Denoise and Contrast for Category Agnostic Shape Completion

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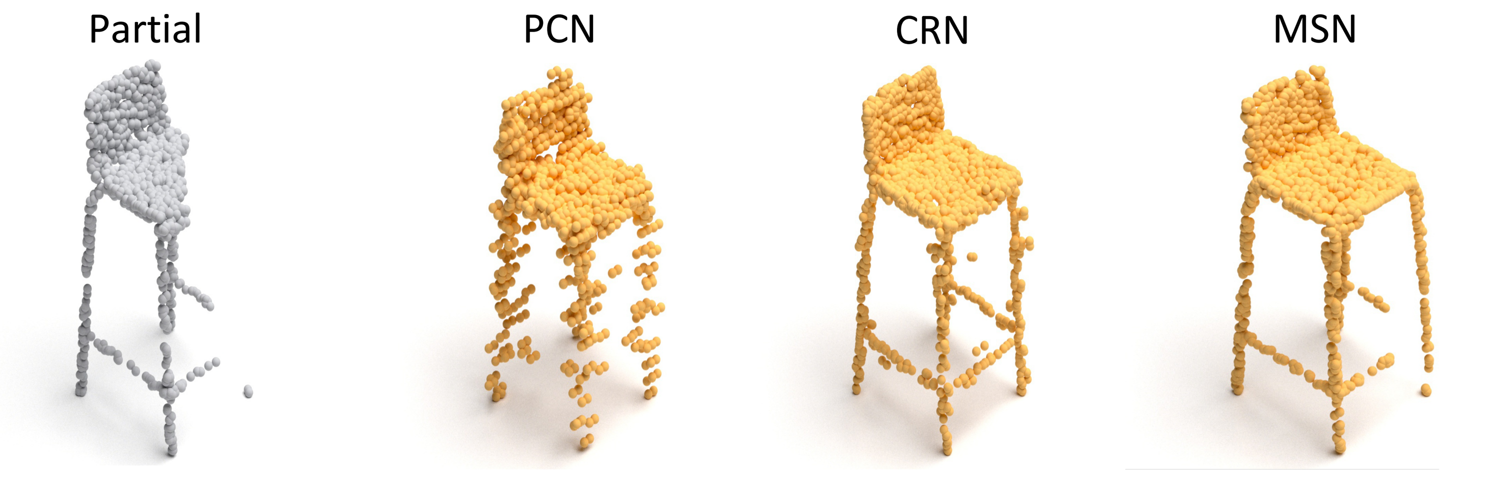
Shape Completion

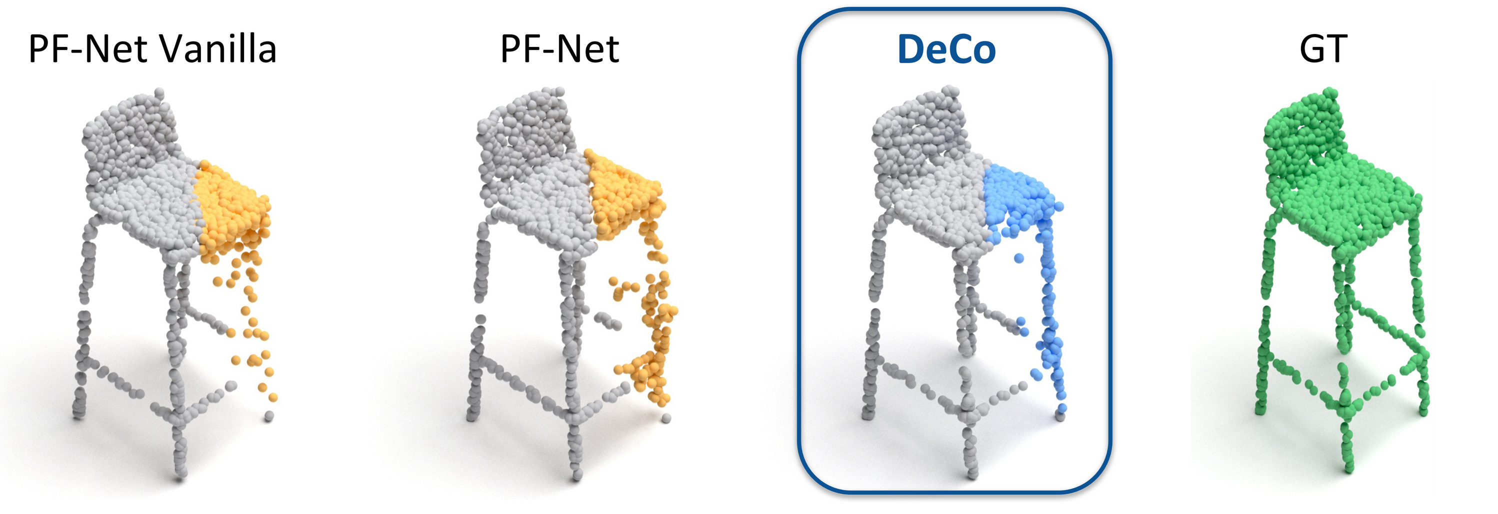
Point Cloud Completion aims to estimate the complete geometry of object from partial observation

