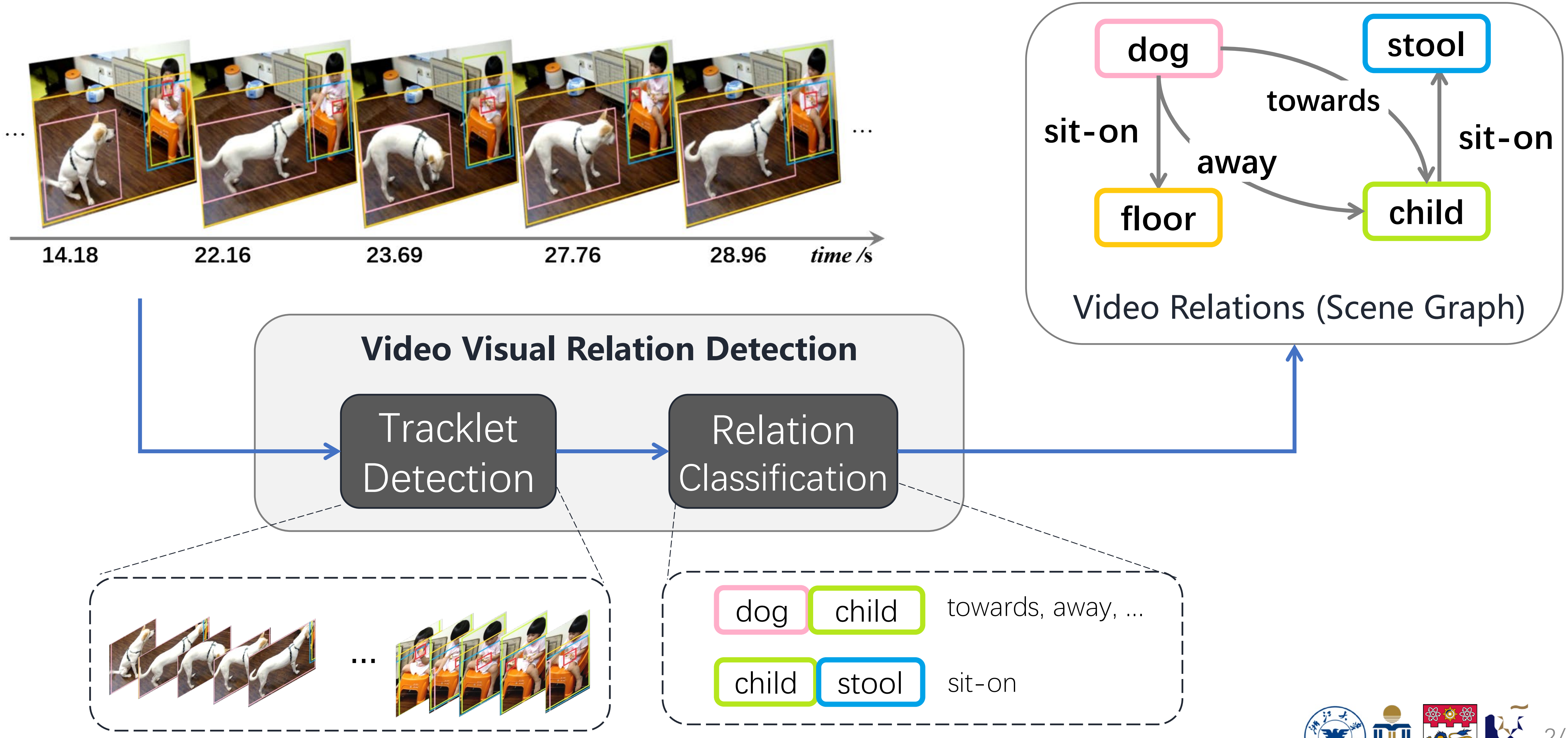
# Compositional Prompt Tuning with Motion Cues for Open-Vocabulary Video Relation Detection

Kaifeng Gao[1] · Long Chen[2] · Hanwang Zhang[3] · Jun Xiao[1] · Qianru Sun[4]

[1]Zhejiang University, [2]The Hong Kong University of Science and Technology,
[3]Nanyang Technological University, [4]Singapore Management University

# 1 Introduction to Video Visual Relation Detection



dog, stool, floor, child

towards, sit-on, away, sit-on

Video Relations (Scene Graph)

