

T-MAD: Target-driven Multimodal Alignment for Stance Detection

Zhaodan Zhang^{1,2,3}, Jin Zhang^{2,3,*}, Xueqi Cheng^{2,3}, Hui Xu²

¹School of Advanced Interdisciplinary Sciences, University of Chinese Academy of Sciences

²State Key Laboratory of AI Safety,

Institute of Computing Technology, Chinese Academy of Sciences

³University of Chinese Academy of Sciences

{zhangzhaodan23s, jinzhang, cxq, xuhui}@ict.ac.cn

Abstract

Multimodal Stance Detection (MSD) aims to determine a user’s stance - support, oppose, or neutral - toward a target by analyzing multimodal content such as texts and images from social media. Existing MSD methods struggle with generalizing to unseen targets and handling modality inconsistencies. To address these challenges, we propose the **Target-driven Multi-modal Alignment and Dynamic Weighting Model (T-MAD)**, which combines target-driven multi-modal alignment and dynamic weighting mechanisms to capture target-specific relationships and balance modality contributions. The model incorporates iterative reasoning to iteratively refine predictions, achieving robust performance in both in-target and zero-shot settings. Experiments on the MMSD and MultiClimate datasets show that T-MAD outperforms state-of-the-art models, with optimal results achieved using **RoBERTa**, **ViT**, and an iterative depth of 5. Ablation studies further confirm the importance of multi-modal alignment and dynamic weighting in enhancing model effectiveness.

1 Introduction

Multimodal Stance Detection (MSD) identifies a user’s stance - support, oppose, or neutral - toward a target by analyzing multimodal content like texts and images, often from social media (Küçük and Can, 2021; Carnot et al., 2023; Liang et al., 2024). MSD is crucial for sentiment analysis and social media monitoring, as understanding public opinion and user intent is vital (Thakkar et al., 2024; Liu et al., 2024a; Hu et al., 2024; Feng et al., 2024). However, detecting stances across text and images remains challenging due to the complexities of combining these modalities.

Despite progress, existing MSD methods face key limitations (Küçük and Can, 2021; Carnot et al.,

2023; Liang et al., 2024). First, models struggle with unseen targets (Liu et al., 2021a; Liang et al., 2022; Wen and Hauptmann, 2023) as social media content often covers unpredictable topics absent during training. Second, modality inconsistencies (Lei et al., 2024; Yang et al., 2023) arise when text and images present conflicting information. For instance, as shown in figure 1, an image might suggest opposition, while the text expresses support.

Current approaches like MLLM-SD and TMPT utilize large language models and target-specific prompts but face challenges in fine-grained alignment between modalities (Niu et al., 2024; Liang et al., 2024). Similarly, methods such as MultiClimate use advanced models but rely on single-pass inference, limiting flexibility for dynamic adjustments (Wang et al., 2024). These limitations reduce performance, especially in complex scenarios with conflicting data.

To overcome these challenges, we propose the **Target-driven Multi-modal Alignment and Dynamic Weighting Model (T-MAD)**. T-MAD integrates target-driven multi-modal alignment and dynamic weighting mechanisms to address these issues. It extracts embeddings for both text and images and aligns them in a unified semantic space, facilitating meaningful cross-modal interactions. The dynamic weighting mechanism balances modality contributions, particularly in cases of conflicting or incomplete information. An iterative multi-step reasoning chain further refines predictions for robust performance in complex scenarios.

Our contributions are as follows:

- We introduce **T-MAD**, a target-driven model that enhances generalization to unseen targets by using **target-driven alignment** and **dynamic weighting**, improving adaptability and stance detection accuracy in cases of modality conflict.
- We conduct extensive experiments on the

* Corresponding author.

MMSD and MultiClimate datasets, showing that T-MAD outperforms state-of-the-art models in both in-target and zero-shot settings. Additionally, we analyze the impact of text and visual encoder choices, and iterative inference depths, with **RoBERTa** and **ViT** yielding the best accuracy, and a depth of 5 optimally balancing accuracy and efficiency.

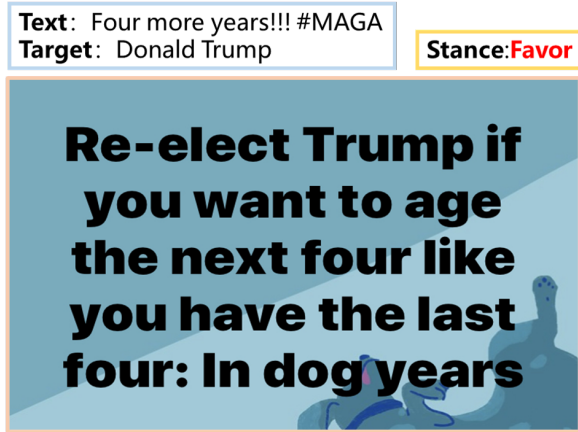


Figure 1: Example of Contradictory Stance: Image Shows Opposition, Text Shows Support for Trump

2 Related Work

Multimodal Stance Detection Stance detection has mainly concentrated on textual analysis (Sun et al., 2018; Zheng et al., 2022; Li and Caragea, 2023; Zhang et al., 2020; Ostendorff et al., 2019), with a significant focus on the stance expressed in social media platforms like Twitter (Somasundaran and Wiebe, 2010; Augenstein et al., 2016; Hasan and Ng, 2014; Küçük and Can, 2020). Yet, a recent trend arose that gradually includes images and videos in stance detection (Barel et al., 2025; Khia-bani and Zubiaga, 2024). MLLM-SD leverages the comprehension capabilities of LLMs to facilitate a detailed understanding of conversational content coupled with image information (Niu et al., 2024; Lee et al., 2024; Liu et al., 2024b). TMPT uses the target information to prompt the pre-trained models for learning multi-modal stance features (Liang et al., 2024). MultiClimate deploys state-of-the-art vision and language models, as well as multimodal models for MultiClimate stance detection (Wang et al., 2024).

Multimodal Stance Detection Datasets Weinzierl and Harabagiu pioneered the creation of the first multimodal stance detection dataset

MMVax specifically for COVID-19, comprising 11,300 instances (Weinzierl and Harabagiu, 2023). Subsequently, Liang et al. expanded existing text-based stance detection datasets (e.g. TSE2020, WT-WT) by incorporating image content and re-annotation to construct the larger MMSD multimodal stance detection datasets, totaling 17,544 annotated instances (Liang et al., 2024). MultiClimate dataset consists of 100 CCrelated YouTube videos in English with 4, 209 frame-transcript pairs (Wang et al., 2024). Multimodal multi-turn conversational stance detection dataset (MmMtCSD) (Niu et al., 2024) encompasses 21,340 instances, with 14,083 of these instances, or 66 %, being related to image content, underscoring the significance of multimodal data inclusion.

