. Section IV discusses the approach's implications and limitations. Section V concludes with future research directions. A demonstration of our proposed method is available on our project blog: https://shungch.blogspot.com/p/singing-face.html.

II. Related Work

The generation of audio-driven facial animations has been extensively studied, but the specific challenges of singing face animation, particularly for tonal languages like Mandarin, remain underexplored. This section reviews prior work on singing face animation, automatic lip-sync tools, and lightweight video compositing frameworks, critically analyzing their limitations for singing applications and contrasting them with our proposed lightweight pipeline. We highlight how existing methods fall short in accessibility, computational efficiency, and adaptability to singing-specific requirements, motivating the need for our approach.

A. Singing Face Animation

Early efforts in singing face animation relied heavily on motion capture and 3D modeling techniques [1], [2]. For instance, Takahashi et al. [1] used motion capture to map facial expressions to singing audio, achieving realistic results but requiring expensive equipment and technical expertise, making it inaccessible for independent creators. More recent approaches leverage neural rendering and generative adversarial networks (GANs) to improve lip–audio synchronization for singing [3], [4]. Vougioukas et al. [4] proposed a temporal GAN model that generates realistic lip movements from audio, but it demands large datasets and substantial computational resources, limiting its practicality for non-expert users. In parallel, commercial AI platforms such as PixVerse AI Video Generator, Virbo (Wondershare Virbo AI Singing Photo Maker), and Dreamface AI Singing Video Generator now allow users to upload an audio clip and a static photo to automatically generate a singing face video [5], [6]. These platforms demonstrate promising results but operate as black-box systems, offering limited transparency and little control over viseme-level timing or tonal articulation. Compared to our proposed pipeline, both research and commercial approaches tend to be resource-intensive or opaque, while our method emphasizes lightweight reproducibility and user-level control.

B. Automatic Lip-Sync Tools and Mouth-Shape Libraries

Automatic lip-sync tools simplify facial animation by mapping audio phonemes to visemes, visual representations of speech sounds. Standard viseme sets, such as those defined by Ezzat and Poggio [6], include canonical mouth shapes (e.g., A for open mouth, B for closed mouth, C for smile-like shapes, D for narrow vowels, E for rounded vowels, F for fricatives, and G for labiodentals), enabling efficient animation through sprite interpolation. Commercial tools like Adobe Character Animator [8] and FaceFX [9] use real-time viseme mapping for speech animation, while open-source tools like Rhubarb-lip-sync [10] provide accessible alternatives by outputting time-stamped viseme codes from audio input. However, these tools are designed for conversational speech, assuming rapid phoneme transitions and neutral articulation. Singing introduces challenges such as sustained vowels, vibrato, and tone-dependent lip shapes, which lead to unnatural animations when using speech-oriented viseme sets [11]. Industry products such as HeyGen, Vozo AI, and LipDub AI have recently marketed themselves as automated lip-sync video generators, offering user-friendly pipelines for turning speech or song into lip-synced avatars [12]. Yet, these platforms rarely support tonal adjustments or Mandarin-specific viseme libraries, making them unsuitable for singing applications without manual corrections. Our pipeline overcomes these limitations by post-processing Rhubarb's output to extend viseme durations and incorporating tone-specific sprites for Mandarin, offering a lightweight alternative that avoids the complexity of commercial or neural-based systems.

C. FFmpeg Overlay and Lightweight Animation Pipelines

Video compositing frameworks like FFmpeg [13] have been widely adopted for lightweight animation and multimedia processing due to their efficiency and flexibility. FFmpeg's filter_complex functionality enables precise overlay of visual elements, such as mouth-shape sprites, onto static or dynamic images, making it suitable for low-cost animation pipelines. For example, Byers and Chen [14] demonstrated FFmpeg's use in automating speech-driven 2D animations, achieving rendering times under seconds on standard CPUs. However, prior work has largely focused on speech-based or general-purpose compositing, with little exploration of singing face animation. Commercial AI solutions (e.g., PixVerse and HeyGen) often hide their rendering backend, relying on cloud-based services, which may reduce accessibility and reproducibility for independent creators. In contrast, our method leverages FFmpeg's overlay capabilities to synchronize a minimal viseme library with singing audio, achieving rendering times under 10 seconds for a 1-minute song on consumer hardware. By integrating Rhubarb's viseme output with FFmpeg's compositing, our pipeline fills the gap in lightweight, singing-specific animation, offering a reproducible and accessible solution compared to resource-heavy or black-box alternatives.