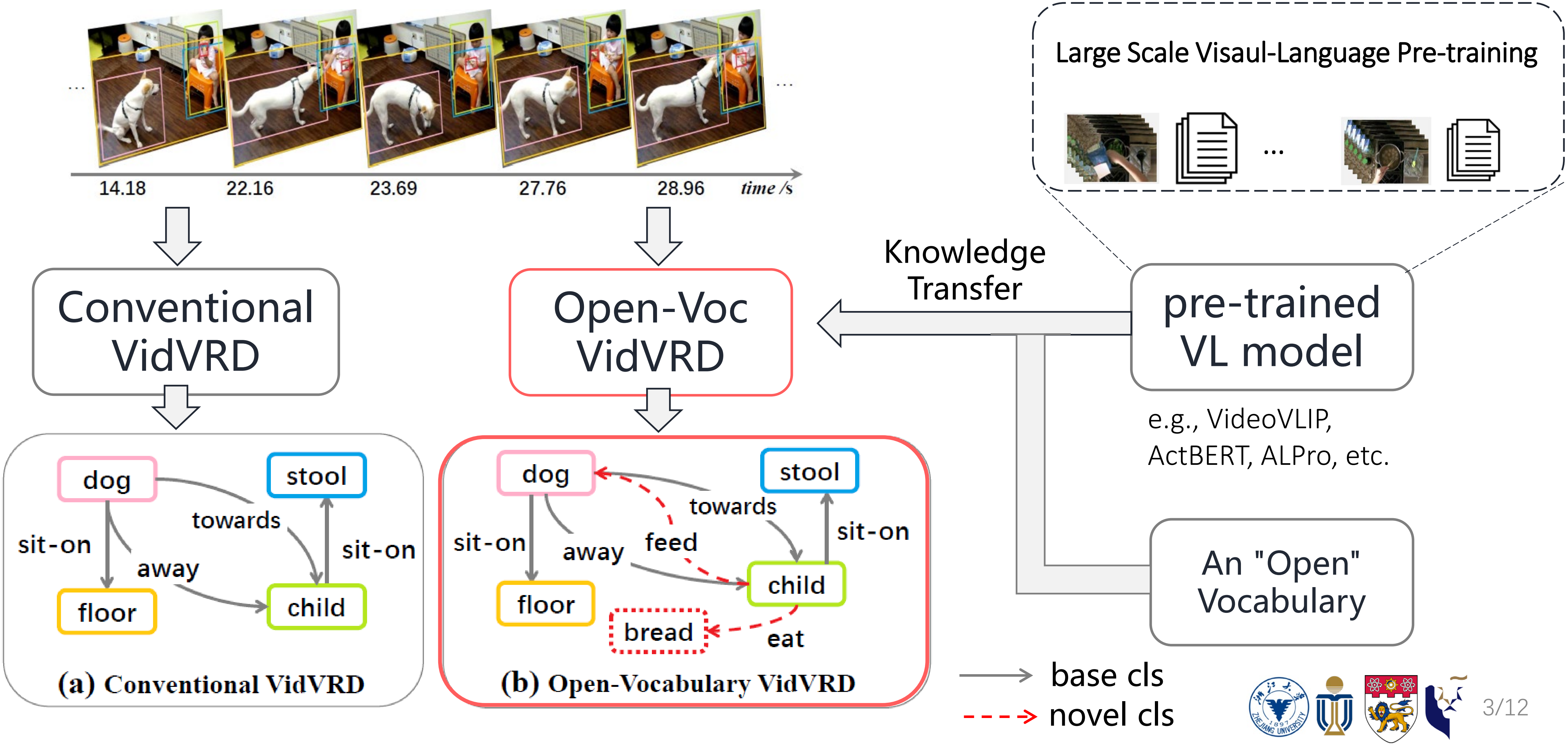
**Video Visual Relation Detection**

Tracklet Detection → Relation Classification

…

| | | |
|---|---|---|
| dog | child | towards, away, … |
| child | stool | sit-on |

# 2 Towards Open-vocabulary Video VRD



Large Scale Visaul-Language Pre-training

Knowledge Transfer

Conventional VidVRD

Open-Voc VidVRD

pre-trained VL model

e.g., VideoVLIP, ActBERT, ALPro, etc.

An "Open" Vocabulary

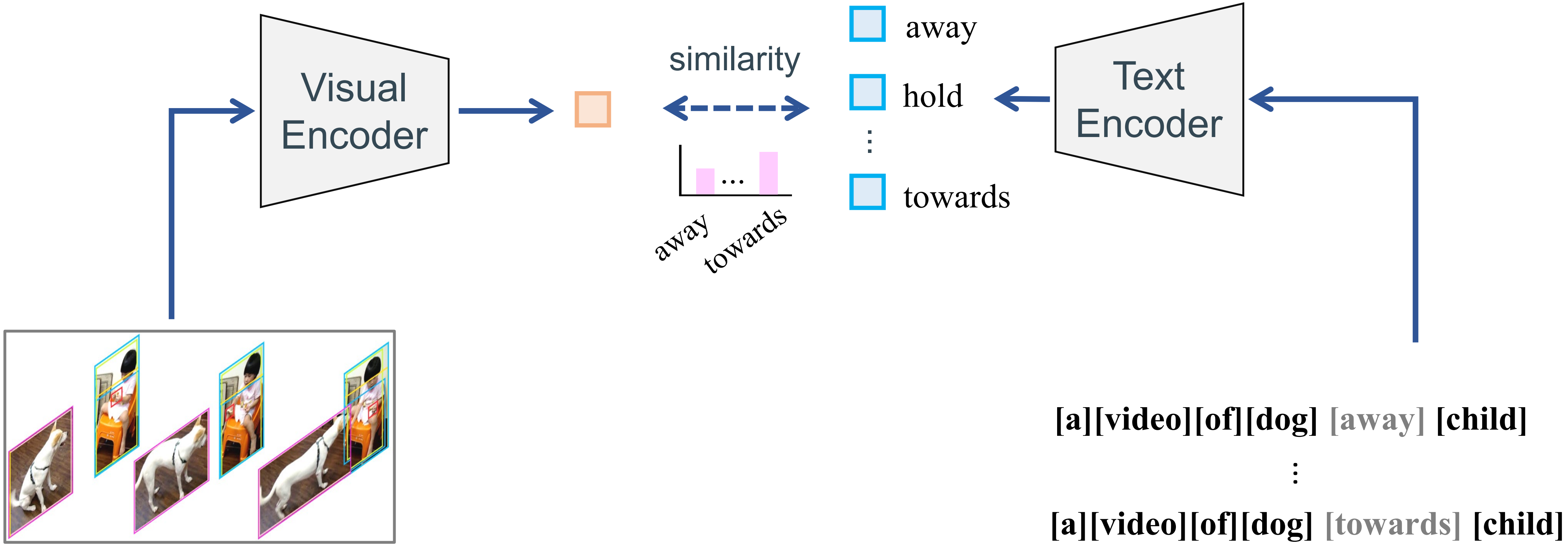
(a) Conventional VidVRD

(b) Open-Vocabulary VidVRD

→ base cls

- - -> novel cls

# Prompt for Pre-trained VLM



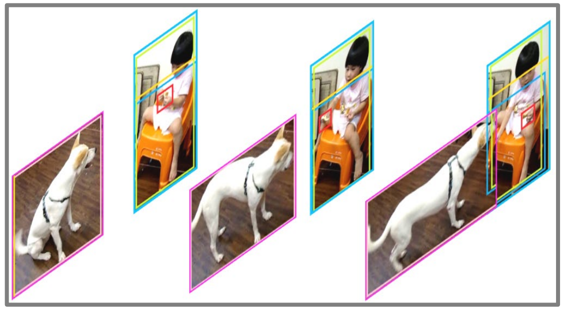
GT: dog-towards child

[a][video][of][dog] [away] [child]