3 Methodology

Let the dataset $\mathcal{D} = \{(S_i, I_i, t_i, y_i)\}_{i=1}^N$ consist of N instances, where each instance (S_i, I_i, t_i, y_i) includes an input text S_i , the corresponding image I_i , and a target t_i . The objective is to determine the stance label y_i for the input S_i and I_i with respect to the target t_i , where $y_i \in \{\text{favor, against, neutral}\}$. The goal of multi-modal stance detection is to predict the stance label y_i for each instance (S_i, I_i, t_i) , inferring the stance of the text S_i and image I_i toward the given target t_i , with possible stance labels being favor, against, or neutral.

We propose a method that consists of the following four main steps. The method is shown in figure 2 : 1) **Feature Extraction for Multi-modal Alignment**: We extract embeddings of the image, text, and target using pre-trained encoders, serving as the foundation for subsequent alignment and reasoning processes; 2) **Target-driven Multi-modal Alignment**: A multi-head attention mechanism is employed to align the embeddings of the image and text with respect to the target, refining the representations while capturing global associations across modalities; 3) **Mutual Information-based Dynamic Weighting**: The model assesses the relevance of multimodal information to the target by estimating mutual information, dynamically assigning adaptive weights to image and text embeddings; 4) **Iterative Reasoning**: A iterative multi-step reasoning process iteratively refines the fused representation of the multimodal inputs and the target to produce the final stance prediction.

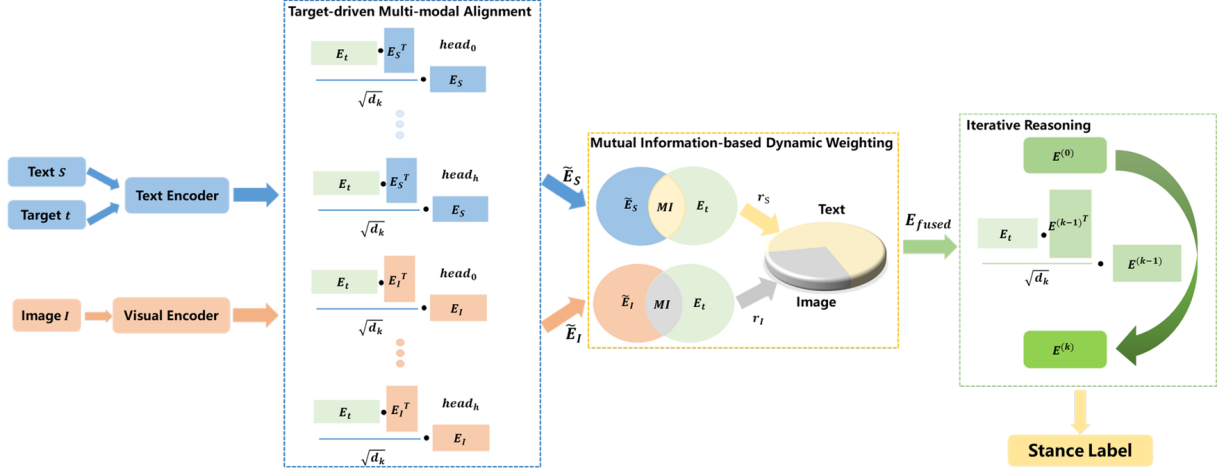


Figure 2: Architecture of the Target-driven Multi-modal Alignment and Dynamic Weighting Model

3.1 Feature Extraction

Given an input image I , text S , and target t , our goal is to extract embeddings for each modality that serve as the foundation for subsequent multi-modal stance detection processes.

First, we use a visual encoder to extract the image embedding E_I from the image I :

$$E_I = f_{\text{image}}(I) \quad (1)$$

where f_{image} captures both global and local visual features within the image.

For the text S and target t , we employ a pre-trained language model to obtain the respective embeddings E_S and E_t :

$$E_S = f_{\text{text}}(S), \quad E_t = f_{\text{text}}(t) \quad (2)$$

where f_{text} encodes semantic, contextual, and target-specific information for both the text and target.

At this stage, the extracted embeddings E_I , E_S , and E_t are used directly as inputs to multimodal alignment mechanisms.

3.2 Target-driven Multi-modal Alignment

We employ a target-driven multi-head cross-modal attention mechanism to align and refine the image and text embeddings E_I and E_S with respect to the target embedding E_t . This mechanism enables the model to learn and capture semantic relationships across modalities. The attention heads work together to refine the embeddings, ensuring a comprehensive understanding of the target-image-text relationship.

The alignment between the target embedding E_t and the image or text embeddings (E_I , E_S) is

achieved using multi-head attention. The attention computation is as follows:

$$\tilde{E}_I = \text{Concat}(\text{head}_1, \dots, \text{head}_h)W_O \quad (3)$$

$$\tilde{E}_S = \text{Concat}(\text{head}_1, \dots, \text{head}_h)W_O \quad (4)$$

where each attention head computes:

$$\text{head}_i = \text{softmax} \left(\frac{(E_t W_Q^i) \cdot (E_I W_K^i)^T}{\sqrt{d_k}} \right) \cdot (E_I W_V^i) \quad (5)$$

and similarly for E_S . Here, W_Q^i, W_K^i, W_V^i : Learnable projection matrices for the i -th head that transform the input embeddings into query, key, and value spaces. W_O : Output projection matrix that combines the outputs of all heads into a unified embedding. d_k : Dimensionality of the query/key vectors in each head, ensuring scale-invariance. h : Number of attention heads, typically set to 12, allowing the model to capture diverse semantic relationships across modalities. The index i ranges from 1 to h .

The output embeddings \tilde{E}_I and \tilde{E}_S are enriched with target-aligned semantic features.

3.3 Mutual Information-based Dynamic Weighting

The *Mutual Information-based Dynamic Weighting* mechanism is a core component of T-MAD, designed to intelligently balance the contributions of the image and text modalities in the final stance prediction. This is particularly crucial for handling *modality inconsistencies*, where the two modalities convey conflicting or ambiguous signals about the user's stance towards the target. Instead of using fixed or heuristic weighting schemes, our model dynamically assigns adaptive weights based on a

principled measure of each modality’s relevance to the target.

The key insight is that the modality which contains more information about the target should be given greater importance. To quantify this "relevance," we employ **Mutual Information (MI)**, a fundamental concept from information theory that measures the statistical dependence between two random variables. In our context, MI measures how much information the aligned image embedding \tilde{E}_I (or text embedding \tilde{E}_S) provides about the target embedding E_t . A higher MI value indicates a stronger semantic association and suggests that the modality is more informative for the stance detection task.

Since MI is intractable to compute directly, we approximate it using a contrastive learning objective. Specifically, we use the **InfoNCE loss** (van den Oord et al., 2018), which serves as a tractable lower bound on the true mutual information. This process, often referred to as *noise-contrastive estimation*, works by training the model to distinguish the "positive" target E_t from a set of "negative" target embeddings $\{E_t^j\}_{j=1}^N$.