- **Preserving details from the partial observation**
- **Modelling the missing part with realistic structure**

Existing models fail to meet both these requirements:

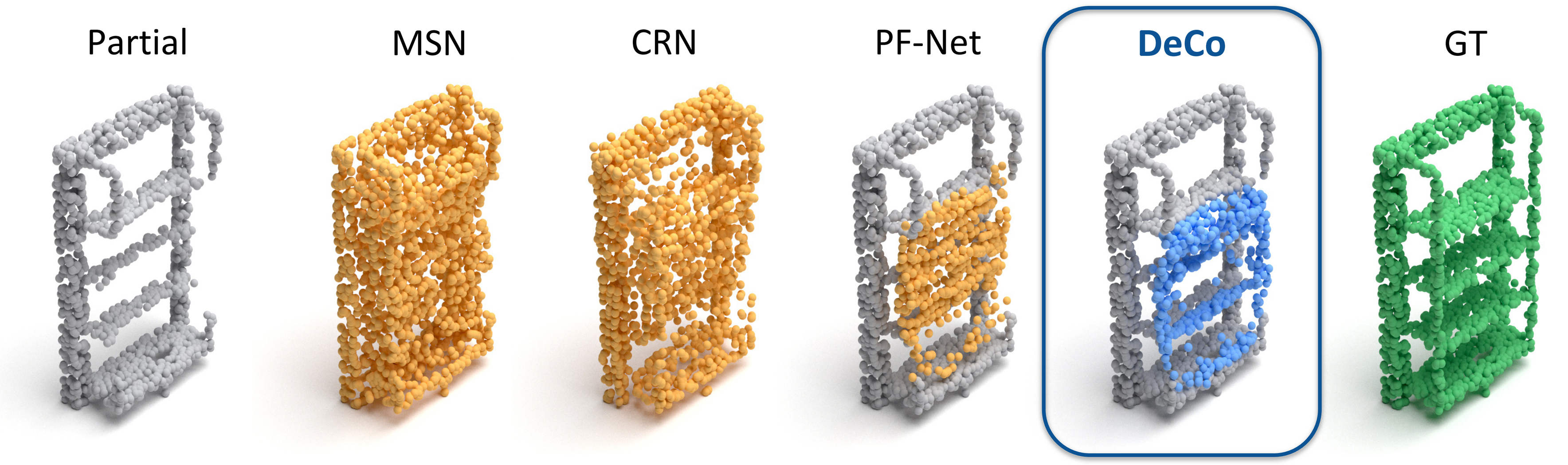


	PCN	CRN	MSN
Partial preservation	✗	✗	✓
Missing part modelling	✗	✗	✗



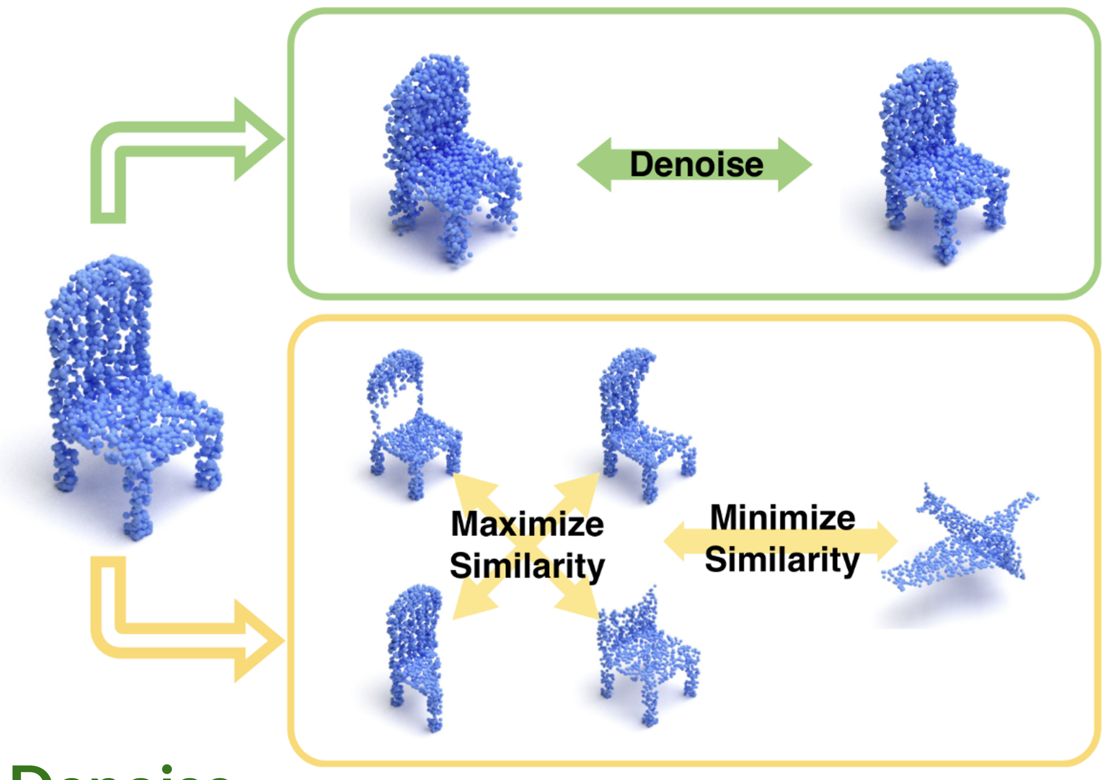
	PF-Net Vanilla	PF-Net	DeCo
Partial preservation	✓	✓	✓