⋮

[a][video][of][dog] [towards] [child]

# 3.1 Prompt for Pre-trained VLM



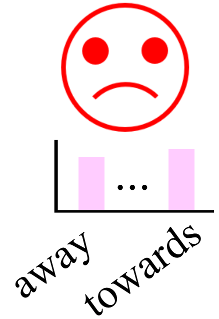
GT: dog-towards child

(a) Fixed (Handcraft) Prompts

[a][video][of][dog] [away] [child]

⋮

[a][video][of][dog] [towards] [child]



[ ... ] class token

[ ... ] fixed prompt token

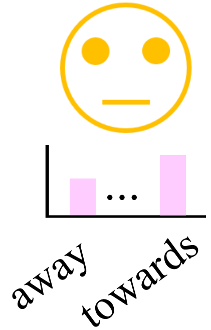
[ ... ] learnable prompt token

(b) Conventional Learnable Prompts

$[w_1]$ $[w_2]$ ... $[w_L]$ [away]

⋮

$[w_1]$ $[w_2]$ ... $[w_L]$ [towards]

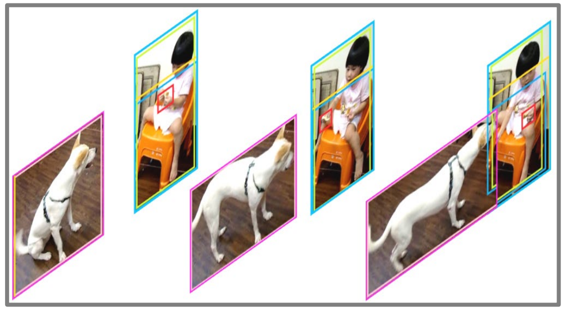


**Drawbacks:**

1) Overfit to base categories in open-vocabulary setting
2) Not consider the spatial-temporal motion information of trajectory pair.

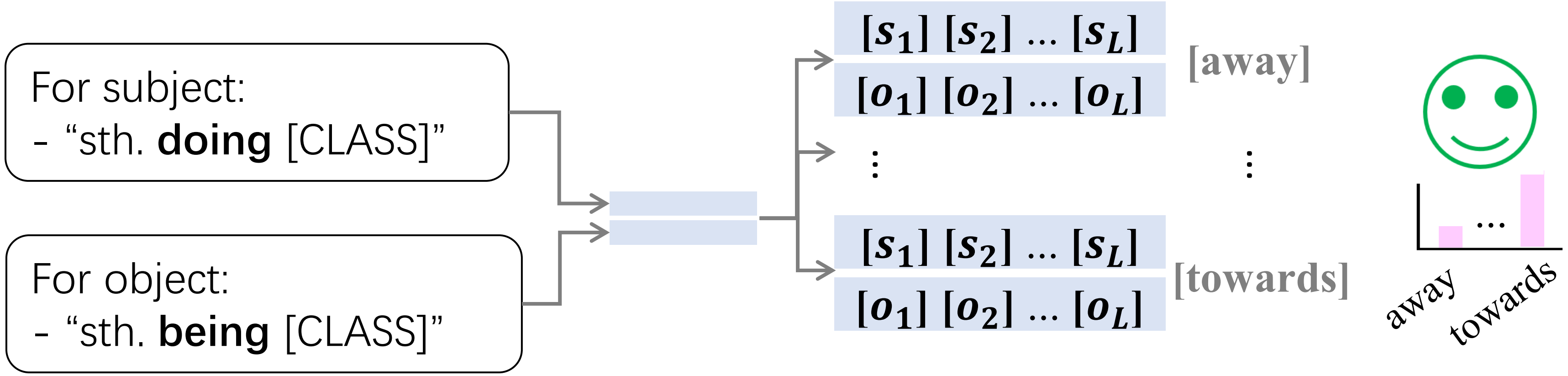
# 3.2 Compositional & Motion –based Prompt