The InfoNCE loss for the image modality is defined as:

$$\mathcal{L}_{\text{InfoNCE}}^{\text{image}} = -\log \frac{\exp(\text{sim}(\tilde{E}_I, E_t)/\tau)}{\sum_{j=1}^N \exp(\text{sim}(\tilde{E}_I, E_t^j)/\tau)} \quad (6)$$

where \tilde{E}_I is the target-aligned image embedding from the previous step, E_t is the embedding of the correct (positive) target, E_t^j are the embeddings of N randomly sampled negative targets from the same batch, $\text{sim}(\cdot)$ is a similarity function (we use cosine similarity), and τ is a temperature parameter that controls the concentration of the distribution. A symmetric loss $\mathcal{L}_{\text{InfoNCE}}^{\text{text}}$ is computed for the text modality using \tilde{E}_S . Similarly, the text modality uses:

$$\mathcal{L}_{\text{InfoNCE}}^{\text{text}} = -\log \frac{\exp(\text{sim}(\tilde{E}_S, E_t)/\tau)}{\sum_{j=1}^N \exp(\text{sim}(\tilde{E}_S, E_t^j)/\tau)} \quad (7)$$

Minimizing this loss encourages the model to assign a high similarity score to the positive pair (\tilde{E}_I, E_t) while assigning low scores to the negative pairs (\tilde{E}_I, E_t^j) . This effectively maximizes the estimated mutual information between the modality and the target.

Based on the estimated MI, we define a *relevance score* for each modality. These scores are

derived from the exponentiated MI to create a positive, non-linear scaling:

$$r_I = \exp(\text{MI}(\tilde{E}_I, E_t)) \quad (8)$$

$$r_S = \exp(\text{MI}(\tilde{E}_S, E_t)) \quad (9)$$

In practice, the MI value is approximated by the negative of the corresponding InfoNCE loss (up to a constant).

Finally, the dynamic weighting mechanism computes the final fused multimodal representation E_{fused} as a weighted average of the aligned image and text embeddings, with the relevance scores r_I and r_S serving as the weights:

$$E_{\text{fused}} = \frac{r_I \cdot \tilde{E}_I + r_S \cdot \tilde{E}_S}{r_I + r_S} + \lambda E_t \quad (10)$$

The term λE_t (where λ is a balancing factor) explicitly incorporates the target embedding into the final fusion, ensuring that the target’s semantic information remains central. This formulation ensures that the more informative modality (the one with higher MI and thus a higher relevance score) dominates the fused representation, allowing T-MAD to make robust predictions even in the face of conflicting multimodal inputs.

3.4 Iterative Reasoning

In this step, we refine the multi-modal fused representation E_{fused} , obtained from the previous steps, through an iterative reasoning process. This process iteratively updates the representation by focusing on progressively finer semantic details, guided by the target embedding E_t . The goal is to enhance the representation’s ability to capture nuanced cross-modal relationships, ultimately leading to a more accurate stance prediction.

Initialization The iterative reasoning process begins with the fused representation:

$$E^{(0)} = E_{\text{fused}} \quad (11)$$

where E_{fused} combines information from image, text, and target modalities, as computed in the previous step.

Iterative Refinement At each reasoning step k , multi-head attention is applied to refine the representation. The target embedding E_t serves as the query Q , while the current representation $E^{(k-1)}$ is used as both the keys K and values V :

$$E^{(k)} = \text{MHA}(Q = E_t, K = E^{(k-1)}, V = E^{(k-1)}) \quad (12)$$

Here, $E^{(k-1)}$ is the representation from the previous step, encoding the progressively refined multi-modal information. E_t ensures that each reasoning step remains target-guided, reinforcing the focus on target-related semantics.

Convergence Criteria The reasoning process proceeds iteratively, refining specific aspects of the representation at each step. The process stops when either of the following conditions is met: A fixed number of steps K is reached, or the representation converges, such that the change between $E^{(k)}$ and $E^{(k-1)}$ falls below a predefined threshold:

$$\|E^{(k)} - E^{(k-1)}\| < \epsilon \quad (13)$$

where ϵ is a small positive constant.

The final refined representation is denoted as:

$$E^{\text{refined}} = E^{(K)} \quad (14)$$

where K is the number of reasoning steps.

Final Prediction The refined representation E^{refined} is then passed through a fully connected layer to produce the final stance prediction:

$$y_{\text{final}} = \text{FC}(E^{\text{refined}}) \quad (15)$$

By incorporating iterative reasoning, the model progressively enriches the multi-modal representation E_{fused} with finer semantic details, while ensuring alignment with the target embedding E_t . This process enhances the model’s ability to handle incomplete or ambiguous information and to make robust stance predictions across diverse inputs.

4 Experiments

4.1 Datasets

We evaluate our proposed method on two multi-modal stance detection datasets: **MMSD** and **MultiClimate**. Detailed statistics for both datasets can be found in the appendices A.

The **MMSD** dataset (Liang et al., 2024) includes five multimodal stance detection tasks across various domains: MTSE, MCCQ, MWTWT, MRUC, and MTWQ. Each instance consists of text S_i , an image I_i , a target t_i , and a stance label y_i . Stance labels include **Favor**, **Against**, **Neutral**, and **Unrelated**. The dataset is split into training, validation, and test sets for both in-target and zero-shot settings, as detailed in Table 8.

The **MultiClimate** dataset (Wang et al., 2024) focuses on climate change content, with 100 English YouTube videos and 4,209 frame-transcript

pairs. Each pair is annotated with one of three stance labels: **Support**, **Neutral**, or **Oppose**. The dataset is split into 80% training, 10% validation, and 10% testing, as summarized in Table 9.

4.2 Evaluation Metrics

For the **MMSD** dataset, we use the **Macro F1-score** to measure the model performance. Macro F1-score provides an equal weight to each class, making it suitable for evaluating performance across the various stance categories in MMSD. For the **MultiClimate** dataset, we use the both **accuracy** and **weighted F1-score** as the evaluation metric, given the imbalanced distribution of the Support, Neutral, and Oppose labels in this dataset. The experimental results are averaged over 5 runs to ensure that the final reported results are statistically stable and not influenced by random initialization.

4.3 Baseline Models

Text-only Models. We use several text-based models: (1) **BERT** (Devlin et al., 2019), (2) **RoBERTa** (Liu et al., 2019), (3) **KEBERT** (Kawintiranon and Singh, 2022), (4) **LLaMA2** (Touvron et al., 2023), and (5) **GPT4**. For MultiClimate, we also evaluate (6) **Llama3** (Dubey et al., 2024) and (7) **Gemma2-9B** (Team et al., 2024).

Image-only Models. The image-based baselines include (1) **ResNet** (He et al., 2016), (2) **ViT** (Dosovitskiy et al., 2021), and (3) **SwinT** (Liu et al., 2021b).

