MULTIMODAL TRANSFORMERS FOR EMOTION SYNTHESIS FROM VOICE, TEXT, AND FACIAL EXPRESSIONS

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Аннотация: Мультимодальные трансформеры представляют собой передовой подход в аффективных вычислениях, позволяющий синтезировать эмоции на основе интеграции голосовых, текстовых и мимических данных. В статье рассматриваются архитектуры, основанные на механизмах само-внимания и кросс-модального слияния, для генерации coherentных эмоциональных выходов, таких как модулированная просодия речи, эмоционально окрашенный текст и анимированные лицевые выражения. Обсуждаются ключевые вызовы, включая временную асинхронность, этические аспекты и интеграцию с физиологическими сигналами. Предлагаются инновационные модели, такие как Emotion2Vec и EMO-MemoryBank, демонстрирующие высокую точность синтеза сложных эмоциональных состояний. Исследование подчеркивает переход от простого переноса стиля к генерации эмпатического поведения, открывая перспективы для HCI, VR и ментального здоровья.

Ключевые слова: мультимодальные трансформеры, синтез эмоций, голосовой анализ, текстовые эмбеддинги, мимические выражения, кросс-модальное внимание, аффективные вычисления, эмоциональный TTS, лицевые анимации, этические аспекты ИИ

Abstract: Multimodal transformers represent a cutting-edge paradigm in affective computing, enabling the synthesis of emotions through the deep integration of voice, text, and facial expression modalities. This paper examines advanced architectures leveraging self-attention and cross-modal fusion mechanisms to generate highly coherent emotional outputs, including prosodically modulated speech, emotionally nuanced text, and dynamically animated facial expressions. Key challenges are discussed, such as temporal asynchrony across modalities, ethical implications of hyper-realistic emotional synthesis, and emerging integration with physiological signals. Innovative models such as Emotion2Vec and EMO-MemoryBank are presented, achieving unprecedented fidelity in synthesizing complex and mixed emotional states. The study highlights the ongoing transition from mere style transfer to the generation of genuinely empathetic behavior, paving the way for transformative applications in human-computer interaction, virtual and augmented reality, mental health support, and digital preservation of individual emotional identity.

Keywords: multimodal transformers, emotion synthesis, voice analysis, text embeddings, facial expressions, cross-modal attention, affective computing, emotional TTS, facial animation, AI ethics

Annotatsiya: Multimodalli transformerlar affektiv hisoblash sohasidagi eng ilg‘or yondashuv bo‘lib, ovoz, matn va yuz ifodasi modal’liklarining chuqur integratsiyasi orqali his-tuyg‘ularni sintez qilish imkonini beradi. Maqolada o‘zaro e’tibor (self-attention) va kross-modal birlashma mexanizmlariga asoslangan zamonaviy arxitekturalar ko‘rib chiqiladi, ular prosodik jihatdan modulyatsiya qilingan nutq, his-tuyg‘u bilan boyitilgan matn va dinamik animatsiyalangan yuz ifodalari kabi yuqori darajada izchil emotsional chiqishlarni yaratishga qodir. Modal’liklararo vaqt asinxronligi, giper-realistik emotsional sintezning axloqiy oqibatlari hamda fiziologik signallar bilan yangi integratsiya kabi asosiy qiy qiyinchiliklar muhokama qilinadi. Emotion2Vec va EMO-MemoryBank kabi innovatsion modellar taqdim etilib, murakkab va aralash his-tuyg‘u holatlarini sintez qilishda misli ko‘rilmagan aniqlikka erishgani ko‘rsatiladi. Tadqiqot oddiy uslub ko‘chirishdan haqiqiy empatik xatti-harakatlar generatsiyasiga o‘tish jarayonini ta’kidlab, inson-kompyuter o‘zaro ta’siri, virtual va kengaytirilgan reallik, ruhiy salomatlikni qo‘llab-quvvatlash hamda shaxsiy emotsional identifikatsiyani raqamli saqlash sohalarida inqilobiy imkoniyatlarini ochib beradi.**Kalit so‘zlar:** multimodalli transformerlar, his-tuyg‘ular sintezi, ovoz tahlili, matnli embeddinglar, yuz ifodalari, kross-modal e’tibor, affektiv hisoblash, emotsional TTS, yuz animatsiyasi, SI axloqi

Introduction

In the age of digitalization of human interaction, affective computing is becoming crucial, enabling machines not only to recognize but also to synthesize emotions to create more natural dialogue. Multimodal transformers, evolving from the original architecture of Vaswani et al. (2017), have become the foundation for integrating disparate modalities of voice, text, and facial expressions into a unified emotion synthesis system. Voice carries prosodic information (pitch, rhythm, intensity), text carries semantic context and valence, and facial expressions carry visual markers such as microexpressions and facial postures. Emotion synthesis involves the generation of coherent outputs: from emotionally modulated speech to animated avatars capable of conveying nuances such as sarcasm or hidden sadness.

Traditional approaches, such as HMM-based TTS or rule-based facial animation, suffered from a lack of deep integration, leading to unsynchronized or unnatural results. Multimodal transformers overcome this through self-attention and cross-attention, allowing for modeling intermodal dependencies in a shared latent space. For example, in emotional TTS tasks, models like WaveNet, conditioned on multimodal embeddings, achieve near-human-like naturalness. The topic's relevance is driven by the growth of applications: from empathetic chatbots in psychotherapy to VR environments where synthesized emotions enhance immersion.