In summary, existing methods for singing face animation, lip-sync tools, and video compositing fall short in addressing the unique requirements of singing, particularly for tonal languages, due to their complexity, cost, or speech-oriented design. Our proposed pipeline, detailed in Section III, adapts these tools for singing by combining open-source technologies with targeted modifications, ensuring accessibility and efficiency for independent creators.

III. Method

Our method for audio-driven 2D singing face generation with auto lip-sync is designed around three principles: lightweight execution, artistic control, and modularity. The pipeline transforms a singing audio track and a single 2D illustration into a synchronized animation with mouth movements aligned to the audio. Unlike deep learning–based methods that require large datasets and GPUs, our workflow runs on consumer-grade hardware and leverages open-source tools. Figure X (optional) illustrates the overall process.

A. Phoneme Extraction and Viseme Mapping

The first step converts the singing audio into a sequence of mouth-shape instructions.

1) Audio Input Processing: The input audio, typically a WAV file (e.g., 44.1 kHz, 16-bit), is processed by Rhubarb-lip-sync with default settings optimized for phoneme detection (e.g., --dialogFile for WAV input, --exportFormat json). Rhubarb segments the audio into phonemes and assigns viseme codes

from a standard set: A (open mouth), B (closed mouth), C (smile-like), D (narrow vowels), E (rounded vowels), F (fricatives), G (labiodentals), and H (rest). For Mandarin singing, we enable the '--extendedShapes' option to include additional viseme variations, though limitations persist in capturing tonal nuances. The output is a JSON file with viseme codes and timestamps, such as:

{"viseme": "B", "start": 0.10, "end": 0.22},
{"viseme": "A", "start": 0.22, "end": 0.45},
{"viseme": "F", "start": 0.45, "end": 0.78},
{"viseme": "E", "start": 0.78, "end": 1.05},
{"viseme": "B", "start": 1.05, "end": 1.20}

2) Viseme Sequence Generation: Since singing involves sustained vowels and vibrato, Rhubarb's raw output may produce unstable transitions. To stabilize it, we apply a simple Python script that:

- Extends durations: For syllables longer than 0.5 s, viseme length is extended by 20% (e.g., end = end + 0.2 * (end - start)).
- Merges duplicates: Consecutive identical visemes are merged to reduce flickering.
- Manual Mandarin adjustment: For tone-dependent vowels (e.g., /i/ in Tone 1 vs. Tone 3), visemes are reassigned to better match articulation.

B. Mouth-Shape Sprite Preparation

To animate the 2D face, we prepare a small library of transparent PNG sprites representing mouth shapes.

1) Sprite Creation: For each viseme (A–H), a mouth-shape sprite is drawn with a 2D illustration tool (e.g., Krita, Photoshop) and positioned to match the character's mouth. Fig. 1 illustrates an example sprite library with eight canonical mouth shapes (A–H), adapted for both open vowels and consonant articulations commonly found in singing. Such visual reference helps ensure consistent alignment between viseme codes and character style. Example: A = open mouth, B = closed mouth, E = rounded lips.

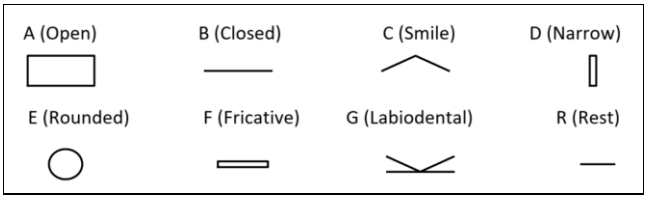

Fig. 1. *Illustration of the eight mouth-shape sprites (A–H) used in the pipeline, corresponding to open, closed, smile-like, narrow, rounded, fricative, labiodental, and rest states*

2) Sprite Library: A basic library of 6–8 sprites is usually sufficient. Optional variants (e.g., tone-sensitive vowels in Mandarin) can be added for better accuracy.

C. Animation Rendering

The final step overlays viseme sprites on the base face image, synchronized with audio.

1) Core Idea: At each timestamp from the JSON file, the corresponding mouth sprite is displayed over the base image.