Multimodal Models. For MMSD, we use (1) **ViLT** (Kim et al., 2021), (2) **CLIP** (Radford et al., 2021), (3) **BERT+ViT**, (4) **Qwen-VL** (Bai et al., 2023), (5) **GPT4-Vision**, (6) **TMPT** (Liang et al., 2024), (7) **TMPT+CoT** (Liang et al., 2024) and (8) **MLLM-SD** (Niu et al., 2024). For MultiClimate, we combine BERT with ViT or ResNet50 embeddings, and also use **CLIP** (Radford et al., 2021), **BLIP** (Li et al., 2022), **IDEFICS** (Alayrac et al., 2022), and **MLLM-SD** (Niu et al., 2024) for stance classification. The baseline models are detailed in the appendix B.

4.4 Experiment Settings

We introduce the **T-MAD+CWVF** model, a variant of our **Target-driven Multi-modal Alignment and Dynamic Weighting Model (T-MAD)**. In this model, we integrate a **Confidence-weighted Voting Fusion (CWVF)** mechanism to combine stance

Modality	Method	MTSE		MCCQ	MWTWT					MRUC		MTWQ	
		DT	JB	CQ	CA	CE	AC	AH	DF	RUS	UKR	MOC	TOC
Textual	BERT	48.25	52.04	66.57	75.62	60.85	63.05	59.24	81.53	41.25	46.80	57.77	45.91
	RoBERTa	58.39	60.79	66.57	69.56	65.03	69.74	67.99	79.21	39.52	57.66	55.22	48.88
	KEBERT	64.50	69.81	66.84	71.67	67.56	69.29	69.74	80.57	41.55	59.01	58.15	47.75
	LLaMA2	53.23	52.67	47.40	34.89	41.95	49.09	44.32	30.21	38.84	38.54	55.31	46.51
	GPT4	68.74	66.39	65.84	63.14	65.12	69.93	71.62	52.69	41.64	53.76	58.05	49.81
Visual	ResNet	37.89	38.59	47.16	39.89	42.20	43.52	37.05	50.34	35.10	40.00	42.02	33.94
	ViT	40.48	40.42	46.64	46.63	50.00	40.16	46.32	50.86	33.31	39.87	38.63	35.53
	SwinT	39.89	40.43	48.80	46.30	46.99	41.02	47.39	51.32	35.01	40.89	35.03	35.47
Multi-modal	BERT+ViT	41.86	45.82	61.32	63.20	44.71	56.45	46.85	73.71	39.28	48.41	47.47	40.86
	ViLT	35.32	48.24	47.85	62.20	56.44	58.06	60.22	73.66	34.62	42.41	44.43	39.51
	CLIP	53.22	65.83	63.65	70.93	67.17	67.43	70.86	79.06	44.99	59.86	55.29	40.98
	Qwen-VL	43.31	45.13	50.51	43.06	45.49	49.79	46.04	27.73	36.50	40.78	42.14	39.34
	GPT4-Vision	70.46	72.82	61.63	44.59	57.47	57.49	57.47	59.37	44.83	56.40	66.72	56.90
	TMPT	55.41	61.61	67.67	76.60	63.19	67.25	62.92	81.19	43.56	59.24	55.68	46.82
	TMPT+CoT	66.61	68.75	71.79	74.40	69.96	68.43	63.00	82.71	45.04	60.52	68.95	59.87
	MLLM-SD	68.4	70.10	72.50	78.20	70.00	71.40	74.60	84.10	47.30	63.80	70.90	61.20
	BERT+ViT+CWVF	43.20	47.10	62.50	64.80	46.10	57.80	48.20	74.90	40.50	49.60	48.70	42.10
	ViLT+CWVF	36.80	49.50	49.10	63.50	57.80	59.40	61.50	74.80	35.90	43.70	45.80	40.80
	CLIP+CWVF	54.60	67.10	64.80	72.10	68.50	68.70	72.10	80.20	46.20	61.10	56.50	42.30
	Qwen-VL+CWVF	44.70	46.50	51.80	44.60	46.80	51.10	47.40	29.10	37.80	41.90	43.40	40.70
	GPT4-V+CWVF	71.80	74.10	62.90	46.10	58.80	58.90	58.80	60.70	46.10	57.80	68.10	58.30
	TMPT+CWVF	56.90	63.10	68.90	78.10	64.50	68.60	64.20	82.40	44.90	60.40	56.90	48.20
	TMPT+CoT+CWVF	68.20	70.40	73.10	75.80	71.30	70.10	64.50	83.90	46.30	61.80	70.20	61.40
	T-MAD	71.12	73.31*	75.05*	80.45*	71.90	73.31	76.10*	86.20	49.25	65.70	72.80*	63.50
	T-MAD+CWVF	75.00*	77.50*	76.20*	81.30*	73.50*	74.80	77.10*	87.30*	50.20	66.90	73.50	64.30

Table 1: Experimental results (%) of in-target multi-modal stance detection. Results with * denote the significance tests of our T-MAD over the baseline models at p-value < 0.05.

labels generated by both T-MAD and MLLM, based on their respective confidence scores.

For MLLM’s output, we use a *repeated generation method* to estimate confidence. Each input instance (S_i, I_i, t_i) is prompted 5 times, and the confidence score is calculated by the frequency of label appearances. For T-MAD’s output, the confidence score is derived from the softmax probability associated with its predicted label. The CWVF mechanism selects the final label based on the highest confidence score, with preferences given to T-MAD’s output in case of ties.

We utilize several pretrained large language models (MLLMs) in our experiments, such as Qwen2-VL-7B-Instruct (Bai et al., 2023), InternVL2_5-1B (Chen et al., 2024), Llama-3.2-11B-Vision-Instruct, and deepseek-vl2 (Wu et al., 2024). For text and target embeddings, we use the uncased BERT-base model (Devlin et al., 2019), and for image embeddings, we use the ViT-base model (Dosovitskiy et al., 2021).

For the multi-modal alignment module, we set the dimensionality of the hidden vectors to $d_h = 768$, with 12 attention heads and a dropout rate of 0.1. The maximum reasoning depth K is set to 5 for iterative refinement. The mutual information-based

dynamic weighting module uses a temperature parameter of $\tau = 0.07$ and 256 negative samples. The balancing factor λ for the fused representation is set to 0.5. Details of experimental configurations are provided in the appendix (C).

5 Results and Discussion

The following section addresses the three research questions (RQs) that this study seeks to answer:

RQ1: How does the performance of T-MAD compare to state-of-the-art models on the MMSD and MultiClimate datasets?

RQ2: Is each component of the T-MAD effective and contributory to overall performance?

RQ3: How do different text and visual encoder combinations and iterative inference depths affect T-MAD’s performance?

