Partially Supervised Multi-Task Network for Single-View Dietary Assessment

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ARTIFICIAL INTELLIGENCE MEETS NUTRITION

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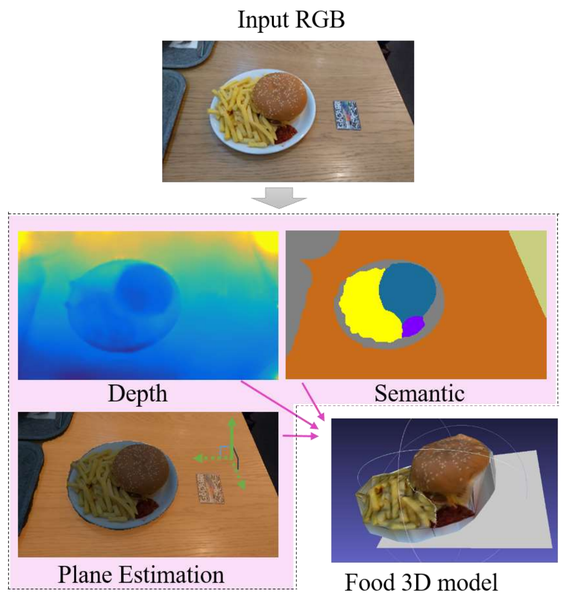
Background and Aims

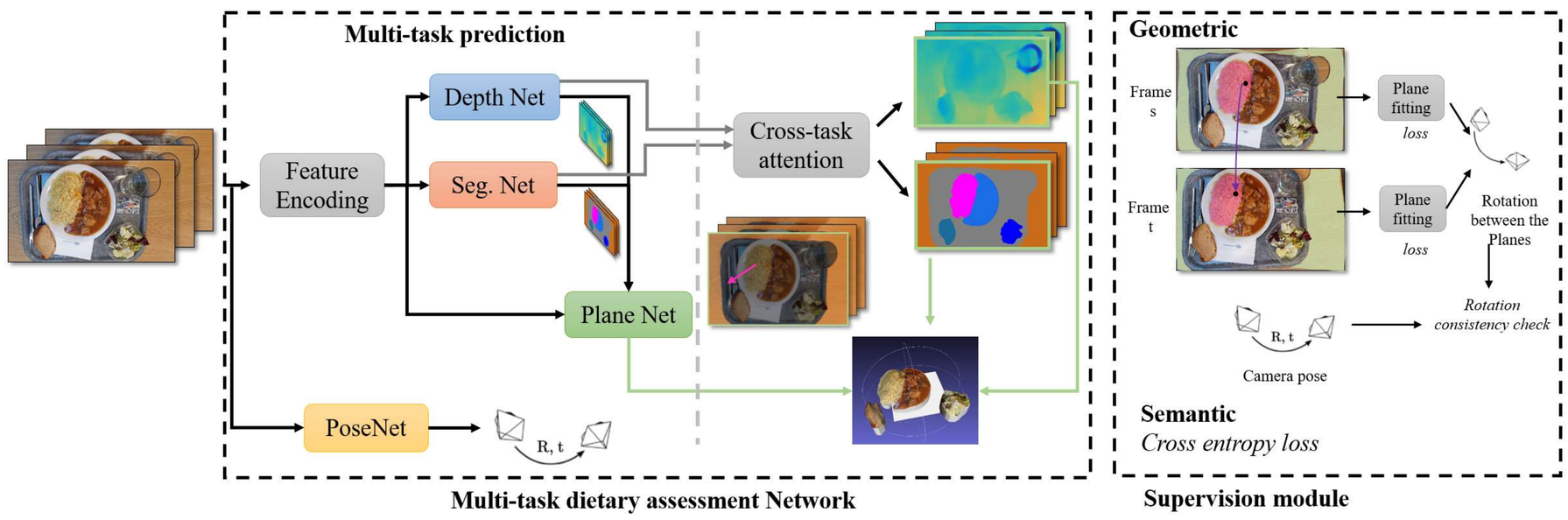
Dietary assessment in terms of calories and macro-nutrient content estimation become more and more important for individuals that want to follow a healthy lifestyle. Food segmentation, recognition and volume estimation are the essential steps of computer vision based dietary assessment. Existing methods require either multi-image input or additional depth maps, reducing convenience of implementation and practical significance.

