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JST CREST Project
COLLECTIVE VISUAL SENSING

Temporal Localization and Spatial Segmentation of Joint Attention in Multiple First-Person Videos

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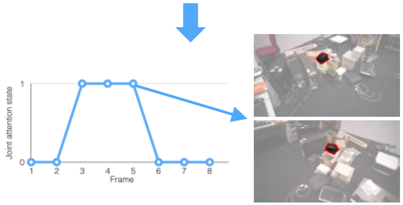
Goal

Discovering objects of joint attention using multiple first-person videos (FPVs) with points of gaze (PoG) data

Task

- **Temporally localize** time intervals of joint attention
- **Spatially segment** the object of joint attention

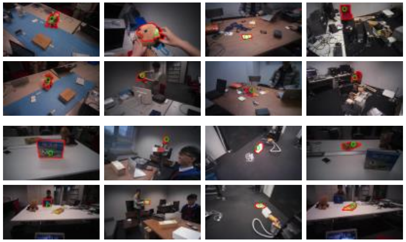
Input: multiple FPVs with PoG data



Output: Joint attention states and object segmentation

Dataset

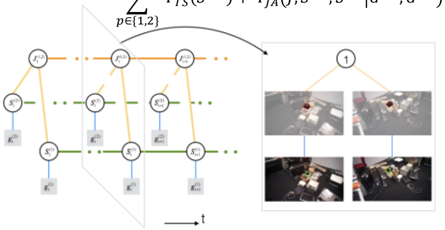
- 24 pairs of egocentric videos with gaze data (20 ~ 60 secs)
- 5 different environments, 20+ different objects
- Annotation of joint attention period & object segments



Problem Formulation

Given gaze position ***G***, we aim to infer joint attention state ***J*** and segment the object of joint attention (***S***), by minimizing the objective function:

$$\Psi(S^{(1)},S^{(2)}|G^{(1)},G^{(2)}) = \sum_{p\in\{1,2\}} \Psi_{GO}(S^{(p)}|G^{(p)}) + \sum_{p\in\{1,2\}} \Psi_{TS}(S^{(p)}) + \Psi_{JA}(J,S^{(1)},S^{(2)}|G^{(1)},G^{(2)}) + \Psi_{TJ}(J)$$



Gaze proximity and objectness

$$\Psi_{GO}(S^{(p)}|G^{(p)}) = \sum_{t=1}^{T}\left(\lambda_{GO1}\frac{\left\|C(s_t^{(p)})-\boldsymbol{g}_t^{(p)}\right\|_2}{\left|s_t^{(p)}\right|^{\frac{1}{2}}} + \lambda_{GO2}\left(1-\frac{\left|s_t^{(p)}\right|}{\left|H(s_t^{(p)})\right|}\right)\right),$$

$C\left(s_t^{(p)}\right)$:Centroid of segment $s_t^{(p)}$, $\left|H\left(s_t^{(p)}\right)\right|$: Area of convex hull of $s_t^{(p)}$

Temporal consistency of segments

$$\Psi_{TS}(S^{(p)}) = \lambda_{TS}\sum_{t=1}^{T-1}(1-f_{sim}(s_t^{(p)},s_{t+1}^{(p)}))$$

f_{sim} : cosine similarity of features extracted from segments

Joint attentionness

$$\Psi_{JA}(J,S^{(1)},S^{(2)}|G^{(1)},G^{(2)}) = \sum_{t=1}^{T}(\lambda_{JA1}Y\left(j_t,s_t^{(1)},s_t^{(2)},\boldsymbol{g}_t^{(1)},\boldsymbol{g}_t^{(2)}\right) + \lambda_{JA2}Z(j_t))$$

Y measures visual similarity of segments:

$$Y\left(j_t,s_t^{(1)},s_t^{(2)},\boldsymbol{g}_t^{(1)},\boldsymbol{g}_t^{(2)}\right) = j_t\left(1-f_{sim}\left(s_t^{(1)},s_t^{(2)}\right)\right) + (1-j_t)\alpha\left(\boldsymbol{g}_t^{(1)},\boldsymbol{g}_t^{(2)}\right)$$

α computes visual similarities around gaze region like [1]

$$Z(j_t) = \begin{cases} j_t\ , magnitude\ of\ global\ motion > \delta_m \\ 0, otherwise \end{cases}$$

Temporal consistency of joint attention

$$\Psi_{TJ}(J) = \lambda_{TJ}\sum_{t=1}^{T-1}|j_t - j_{t+1}|$$

[1] Kera et. al. CVPRW2016

Experiment

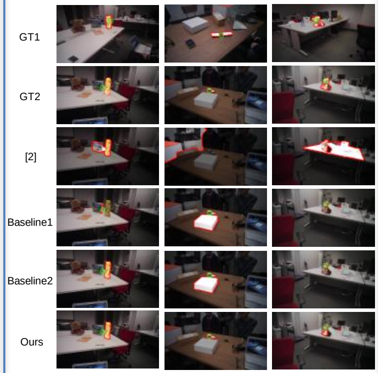
Spatial segmentation task

Method	FtF-large	FtF-small	SbS-large	SbS-small	Avg.
ObMiC [2]	0.287	0.212	0.065	0.336	0.225
Baseline1	0.552	0.599	0.681	0.691	0.631
Baseline2	0.611	0.629	0.723	0.726	0.672
Ours	**0.633**	**0.660**	**0.730**	**0.735**	**0.690**

Temporal localization task

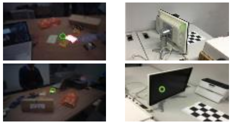
Method	FtF-large (%)		FtF-small (%)		SbS-large (%)		SbS-small (%)		Avg. (%)
	P	R	P	R	P	R	P	R	F1 score
Kera *et al.* [1]	74.5	89.7	69.7	**93.8**	72.9	**96.5**	67.1	83.4	79.0
Ours	**91.9**	**92.8**	**84.7**	86.5	**94.3**	92.6	**79.7**	**98.7**	**89.3**

Visualizations



- GT1,2: ground truth of person 1,2
- Baseline1: Ψ_{GO} only, Baseline2: $\Psi_{GO} + \Psi_{TS}$
- [2]: Fu et. al. CVPR2014

Failure cases



- Different objects with similar appearance
- Same object with different appearances

Future work

- Use predicted gaze instead of eye tracker
- Use 3D geometric relation between FPVs