## Ours



GT: dog-towards child

Separate Prompt, e.g.,



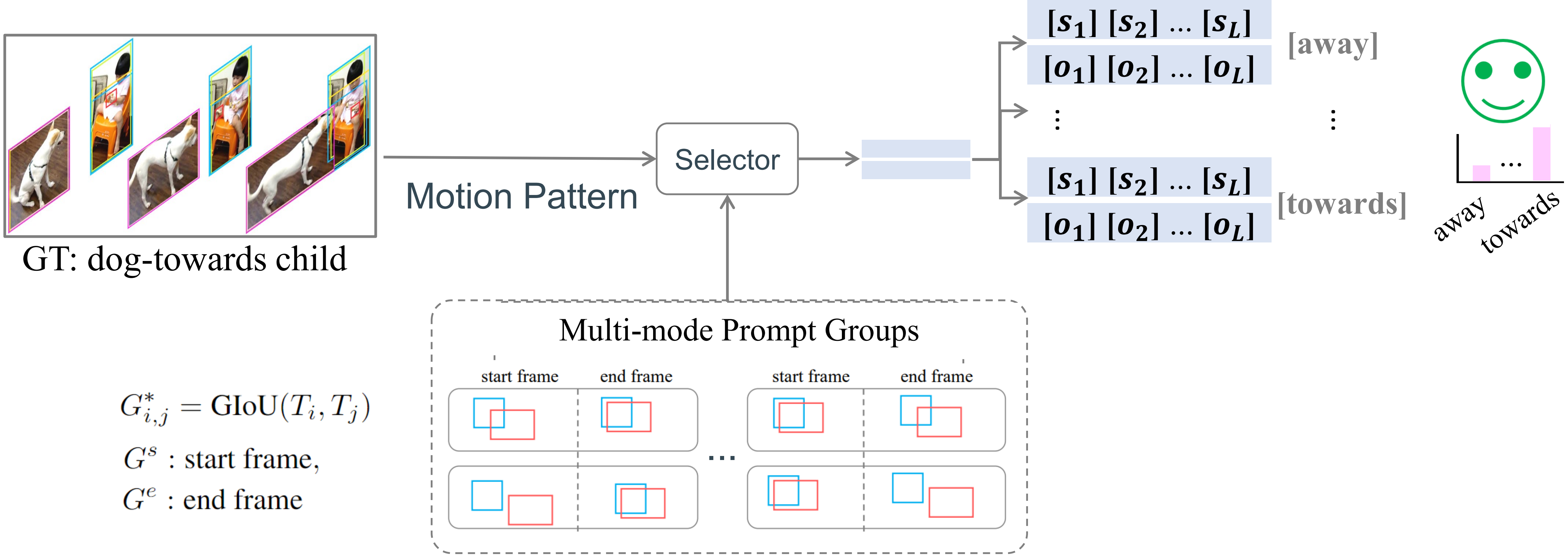
For subject:
- “sth. **doing** [CLASS]”

For object:
- “sth. **being** [CLASS]”

$[s_1]\ [s_2]\ \ldots\ [s_L]$
$[o_1]\ [o_2]\ \ldots\ [o_L]$
[away]
⋮
⋮
$[s_1]\ [s_2]\ \ldots\ [s_L]$
$[o_1]\ [o_2]\ \ldots\ [o_L]$
[towards]
…
away
towards

# 3.2 Compositional & Motion –based Prompt

## Ours



$$G^*_{i,j} = \mathrm{GIoU}(T_i, T_j)$$

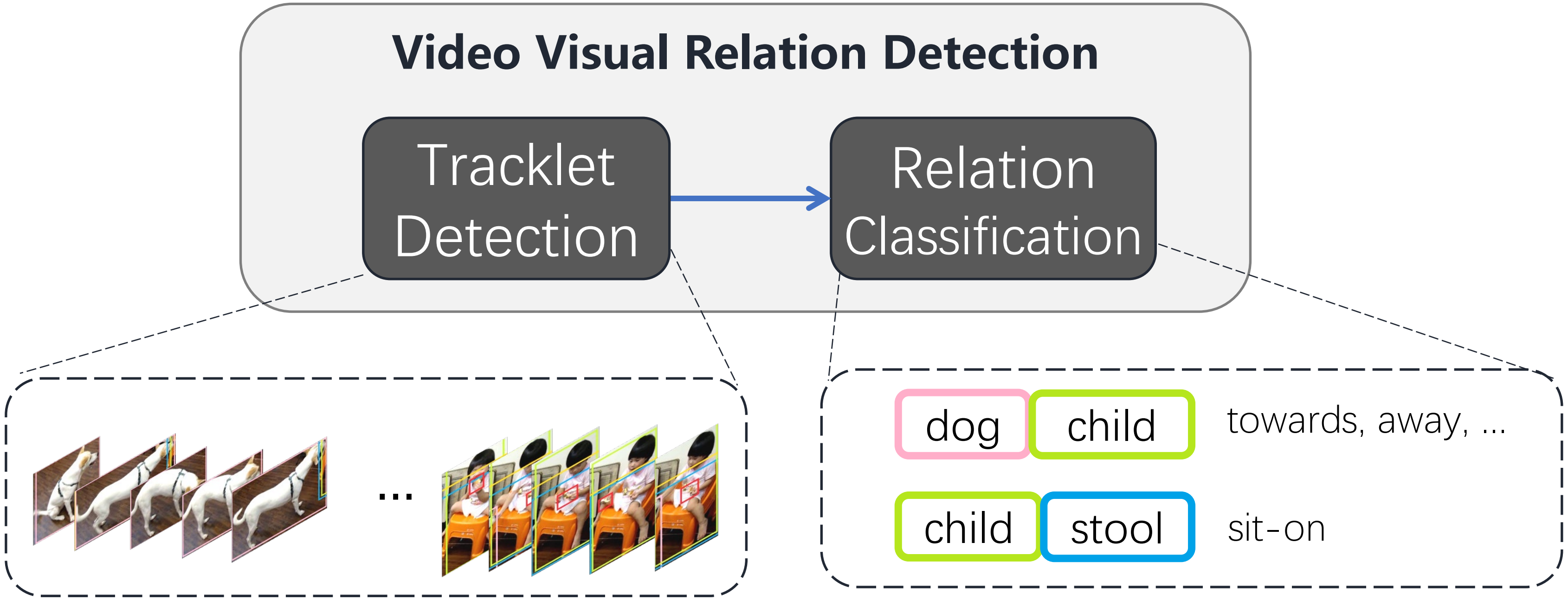
$G^s$ : start frame,

$G^e$ : end frame

$$\boldsymbol{m}_{i,j} = \mathrm{sign}([G^s_{i,j} - \gamma, G^e_{i,j} - \gamma, G^e_{i,j} - G^s_{i,j}]),\ \boldsymbol{m}_{i,j} \in \{+,-\}^3,$$

# 4.1 Knowledge Transfer from Pre-trained VLM

A popular two-stage pipeline:



Video Visual Relation Detection

Tracklet Detection

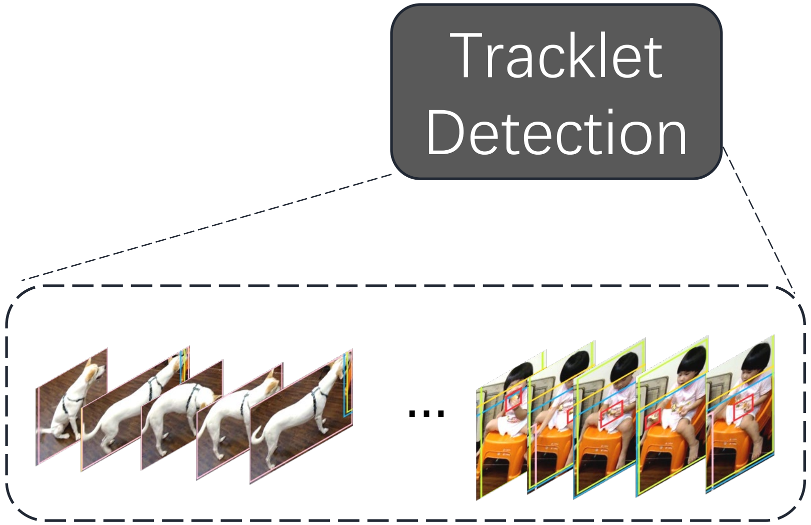
Relation Classification

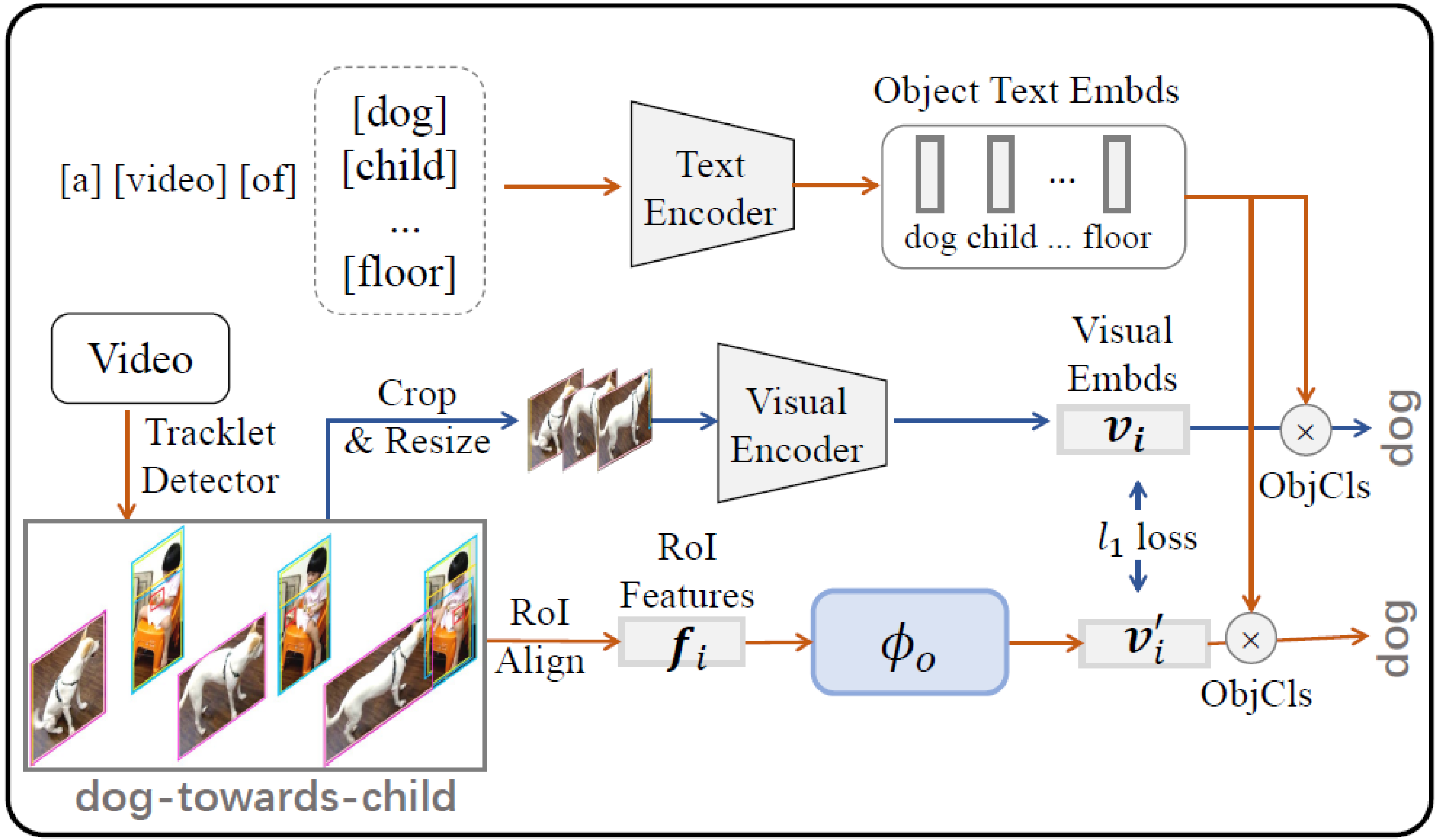
...

dog child towards, away, ...