Performance Comparison with State-of-the-Art Models

To rigorously evaluate the performance of our proposed T-MAD model, we conducted extensive experiments on the MMSD and MultiClimate datasets, comparing against a comprehensive suite of state-of-the-art baselines. The results, presented in Tables 1, 2, and 3, demonstrate T-MAD’s superior performance across both in-target

Modality	Method	MTSE		MWTWT				MRUC		MTWQ	
		DT	JB	CA	CE	AC	AH	RUS	UKR	MOC	TOC
Textual	BERT	32.52	29.97	63.55	61.30	59.18	52.89	22.01	15.45	28.04	9.57
	RoBERTa	26.60	32.41	59.22	64.86	57.46	57.17	27.10	19.98	30.62	15.84
	KEBERT	26.17	31.81	59.79	60.74	59.25	55.53	28.29	17.19	29.97	18.89
	LLaMA2	33.57	33.92	32.47	38.37	48.06	36.31	36.13	38.16	51.46	44.10
	GPT4	70.78	68.83	57.19	60.56	65.63	69.01	40.32	38.49	62.10	52.12
Visual	ResNet	25.52	29.70	23.01	24.11	25.21	25.27	22.57	20.19	27.59	24.88
	ViT	28.63	29.70	24.59	31.48	34.06	33.29	25.81	29.37	23.51	29.42
	SwinT	28.54	30.85	28.53	35.87	43.32	37.39	24.54	27.99	19.69	19.69
Multi-modal	BERT+ViT	26.70	31.57	59.21	59.30	50.04	59.22	23.33	15.21	24.76	11.70
	ViLT	28.08	29.74	38.36	46.00	51.01	48.55	21.99	23.96	23.54	19.18
	CLIP	28.21	28.99	55.46	61.08	55.46	59.96	27.21	25.46	21.55	15.60
	Qwen-VL	47.62	46.14	38.57	43.36	47.82	41.01	35.97	41.51	44.32	44.08
	GPT4-Vision	72.68	71.28	42.23	45.92	54.59	53.19	42.09	47.00	65.00	52.36
	TMPT	31.69	32.65	66.36	66.30	66.39	64.87	23.87	24.71	32.18	26.48
	MLLM-SD	55.30	59.70	69.80	68.50	67.30	66.80	50.40	53.10	47.50	44.80
	TMPT+CoT	54.30	58.46	67.28	63.73	64.87	54.26	48.99	51.75	45.32	43.70
	BERT+ViT+CWVF	28.50	33.40	61.70	61.90	52.30	61.50	25.10	17.30	26.90	13.80
	ViLT+CWVF	29.90	31.50	40.80	48.50	53.50	51.20	24.30	26.20	25.80	21.40
	CLIP+CWVF	30.10	30.80	57.90	63.50	57.90	62.30	29.50	27.60	23.80	17.70
	Qwen-VL+CWVF	49.80	48.50	40.80	45.90	50.30	43.50	37.80	43.70	46.90	46.30
	GPT4-Vision+CWVF	74.10	73.50	44.80	48.50	57.30	55.90	44.20	49.30	67.50	54.80
	TMPT+CWVF	33.80	34.90	68.90	68.80	68.90	67.50	25.90	26.80	34.50	28.70
	TMPT+CoT+CWVF	56.80	60.90	69.50	66.20	67.50	56.90	51.20	53.90	47.80	45.90
	T-MAD	58.10	62.80	71.50*	70.40*	69.90*	69.00*	52.20	55.60	49.80	47.20
	T-MAD+CWVF	77.20*	75.60*	72.40*	71.80*	70.80*	70.20	53.50	56.40	69.30*	56.60

Table 2: Experimental results (%) of zero-shot multi-modal stance detection. Best scores of each group are in bold. Results with * denote the significance tests of our T-MAD over the baseline models at p-value < 0.05.

and zero-shot settings.

On the MMSD dataset under the *in-target* setting (Table 1), **T-MAD+CWVF** establishes a new state-of-the-art, achieving the highest Macro F1 scores across all five sub-tasks. Its performance is particularly dominant in the MTSE task, where it attains **75.00%** and **77.50%** Macro F1, respectively. This represents a significant improvement over strong multimodal baselines like GPT4-Vision (70.46% on MTSE-DT) and TMPT+CoT (68.75% on MTSE-JB). Notably, even when other models are enhanced with the same Confidence-weighted Voting Fusion (CWVF) mechanism, T-MAD+CWVF still outperforms them. For instance, GPT4-Vision+CWVF scores 71.80% on MTSE-DT, while TMPT+CoT+CWVF scores 68.20%, both falling short of T-MAD+CWVF’s 75.00%. This indicates that the performance gain is not merely a byproduct of the fusion mechanism but is fundamentally driven by the high quality of T-MAD’s base predictions.

In the more challenging *zero-shot* setting (Table 2), T-MAD+CWVF’s ability to generalize to unseen targets is further highlighted. It achieves the best results on the majority of sub-tasks, showcasing its robustness. For example, it sets a new

high mark of **77.20%** on MTSE-DT, significantly surpassing the previous best of 74.10% by GPT4-Vision+CWVF. Similarly, on the MWTWT and MRUC tasks, T-MAD+CWVF demonstrates superior generalization. The consistent outperformance across diverse domains (e.g., elections, corporate mergers, geopolitical conflicts) underscores the model’s effectiveness in adapting to new and unpredictable targets.

The evaluation on the domain-specific MultiClimate dataset (Table 3) further validates T-MAD’s broad applicability. In this zero-shot setting, T-MAD+CWVF achieves a remarkable **78.0% accuracy** and **80.8% F1 score**, outperforming all other multimodal models, including fine-tuned variants like IDEFICS. Even the enhanced baseline BERT+ViT+CWVF is surpassed by T-MAD+CWVF. This result is particularly significant as it demonstrates that T-MAD’s architecture is not only effective for social media content but also excels in specialized domains like climate change discourse analysis.

In summary, the experimental results across multiple datasets and settings consistently show that T-MAD+CWVF achieves state-of-the-art performance. Its success stems from the synergy between

Modality	Method	ACC	F1
Textual	BERT	0.705	0.705
	Llama3 (zero-shot)	0.485	0.451
	Gemma2 (zero-shot)	0.461	0.382
Visual	ResNet50	0.424	0.399
	ViT	0.460	0.462
Multi-modal	BERT + ResNet50	0.717	0.714
	BERT + ViT	0.747	0.749
	CLIP	0.431	0.298
	BLIP	0.462	0.292
	IDEFICS (zero-shot)	0.347	0.270
	IDEFICS (fine-tuned)	0.600	0.591
	MLLM-SD	0.735	0.740
	BERT+ResNet50+CWVF	0.725	0.723
	BERT+ViT+CWVF	0.751	0.754
	CLIP+CWVF	0.450	0.315
	BLIP+CWVF	0.480	0.305
	IDEFICS (zero-shot)+CWVF	0.365	0.285
	IDEFICS (fine-tuned)+CWVF	0.620	0.610
	MLLM-SD	0.735	0.740
	T-MAD	0.752*	0.755*
	T-MAD+CWVF	0.780*	0.808*
HUMAN		0.826	0.823

Table 3: Text-only, image-only, and multi-modal model results on the MultiClimate test set. Best scores are in bold. Results with * denote the significance tests of our T-MAD over the baseline models at p-value < 0.05.

its core components - the target-driven alignment, dynamic weighting, and iterative reasoning - which produce high-fidelity base predictions. This allows the CWVF mechanism to effectively consolidate the final decision, leading to robust and accurate stance detection in both familiar and novel scenarios.