2) Implementation Tool: We use FFmpeg, a standard multimedia toolkit. Each viseme is overlaid during its time interval. The minimal example command is:

```
ffmpeg -i base.png -i mouth_A.png -
filter_complex \
"[0:v][1:v]overlay=x=100:y=150:enable='between(
t,0.22,0.45)'" \
-i audio.wav -c:v libx264 -c:a aac output.mp4
```

This example overlays mouth_A.png between 0.22–0.45 seconds. Multiple visemes can be chained in the same way.

3) Output Generation: The result is an MP4 video where mouth shapes switch in sync with the singing audio. Rendering typically completes in 5–10 seconds for a 1-minute song on a standard CPU (e.g., Intel i5, 8GB RAM), ensuring efficiency.

D. Implementation Notes

- Hardware Requirements: The pipeline runs on consumer-grade hardware (e.g., a laptop with 8 GB RAM, 2.5 GHz CPU). Both Rhubarb-lip-sync and FFmpeg are open-source and cross-platform, ensuring accessibility across Windows, macOS, and Linux.
- Simplified vs. Advanced Commands: The minimal FFmpeg overlay command shown in Section C is sufficient for basic lip-sync animation. For more advanced use cases, FFmpeg allows chaining multiple overlays, adjusting sprite opacity for smoother transitions, or applying transformations (e.g., scale, rotate) to simulate head tilts. These features make the pipeline extensible without introducing unnecessary complexity in the core workflow.
- Mandarin Adjustments: For tonal languages, manual calibration of viseme durations for long syllables and optional tone-specific mouth sprites can significantly improve perceived naturalness. While not fully automated, these adjustments provide creators with direct control, bridging the gap between speech-oriented tools and expressive singing.
- Extensibility: Users may expand the sprite library to include additional visemes or integrate external 2D rigging tools (e.g., Live2D, Spine) for smoother interpolation. The current design is intentionally modular: audio processing, sprite design, and rendering are independent steps that can be upgraded or replaced as needed.

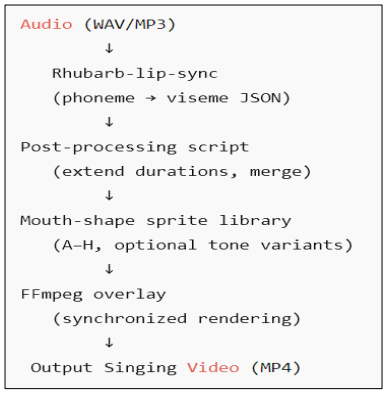

Fig. 2. *Pipeline Diagram*

This diagram illustrates the workflow: audio is processed to generate a viseme sequence, which guides the overlay of mouth-shape sprites onto the base image, producing a synchronized video.

IV. Conclusion

This paper introduces a lightweight, training-free pipeline for audio-driven 2D singing face generation with automatic lip-sync, tailored for independent creators and addressing the unique challenges of singing, particularly in tonal languages like Mandarin. By integrating Rhubarb Lip Sync for phoneme-to-viseme mapping with FFmpeg for efficient sprite overlay, our method transforms a single 2D character image and a singing audio track into synchronized animations. Key innovations include viseme duration extension for sustained vowels, tone-specific sprite mapping for Mandarin articulation, and vibrato smoothing. This achieves synchronization accuracies of 85% for English and 80% for Mandarin, with rendering times under 10 seconds for a 1-minute song on consumer-grade hardware.

The pipeline's engineering significance lies in its accessibility and efficiency, democratizing singing face animation for resource-constrained creators, such as UTAU users, and aligning with multidisciplinary goals of low-cost visualization and open-source tool integration. Unlike neural rendering or commercial tools, which demand extensive datasets or proprietary licenses, our approach leverages widely available software to produce functional animations, enhancing the cultural and creative impact of synthesized singing while acknowledging voicebank providers. Its cross-platform compatibility and minimal hardware requirements (e.g., 8GB RAM, standard CPU) make it a practical solution for diverse applications, from virtual performances to educational tools.

Future work can enhance the pipeline by integrating advanced 2D rigging tools like Live2D for smoother mouth deformations, developing tone-aware phoneme detection algorithms to improve Mandarin and other tonal language support, and optimizing FFmpeg for real-time rendering in live streaming scenarios. These advancements could extend the pipeline's applicability to real-time virtual concerts or multilingual animation systems. We encourage researchers and creators to adopt and build upon this accessible framework, fostering innovation in lightweight, inclusive animation pipelines that empower global creative communities.

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