child stool sit-on

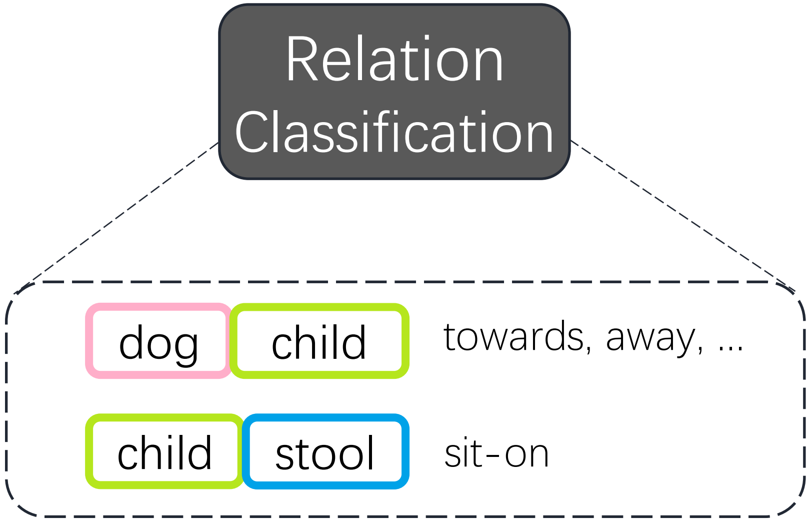
# 4.1 Knowledge Transfer from Pre-trained VLM