Effectiveness of T-MAD Components The ablation study in Table 4 demonstrates the contribution of each component in the T-MAD model. The full T-MAD model achieves the best performance across all tasks, with Macro F1 scores of **72.22** for **MTSE**, **75.05** for **MCCQ**, and **80.59** for **MWTWT**, showing the effectiveness of all model components working together.

When the Target-driven Multi-modal Alignment (TMA) module is removed, the model performance decreases significantly, particularly in **MTSE** and **MCCQ**, with Macro F1 scores dropping to 67.10 and 70.00, respectively. This indicates that the alignment between text, image, and target is crucial for maintaining high performance in stance detection tasks.

Removing the Mutual Information-based Dynamic Weighting (DW) mechanism also leads to a noticeable drop in performance, with the Macro

F1 scores for **MWTWT** and **MRUC** decreasing to 74.20 and 72.90, respectively. This highlights the importance of dynamically adjusting the weight of each modality to better handle modality inconsistencies and improve prediction accuracy. The

Method	MTSE	MCCQ	MWTWT	MRUC	MTWQ
T-MAD	72.22	75.05	80.59	78.48	75.15
w/o TMA	67.10	70.00	74.30	72.80	72.10
w/o DW	68.00	71.50	74.20	72.90	71.20
w/o IR	69.00	71.80	75.50	73.20	70.30

Table 4: Macro F1-scores of ablation study on T-MAD across all targets in MMSD dataset on in-target multi-modal stance detection. Best scores are in bold.

removal of the Iterative Reasoning (IR) mechanism results in a slight decrease in performance, with Macro F1 scores of 69.00 and 71.80 for **MTSE** and **MCCQ**. Although the decrease is smaller compared to the removal of other components, it suggests that iterative reasoning does provide additional refinement to the final predictions, especially in tasks with more complex modality interactions.

Text	MTSE	MCCQ	MWTWT	MRUC	MTWQ
BERT	69.22	71.05	74.45	76.80	73.25
RoBERTa	72.22	75.05	80.59	78.48	75.15
KE-BERT	69.22	72.20	75.02	76.45	71.00
LLaMA2	67.95	70.40	73.10	74.30	74.20
GPT-4	70.45	72.50	75.10	76.90	71.80

Table 5: Macro F1-scores of T-MAD with different text encoders on MMSD dataset. Best scores are in bold.

Visual	MTSE	MCCQ	MWTWT	MRUC	MTWQ
ResNet50	69.00	70.30	73.00	73.10	72.50
ViT	72.22	75.05	80.59	78.48	75.15
SwinT	68.50	71.60	73.90	74.00	72.60
CLIP	68.80	71.85	74.20	73.95	71.90
Qwen-VL	67.80	70.85	73.50	73.60	70.10

Table 6: Macro F1-scores of T-MAD with different visual encoders on MMSD dataset. Best scores are in bold.

Impact of Text and Visual Encoder Combinations and Iterative Inference Depths on T-MAD Performance The performance of T-MAD with different text and visual encoder combinations, as well as varying iterative inference depths, is evaluated across the MMSD and MultiClimate datasets. The results for the MultiClimate dataset are provided in the appendix D.

Depth	MTSE	MCCQ	MWTWT	MRUC	MTWQ
1	66.50	69.10	72.00	72.30	73.10
3	68.45	71.30	73.90	73.80	74.50
5	72.22	75.05	80.59	78.48	75.15
7	68.80	74.60	74.10	74.20	74.80
9	68.30	73.10	73.50	73.70	74.20

Table 7: Macro F1-scores of T-MAD with different inference depths on MMSD dataset across sub-tasks. Best scores are in bold.

Text and Visual Encoder Combinations: As shown in Table 5, 6, 10 and 11, RoBERTa and ViT consistently achieve the highest Macro F1 scores across both datasets. Specifically, RoBERTa and ViT reaches a Macro F1 of **75.05** on MCCQ, **75.15** on MTWQ and **0.808** on MultiClimate. These results suggest that RoBERTa excels at capturing textual features, enhancing the model’s ability to understand complex textual information, which is crucial for multimodal tasks. On the other hand, ViT shows a stronger capability in capturing fine-grained visual features, improving the model’s understanding of visual information. These findings highlight the importance of selecting powerful models for both text and visual encodings to achieve optimal performance in multimodal tasks.

Iterative Inference Depths: As shown in Table 7 and Table 12, the depth of iterative reasoning significantly influences model performance. For both datasets, increasing the inference depth up to 5 steps improves Macro F1 scores, with the highest values achieved at depth 5. Specifically, T-MAD reaches a Macro F1 of **75.15** on MTWQ and **0.808** on MultiClimate at depth 5, demonstrating that deeper iterative reasoning contributes to more accurate stance predictions. However, when the depth is increased to 7 and 9, performance declines, indicating that excessively deep iteration may lead to overfitting or amplified noise, negatively impacting the model’s generalization ability. Therefore, depth 5 is considered the optimal configuration for T-MAD, as it strikes the right balance between high performance and avoiding unnecessary computational complexity.

Overall, the combination of the best text encoder (RoBERTa) and visual encoder (ViT), along with a iterative reasoning depth of 5, provides the most robust performance across both datasets.

Case Study To further illustrate the model’s reasoning process, we analyze a challenging instance from the MMSD dataset where modalities conflict.

The input consists of the text “Four more years!!! #MAGA”, a supportive image caption “Re-elect Trump if you want to age the next four like you have the last four: In dog years.”, and the target “Donald Trump”. While the text is explicitly favorable, the image uses sarcasm, which could be misinterpreted as opposition. Our model first extracts features using RoBERTa and ViT. The target-driven multi-modal alignment mechanism then refines the text and image embeddings by aligning them with the target embedding, ensuring both modalities are interpreted in the context of “Donald Trump”. Subsequently, the mutual information-based dynamic weighting module estimates the relevance of each modality to the target. It assigns a higher weight to the text embedding due to its direct and unambiguous support, while assigning a lower weight to the image due to its indirect and ironic nature. Finally, the iterative reasoning process refines the fused representation over multiple steps, guided by the target, to emphasize the dominant supportive signal. As a result, T-MAD correctly predicts the stance as *Favor*, aligning with the ground truth and demonstrating its ability to resolve modality conflicts through targeted alignment and dynamic weighting.

6 Conclusion

In this work, we proposed **T-MAD**, a novel model for multimodal stance detection that effectively handles target generalization and modality inconsistency. Our approach consists of four key steps: feature extraction, target-driven multi-modal alignment, mutual information-based dynamic weighting, and iterative reasoning. Experimental results on the **MMSD** and **MultiClimate** datasets show that T-MAD outperforms state-of-the-art models, with optimal results achieved using **RoBERTa**, **ViT**, and an iterative depth of 5. Ablation studies further confirm the importance of multi-modal alignment and dynamic weighting in enhancing model effectiveness. Despite its strong performance, T-MAD has some limitations, including the computational complexity introduced by the iterative reasoning process, particularly for large datasets or real-time applications. Future work will focus on optimizing the efficiency of the inference process and improving the model’s handling of modality conflicts and generalization to new, unseen data.