To this end, we propose a partially supervised network architecture, which:

- jointly performs geometric understanding (depth prediction and 3D plane estimation) and semantic prediction on single food image,
- needs only monocular videos with semantic ground truth and
- enables a robust and accurate food volume estimation on non-ideal scenarios (e.g. texture less scenario).



Methodology



Overview of the network architecture

Loss Functions

- View Synthesis Loss

$$\mathcal{L}_{vs} = \alpha \frac{1 - SSIM(I_t - I_s^w)}{2} + (1-\alpha)\|I_t - I_s^w\|_1$$

- Semantic loss

$$\mathcal{L}_{s_c} = \|S_s^w - S_t\|_2$$

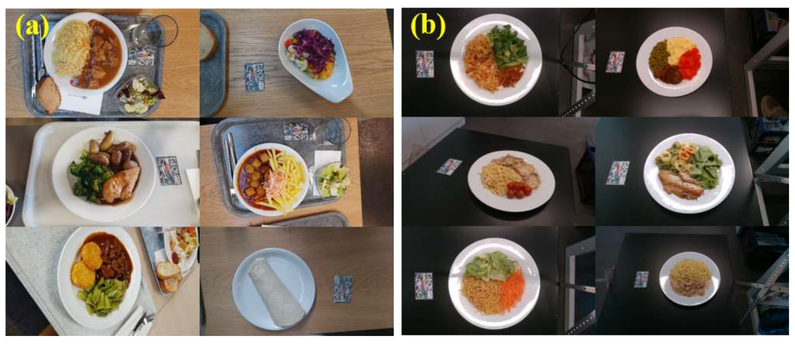
- Plane loss

$$\mathcal{L}_p = \frac{1}{N_{tab.}} \sum_{P \in tab.} |\mathbf{n}^T P - 1|$$

- Consistency loss between table plane and camera pose:

$$\mathcal{L}_c = \| \Delta q_{s\to t}^p - \Delta q_{s\to t}^c \|_2$$

Databases

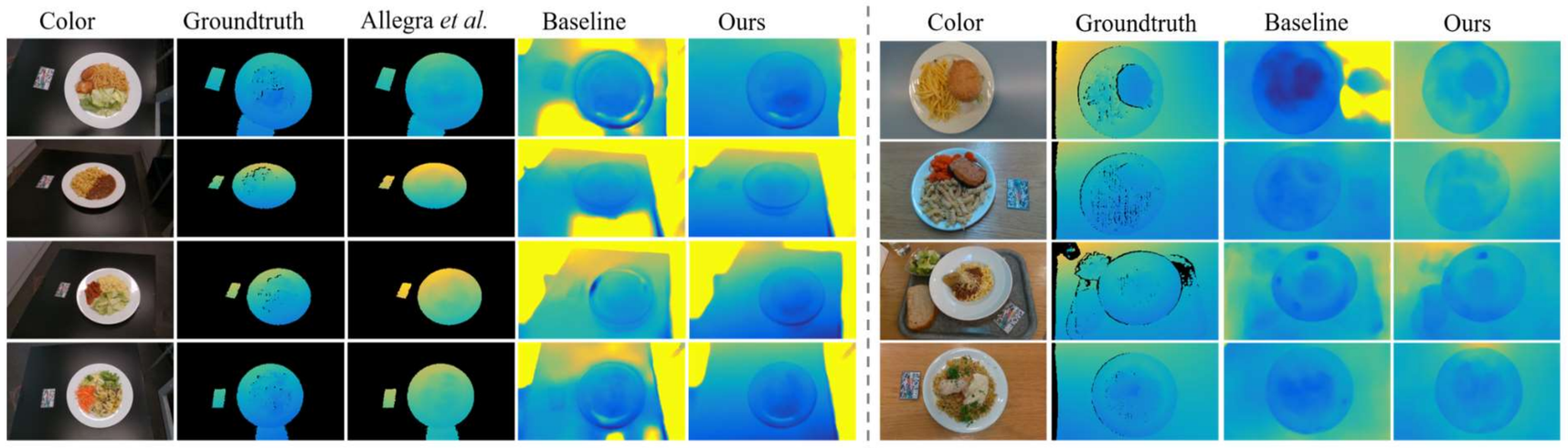


(a) Canteen database (contains 92 meals / videos); (b) MADiMa database [1] (contains 80 meals / videos)

Results

COMPARISON RESULTS OF DEPTH ESTIMATION. "M" AND "C" INDICATE MADIMA AND CANTEEN DATABASE, RESPECTIVELY. THE **BOLD** INDICATES THE BEST PERFORMANCE WITH UNSUPERVISED APPROACH, WHILE THE "_" IS THE BEST PERFORMANCE OF SUPERVISED METHOD.

Method	DB	Supervision	Error metrics				Accuracy metrics		
			Abs. Rel.	Sq. Rel.	RMSE	RMSE log	$\delta < 1.05$	$\delta < 1.05^2$	$\delta < 1.05^3$
Allegra *et al.* [1]	M	Depth	0.017	0.279	11.63	0.023	0.977	0.999	1.0
Lu *et al.* [2]	M	Depth	0.013	0.181	9.27	0.018	0.988	0.999	1.0
GeoNet [3]	M	Mono	0.028	1.719	26.55	0.046	0.885	0.955	0.974
Monodepth2 [4]	M	Mono	0.027	0.647	17.36	0.032	0.863	0.984	**0.998**
Ours	M	Mono	**0.022**	**0.488**	**14.86**	**0.029**	**0.907**	**0.989**	0.996
GeoNet [3]	C	Mono	0.080	4.160	29.90	0.097	0.434	0.721	0.873
Monodepth2 [4]	C	Mono	0.063	7.617	30.01	0.086	0.527	0.836	0.947
Ours	C	Mono	**0.056**	**1.536**	**20.53**	**0.070**	**0.535**	**0.834**	**0.951**



Ground truth is created with depth sensor; Allegra et al. uses the method from [1]; Baseline uses the method from [3]

COMPARISON RESULTS OF FOOD VOLUME ESTIMATION. "M" AND "C" INDICATE THE MADIMA AND CANTEEN DATABASE, RESPECTIVELY.

Method	Supervision	Img. Num.	DB	MAPE
Lu *et al.* [2]	Depth+Vol.	1	M	19.1%
Dehais *et al.* [5]	Mono views	2	M	36.1%
Ours	Mono	1	M	**25.2%**
Ours	Mono	1	C	20.3%

[1] and [2] are fully supervised approaches; [3] and [4] are video supervised approaches; [5] is Structure from Motion (SfM) based approach

Conclusions

- We propose a partially supervised network architecture that jointly predicts depth map, semantic segmentation map and 3D table plane from a single RGB food image, for the first time enabling a full-pipeline single-view dietary assessment.
- The training procedure is only supervised by monocular videos with small number of semantic ground truth.
- The proposed network significantly outperforms the SfM-based approach and the SOTA unsupervised approach, while presenting a comparable performance with respect to the fully supervised approach.

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References

[1] Allegra et al., "A multimedia database for automatic meal assessment system", ICIAP, 2017
[2] Lu et al. ,"A multi-task learning approach for meal assessment", MADiMa@IJCAI, 2018
[3] Z. Yin and J. Shi, "GeoNet: Unsupervised learning of dense depth, optical flow and camera pose," CVPR, 2018
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[5] J. Dehais et al., "Two-view 3D reconstruction for food volume estimation", TMM, 2017.