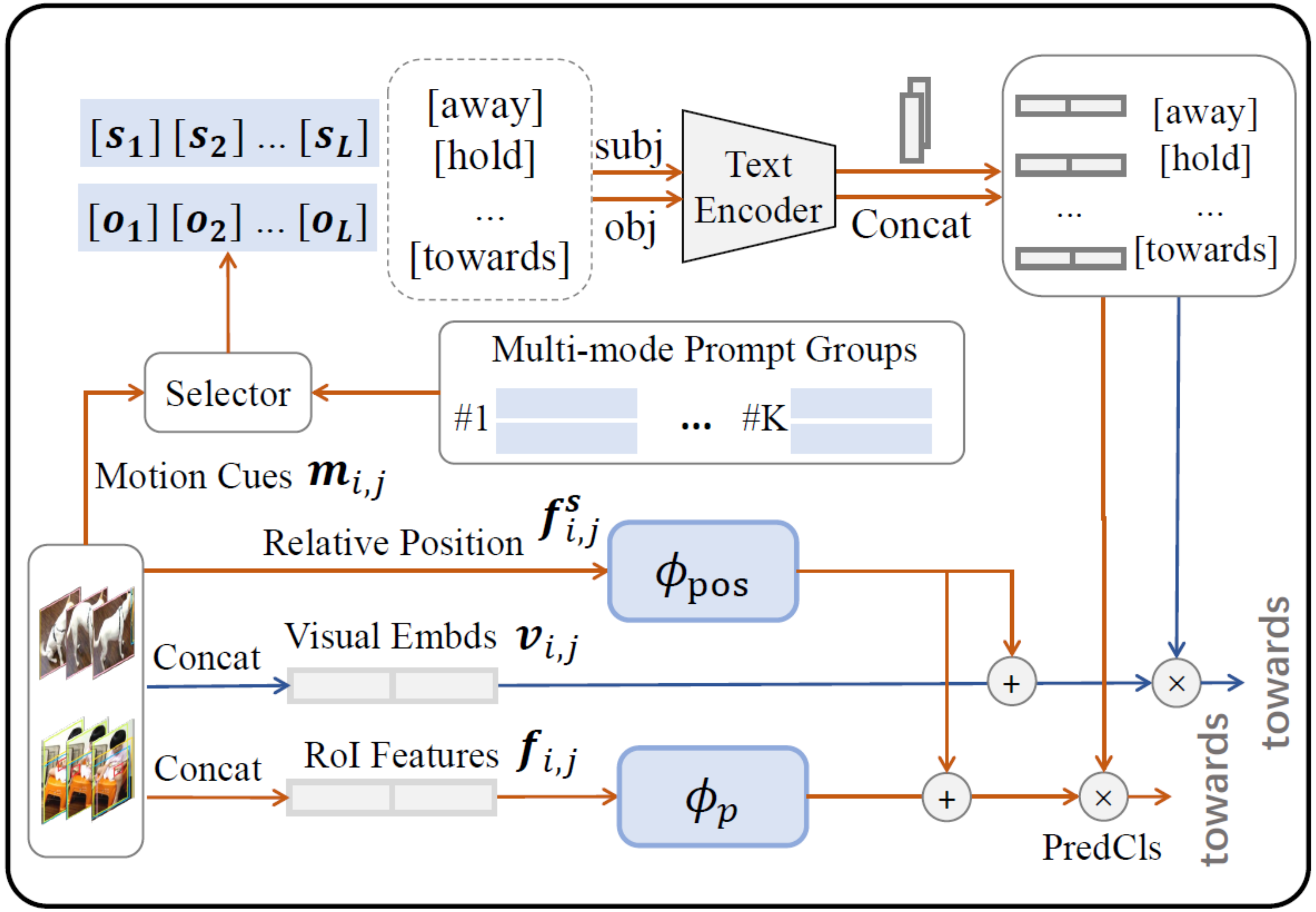




▭ learnable ⏢ fixed ⊗ dot-product ⊕ add → training → training & test

# 4.2 Knowledge Transfer from Pre-trained VLM





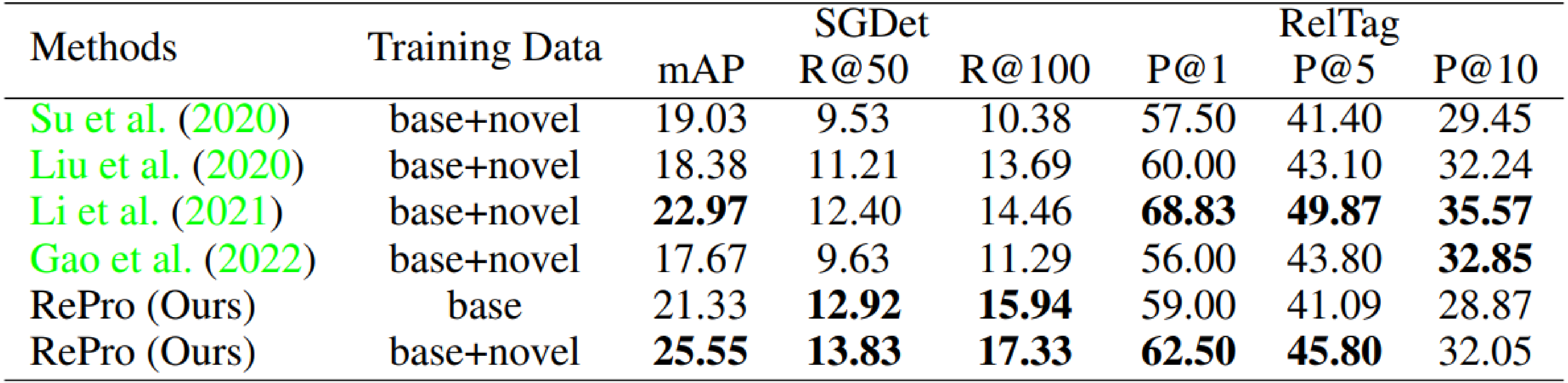
🟦 learnable ▭ fixed ⊗ dot-product ⊕ add

→ training

→ training & test

# 5 Experiments Results

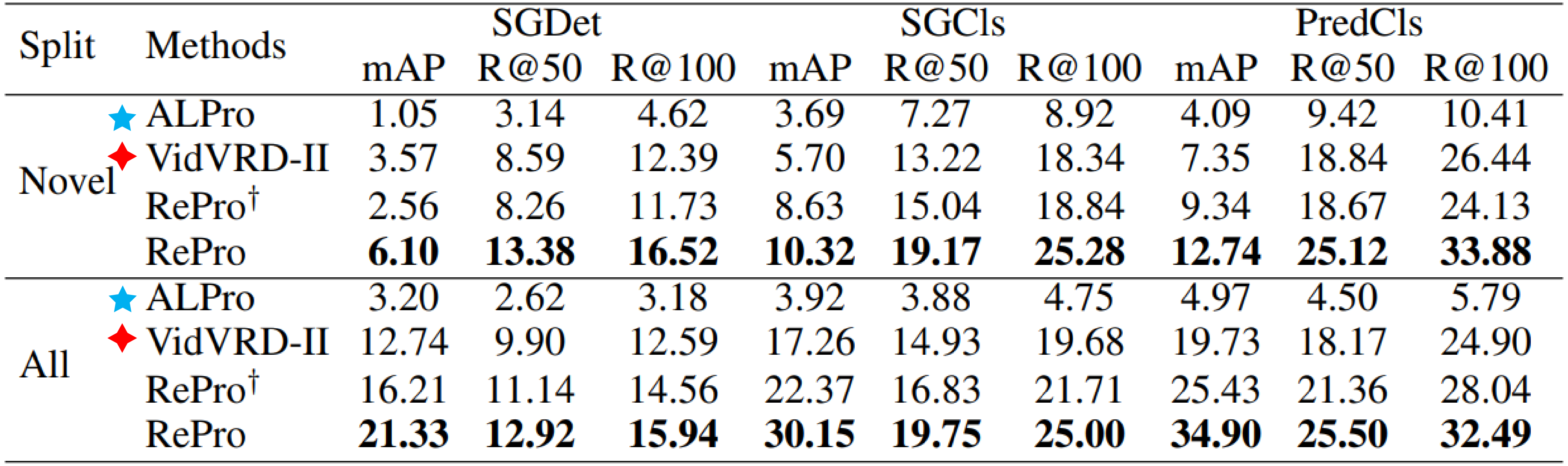
- Compare with SOTA in conventional setting



| Methods | Training Data | SGDet |  |  | RelTag |  |  |
|---|---|---|---|---|---|---|---|
|  |  | mAP | R@50 | R@100 | P@1 | P@5 | P@10 |
| Su et al. (2020) | base+novel | 19.03 | 9.53 | 10.38 | 57.50 | 41.40 | 29.45 |
| Liu et al. (2020) | base+novel | 18.38 | 11.21 | 13.69 | 60.00 | 43.10 | 32.24 |
| Li et al. (2021) | base+novel | **22.97** | 12.40 | 14.46 | **68.83** | **49.87** | **35.57** |
| Gao et al. (2022) | base+novel | 17.67 | 9.63 | 11.29 | 56.00 | 43.80 | **32.85** |
| RePro (Ours) | base | 21.33 | **12.92** | **15.94** | 59.00 | 41.09 | 28.87 |
| RePro (Ours) | base+novel | **25.55** | **13.83** | **17.33** | **62.50** | **45.80** | 32.05 |

# 5 Experiments Results

## ➢ Comparison in the Open-Vocabulary setting



| Split | Methods | SGDet | | | SGCls | | | PredCls | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | mAP | R@50 | R@100 | mAP | R@50 | R@100 | mAP | R@50 | R@100 |
| Novel | ★ ALPro | 1.05 | 3.14 | 4.62 | 3.69 | 7.27 | 8.92 | 4.09 | 9.42 | 10.41 |
| | ✦ VidVRD-II | 3.57 | 8.59 | 12.39 | 5.70 | 13.22 | 18.34 | 7.35 | 18.84 | 26.44 |
| | RePro† | 2.56 | 8.26 | 11.73 | 8.63 | 15.04 | 18.84 | 9.34 | 18.67 | 24.13 |
| | RePro | **6.10** | **13.38** | **16.52** | **10.32** | **19.17** | **25.28** | **12.74** | **25.12** | **33.88** |
| All | ★ ALPro | 3.20 | 2.62 | 3.18 | 3.92 | 3.88 | 4.75 | 4.97 | 4.50 | 5.79 |
| | ✦ VidVRD-II | 12.74 | 9.90 | 12.59 | 17.26 | 14.93 | 19.68 | 19.73 | 18.17 | 24.90 |
| | RePro† | 16.21 | 11.14 | 14.56 | 22.37 | 16.83 | 21.71 | 25.43 | 21.36 | 28.04 |
| | RePro | **21.33** | **12.92** | **15.94** | **30.15** | **19.75** | **25.00** | **34.90** | **25.50** | **32.49** |