Limitations

One limitation of T-MAD is its partial reliance on labeled training data, which can hinder its ability to generalize to completely unseen targets. While the model incorporates mechanisms to enhance zero-shot performance, it may still struggle with topics or stances that lack sufficient annotated examples, as it has been trained to rely on prior exposure to similar data. Additionally, T-MAD's use of iterative reasoning chains to gain deeper insights results in significant computational complexity, which limits its applicability for real-time or resource-constrained environments. Despite the dynamic weighting mechanism, extreme modality inconsistencies—where text and image convey entirely contradictory stances—remain a challenge, potentially leading to inaccurate predictions in certain cases. Furthermore, T-MAD's interpretability is constrained by its complex, multi-step reasoning process, making it difficult to fully understand the rationale behind its predictions in sensitive applications.

Ethical Considerations

The T-MAD approach to multimodal stance detection must be applied with careful attention to its ethical implications. Given its reliance on diverse data sources, there is a risk that unvetted or biased external data may propagate misinformation or reinforce existing biases within the model. Furthermore, as an automated stance detection system, T-MAD has the potential to influence public opinion and impact social or political dynamics through large-scale analysis. To mitigate these risks, it is essential to ensure transparency in the stance prediction process and implement mechanisms to identify and correct errors. Addressing privacy concerns is also critical, particularly when the model is used to analyze personal or sensitive content from social media. Adherence to data protection regulation is necessary to maintain user trust and uphold ethical standards in multimodal stance detection.

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A Datasets

A.1 MMSD Dataset

The **MMSD** dataset (Liang et al., 2024) comprises five multimodal stance detection datasets from different domains, designed to support this task: Multi-modal Twitter Stance Election 2020 (MTSE), Multi-modal COVID-CQ (MCCQ), Multi-modal Will-They-Won’t-They (MWTWT), Multi-modal Russo-Ukrainian Conflict (MRUC), and Multi-modal Taiwan Question (MTWQ). Each instance in MMSD includes an input text S_i , a corresponding image I_i , a target t_i , and a stance label y_i . The stance labels vary across domains, including categories such as **Favor**, **Against**, **Neutral**, and **Unrelated**. The dataset is split into training, validation, and test sets for both in-target and zero-shot scenarios, as detailed in Table 8.

A.2 MultiClimate Dataset

The **MultiClimate** dataset (Wang et al., 2024) is focused on climate change-related content and includes 100 English YouTube videos, yielding a total of 4,209 frame-transcript pairs. Each frame-transcript pair is annotated with one of three stance labels: **Support**, **Neutral**, or **Oppose**, indicating the stance towards climate change. The dataset is divided into 80% for training, 10% for validation, and 10% for testing, enabling a thorough evaluation within a domain-specific context. Table 9 provides a summary of the data distribution in MultiClimate.

B Baseline Models

Text-only Models. We use a variety of text-based models: (1) **BERT** (Devlin et al., 2019), the un-

Task	Dataset	Target	Train	Valid	Test
In-target	MTSE	DT	1150	170	327
		JB	882	128	250
	MCCQ	CQ	934	141	280
		CVS_AET	1216	179	352
	MWTWT	CI_ESRX	628	91	180
		ANTM_CI	825	114	238
		AET_HUM	674	97	186
		DIS_FOXA	2081	306	599
	MRUC	RUS	777	111	222
		UKR	756	108	217
	MTWQ	MOC	977	140	280
		TOC	1349	193	386
Zero-shot	MTSE	DT	1114	146	1647
		JB	1434	212	1260
	MWTWT	CVS_AET	5253	737	1747
		CI_ESRX	5994	841	899
		ANTM_CI	5694	804	1177
		AET_HUM	5884	840	957
	MRUC	RUS	945	136	1110
		UKR	971	139	1081
	MTWQ	MOC	1686	242	1397
		TOC	1222	175	1928

Table 8: Overview of MMSD statistics.

	Videos	Support	Neutral	Oppose	Total
Train	1449	1036	887	3372	
Dev	204	83	130	417	
Test	194	73	153	420	
Total	1847	1192	1170	4209	

Table 9: Overview of MultiClimate statistics.

cased BERT-base; (2) **RoBERTa** (Liu et al., 2019), the RoBERTa-base; (3) **KEBERT** (Kawintiranon and Singh, 2022), a BERTweet-base model with specific knowledge of Twitter political posts; (4) **LLaMA2** (Touvron et al., 2023), the LLaMA2-70b-chat; (5) **GPT4**. For the MultiClimate dataset, we also use (6) **Llama3** (Meta-Llama3-8B) (Dubey et al., 2024) and (7) **Gemma2-9B** (gemma-2-9b) (Team et al., 2024), are evaluated in a zero-shot setting with a climate-specific prompt on the Olama platform.

Image-only Models. The image-only baselines include (1) **ResNet** (He et al., 2016), specifically ResNet-50 v1.5; (2) **ViT** (Dosovitskiy et al., 2021), the ViT-base-patch16-224; and (3) **Swin Transformer** (SwinT), the SwinV2-base-patch4-window12-192-22k (Liu et al., 2021b).

Multimodal Models. The multimodal baselines for MMSD include (1) **ViLT** (Kim et al., 2021), the vilt-b32-mlm; (2) **CLIP** (Radford et al., 2021), the clip-vit-base-patch32; (3) **BERT+ViT**, where BERT serves as the textual encoder and ViT as the visual encoder, with concatenation of [CLS] tokens from both modalities for stance detection;

(4) **Qwen-VL**(Bai et al., 2023), the Qwen-VL-Chat7b; (5) **GPT4-Vision**; (6) **TMPT** (Liang et al., 2024), which uses target information to prompt pre-trained models for multimodal stance feature learning; and (7) **TMPT+CoT** (Liang et al., 2024), a variant of TMPT that utilizes GPT4-Vision to generate a chain of thought from the text and image, which is then concatenated with the text as input for TMPT+CoT. For MultiClimate, our multimodal fusion models combine BERT with ViT or ResNet50 embeddings. Additionally, we employ **CLIP**(Radford et al., 2021) and **BLIP**(Li et al., 2022) to capture joint image-text information, as well as **IDEFICS** (Alayrac et al., 2022), an open-source multimodal large language model, which we prompt with the frame and transcript in both zero-shot and fine-tuned settings to classify the stance as NEUTRAL, SUPPORT, or OPPOSE.