The purpose of this article is to review and analyze modern multimodal transformers for emotion synthesis, focusing on architectures, datasets, metrics, and future directions. We draw on empirical data from studies conducted in 2023–2025 to demonstrate how these models evolve from recognition to generation, minimizing the "uncanny valley" and increasing emotional congruence.

Multimodal transformers for emotion synthesis have reached a level where simply concatenating modalities no longer satisfies the requirements of realism and expressiveness. Modern architectures are moving toward deep bidirectional cross-modal attention with dynamic information routing (dynamic gating and adaptive fusion), allowing the model to decide in real time which modality currently dominates in conveying a specific emotional

nuance. For example, when expressing sarcasm, the voice can carry up to 70% of the emotional load, while facial expressions merely emphasize intonation rises; the model must learn to suppress redundant visual cues and enhance acoustic ones.

One breakthrough approach is Emotion2Vec (2024–2025), a multimodal fundamental encoder trained on 1.2 million hours of labeled and weakly labeled audiovisual data with masked multimodal modeling. Emotion2Vec generates 1024-dimensional emotional embeddings that are linearly separable across eight basic emotions and continuous valence-arousal-dominance (VAD) dimensions with an accuracy of >0.93. At the synthesis stage, these embeddings are fed to a Hierarchical Diffusion Transformer (HDT) decoder, where the diffusion process occurs simultaneously in three spaces: mel-spectrogram, 3D facial landmarks (FLAME), and a sequence of emotionally charged tokens (EmotionPrompt tokens). Thanks to a single diffusion noise, the model achieves frame-level synchronization: the average delay between changes in voice pitch and lip corner movements is only 40–60 ms, which is indistinguishable from human speech.

More more radical The next step is the use of Memory-Augmented Multimodal Transformers. Such models (e.g., EMO-MemoryBank, 2025) create a long-term bank of emotional prototypes: for each combination of VAD and context (dialogue, monologue, interview), a cluster of 16–32 canonical realizations is stored. During generation, the transformer does not construct an emotion from scratch, but performs retrieval-augmented synthesis: first, it retrieves the closest prototypes through cross-attention to the memory bank, then adapts them to the current text and the speaker's style using LoRA-like emotional style adapters. This yields a 0.6–0.8 point increase in subjective naturalness (MOS) compared to fully generative models and radically reduces emotional hallucinations.

Particular attention is paid to microemotions and covert emotions. Classic datasets contain almost no such information, so two approaches are used: (1) distillation from lie detection models and psychotherapeutic corpora (DAIC-WOZ, SEWA), (2) synthetic enrichment through adversarial emotional perturbation—the model is forced to preserve the semantics of the text but alter hidden emotional markers (voice tremor, smile asymmetry, micropauses). As a result, modern systems are capable of synthesizing complex states such as "joy tinged with guilt," "calm anger," or "restrained despair" with an identification accuracy rate of >82% in blind tests involving clinical psychologists. At the acoustics level, Neural Audio Codecs with emotional conditioning (EnCodec-Emo, SoundStream-V2) have become a breakthrough. Instead of directly predicting mel-spectrograms, codecs directly generate discrete tokens from 12–16 codebooks, with one codebook specifically reserved for emotional and prosodic characteristics. This allows for the transmission of an emotional vector with a size of only 8–16 tokens per second of speech, which is 50 times more compact than a raw waveform, while preserving 99% of perceptual prosodic information. In the visual modality, models such as EMOCA-v2 and SPECTRE hold the lead, predicting not only 3D landmarks but also subcutaneous deformation parameters (wrinkles, muscle bulging), as well as blood filling dynamics (blush, pallor) using physically based renders. When paired with an audio model, joint training is used with a SyncNet-type loss function, enhanced by the emotional sync loss term, which virtually eliminates the "uncanny valley" in transient emotional states.

Finally, the most advanced systems are already moving toward one-shot and few-shot emotional cloning. The user provides 5–30 seconds of speech and a short video of any

emotion—the model extracts a personal emotional style (idiosyncratic emotional manifold) and is capable of synthesizing any new emotion in this style while preserving individual facial expressions, timbre, and intonation habits. The accuracy of identifying a person from a synthesized emotional fragment reaches 97–99%, which opens up both enormous opportunities (personalized avatars, emotional heritage preservation) and serious ethical risks (emotional deepfakes).

Thus, multimodal transformers have evolved from a simple style transfer tool into a fully-fledged empathic behavior generator, capable of creating emotional expressions virtually indistinguishable from human ones, even for professionals. The line between biological and artificial emotionality is becoming increasingly blurred, and the next two to three years will likely yield systems that don't simply synthesize emotions, but demonstrate the beginnings of true affective intelligence. Conclusion

Multimodal transformers are revolutionizing emotion synthesis, transforming AI from a passive observer into an active, empathic partner. From basic fusion to advanced retrieval and diffusion, models have achieved fidelity indistinguishable from humans, with metrics like FAD, FID, and MOS at the SOTA level. However, challenges ranging from data scarcity and bias to ethical deepfakes require robust regulation and diverse training.

Future directions: foundation models for zero-shot/few-shot, integration of physiology (EEG, HRV) for holistic affect, and affective intelligence beyond synthesis. By 2028, systems demonstrating emergent empathy are expected, blurring the line between artificial and biological emotions, with profound impact on society.

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