★ Pre-trained VLM zero-shot inference

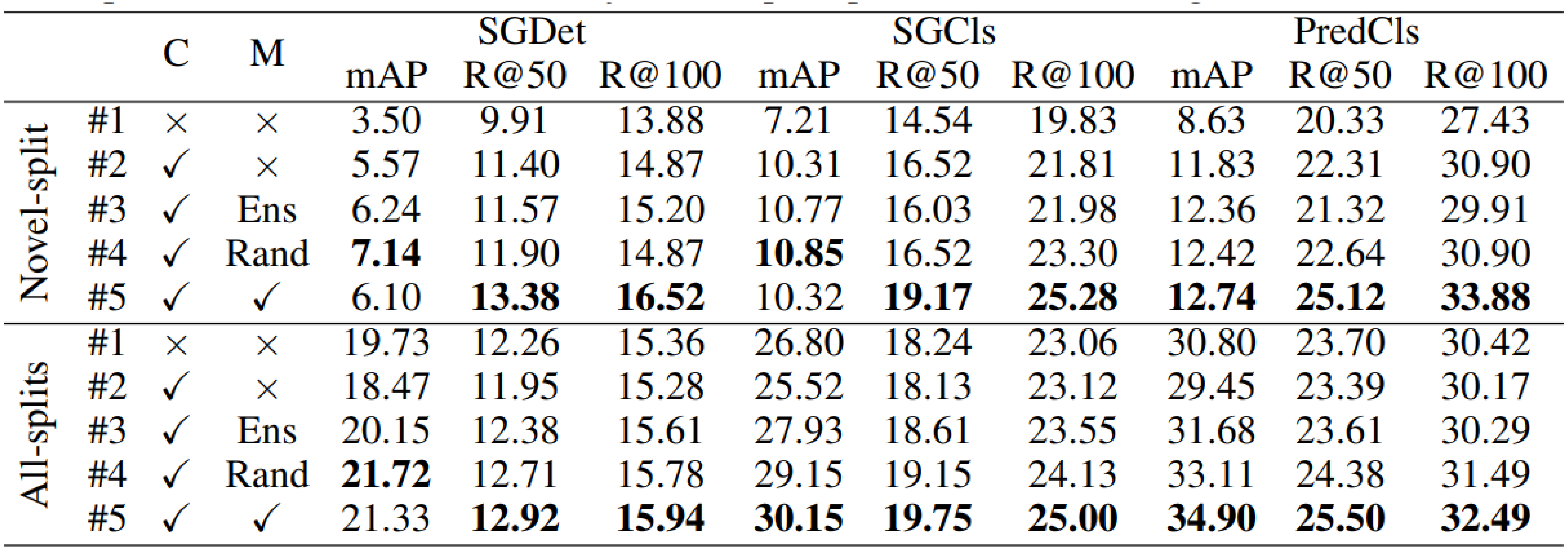
- Li, Dongxu, et al. "Align and prompt: Video-and-language pre-training with entity prompts." In CVPR 2022.

✦ Baseline VidVRD model

- Shang, Xindi, et al. "Video visual relation detection via iterative inference." ACM Multimedia. 2021.

# 5 Experiments Results

## ➢ Ablation Studies for Comp. & Motion Prompting



| | | C | M | SGDet | | | SGCls | | | PredCls | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | mAP | R@50 | R@100 | mAP | R@50 | R@100 | mAP | R@50 | R@100 |
| Novel-split | #1 | × | × | 3.50 | 9.91 | 13.88 | 7.21 | 14.54 | 19.83 | 8.63 | 20.33 | 27.43 |
| | #2 | ✓ | × | 5.57 | 11.40 | 14.87 | 10.31 | 16.52 | 21.81 | 11.83 | 22.31 | 30.90 |
| | #3 | ✓ | Ens | 6.24 | 11.57 | 15.20 | 10.77 | 16.03 | 21.98 | 12.36 | 21.32 | 29.91 |
| | #4 | ✓ | Rand | **7.14** | 11.90 | 14.87 | **10.85** | 16.52 | 23.30 | 12.42 | 22.64 | 30.90 |
| | #5 | ✓ | ✓ | 6.10 | **13.38** | **16.52** | 10.32 | **19.17** | **25.28** | **12.74** | **25.12** | **33.88** |
| All-splits | #1 | × | × | 19.73 | 12.26 | 15.36 | 26.80 | 18.24 | 23.06 | 30.80 | 23.70 | 30.42 |
| | #2 | ✓ | × | 18.47 | 11.95 | 15.28 | 25.52 | 18.13 | 23.12 | 29.45 | 23.39 | 30.17 |
| | #3 | ✓ | Ens | 20.15 | 12.38 | 15.61 | 27.93 | 18.61 | 23.55 | 31.68 | 23.61 | 30.29 |
| | #4 | ✓ | Rand | **21.72** | 12.71 | 15.78 | 29.15 | 19.15 | 24.13 | 33.11 | 24.38 | 31.49 |
| | #5 | ✓ | ✓ | 21.33 | **12.92** | **15.94** | **30.15** | **19.75** | **25.00** | **34.90** | **25.50** | **32.49** |

**C**: Compositional; **M**: Motion cues;

**Ens**: ensemble all the learned prompts by averaging their representations.

**Rand**: randomly select a prompt without considering motion cues

# Thank You !

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For more information, refer to

Open Review & GitHub