C Experiment Settings

To leverage the powerful capabilities of large language models (MLLMs), we propose a variant of our **Target-driven Multi-modal Alignment and Dynamic Weighting Model (T-MAD)**, named **T-MAD+CWVF**. In this variant, we employ a **Confidence-weighted Voting Fusion (CWVF)** mechanism to combine the stance labels generated independently by MLLM and T-MAD, using their respective confidence scores as the basis for fusion.

For MLLM’s output, we use a *repeated generation method* to estimate the confidence score. Specifically, for each input instance (S_i, I_i, t_i) , the model is prompted 5 times to generate stance labels. This process involves repeating the generation of stance predictions, and for each prompt, MLLM provides a stance label (either "Favor", "Against", or "Neutral"). Once all 5 labels are generated, the confidence score is calculated by dividing the number of times a specific label appears by the total number of prompts. Mathematically, if label y_{MLLM} appears N_{MLLM} times out of the total 5 prompts, the confidence score C_{MLLM} is computed as:

$$C_{\text{MLLM}} = \frac{N_{\text{MLLM}}}{5}$$

For T-MAD’s output, the confidence score is derived directly from the softmax probability associated with the predicted label. Specifically, for the output label $y_{\text{T-MAD}}$, the confidence score $C_{\text{T-MAD}}$ is the probability value obtained from the soft-

max function applied to the logits produced by the model, which ranges between 0 and 1:

$$C_{\text{T-MAD}} = \text{softmax}(y_{\text{T-MAD}})$$

In the **Confidence-weighted Voting Fusion (CWVF)** mechanism, the final stance prediction is determined by comparing the confidence scores of both models. The mechanism prioritizes the label with the higher confidence score from either model. Specifically:

1. If the confidence score of MLLM for label y_{MLLM} is higher than T-MAD’s confidence score for $y_{\text{T-MAD}}$, the final label y_{fusion} is set to y_{MLLM} .

$$C_{\text{MLLM}} > C_{\text{T-MAD}} \Rightarrow y_{\text{fusion}} = y_{\text{MLLM}}$$

2. If T-MAD’s confidence score is higher, the final label is set to $y_{\text{T-MAD}}$.

$$C_{\text{T-MAD}} > C_{\text{MLLM}} \Rightarrow y_{\text{fusion}} = y_{\text{T-MAD}}$$

3. If both confidence scores are equal, T-MAD’s output is preferred as the final label.

$$C_{\text{MLLM}} = C_{\text{T-MAD}} \Rightarrow y_{\text{fusion}} = y_{\text{T-MAD}}$$

This confidence-based fusion mechanism ensures that the model selects the most reliable stance label, prioritizing the output with higher certainty. This approach is consistently applied during both the training and testing phases, ensuring robust stance predictions across different multimodal instances.

We utilize several pretrained large language models (MLLMs) in our experiments, including Qwen2-VL-7B-Instruct (Bai et al., 2023), InternVL2_5-1B(Chen et al., 2024), Llama-3.2-11B-Vision-Instruct and deepseek-vl2 (Wu et al., 2024). These models are used to generate stance labels for the text-image-target instances, which are then combined with the T-MAD outputs using the CWVF mechanism.

For embedding the text and target, we utilize the pretrained uncased BERT-base model (Devlin et al., 2019), which embeds each word in the text S and target t as 768-dimensional embeddings, with $d_T = 768$.

For image embeddings, we employ the pre-trained ViT-base model (Dosovitskiy et al., 2021),

where each image patch is represented as a 768-dimensional vector, i.e., $d_I = 768$. The resolution of each visual patch is set to 16×16 pixels.

In the target-driven multi-modal alignment module, we set the dimensionality of the hidden vectors to $d_h = 768$. The number of attention heads is set to 12, with a multi-head attention dropout rate of 0.1. In the iterative reasoning chain, the maximum reasoning depth K is set to 5, allowing the model to refine the stance prediction progressively.

For the mutual information-based dynamic weighting module, we set the temperature parameter $\tau = 0.07$ in the InfoNCE loss, and use 256 negative samples to estimate mutual information between image and target, and text and target embeddings. The balancing factor λ for the fused representation is set to 0.5.

D MultiClimate Dataset Results (RQ3)

The results for the MultiClimate dataset are provided in the appendix. These results include the performance of T-MAD with different text encoders, visual encoders, and iterative inference depths. The three tables presented in the appendix are as follows:

D.1 Text Encoders on MultiClimate

The results in Table 10 show the performance of T-MAD with different text encoders on the MultiClimate dataset. RoBERTa outperforms all other text encoders, achieving the highest accuracy (0.780) and Macro F1 score (0.808), demonstrating its ability to effectively capture the nuanced relationships in text data. BERT also performs well, with an accuracy of 0.752 and a macro F1 score of 0.750. In contrast, KE-BERT and LLaMA2 perform relatively poorly, with macro F1 scores below 0.750, highlighting the superiority of RoBERTa in this task. GPT-4 delivers moderate performance with an accuracy of 0.754 and a macro F1 of 0.752, showing that it is competitive but does not surpass RoBERTa.

D.2 Visual Encoders on MultiClimate

The performance of different visual encoders is presented in Table 11. ViT achieves the highest accuracy (0.780) and Macro F1 score (0.808), demonstrating its excellent ability to process visual features for stance detection. The ResNet50 encoder also performs well, with an accuracy of 0.741 and a macro F1 of 0.770. Qwen-VL achieves decent

Text Encoder	ACC	Macro F1
BERT	0.752	0.750
RoBERTa	0.780	0.808
KE-BERT	0.750	0.748
LLaMA2	0.735	0.732
GPT-4	0.754	0.752

Table 10: Performance of T-MAD with different text encoders on MultiClimate dataset. Best scores are in bold.

performance, with a Macro F1 score of 0.773, making it competitive with other models. Swin Transformer and CLIP perform slightly worse, showing that ViT is the most effective visual encoder for this task on the MultiClimate dataset.

Visual Encoder	ACC	Macro F1
ResNet50	0.741	0.770
ViT	0.780	0.808
SwinT	0.748	0.767
CLIP	0.752	0.750
Qwen-VL	0.765	0.773

Table 11: Performance of T-MAD with different visual encoders on MultiClimate dataset. Best scores are in bold.

D.3 Inference Depths on MultiClimate

Depth	ACC	Macro F1
1	0.728	0.746
3	0.764	0.782
5	0.780	0.808
7	0.767	0.775
9	0.752	0.750

Table 12: Performance of T-MAD with different inference depths on MultiClimate dataset. Best scores are in bold.

Table 12 presents the results for T-MAD with different inference depths on the MultiClimate dataset. The best performance is achieved at an inference depth of 5, with the highest accuracy (0.780) and Macro F1 score (0.808), indicating that this depth strikes the best balance between model performance and computational efficiency. Increasing the depth to 7 or 9 results in a decline in performance, especially in terms of accuracy and Macro F1, with

scores dropping to 0.767 and 0.752, respectively. This suggests that while deeper inference can help improve the model's predictions, it may lead to diminishing returns or overfitting, and a depth of 5 is optimal for the MultiClimate dataset.