Missing part modelling	✗	✗	✓

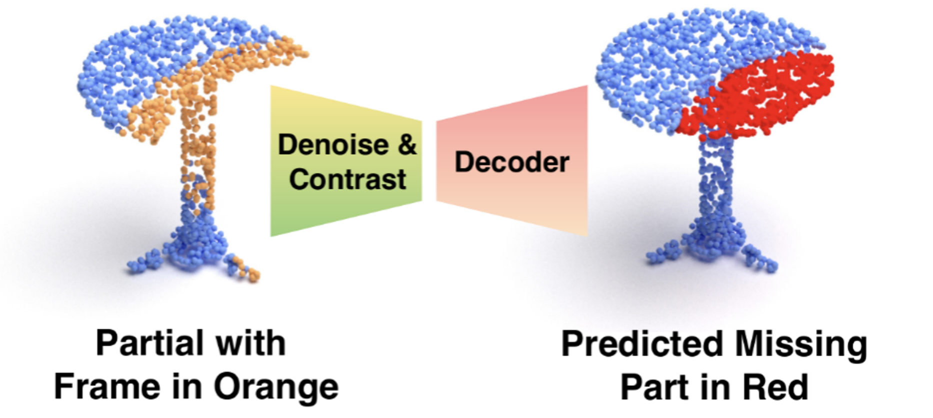
- **What about completion of Unknown categories?**



	MSN	CRN	PF-Net	DeCo
Partial preservation	✗	✗	✓	✓
Missing part modelling	✗	✗	✗	✓

Method





- **Denoise**
  - Accounting for local structures in the shape topology
  - Local features better generalize to Unknown classes

$\tilde{X}$: noised point clouds

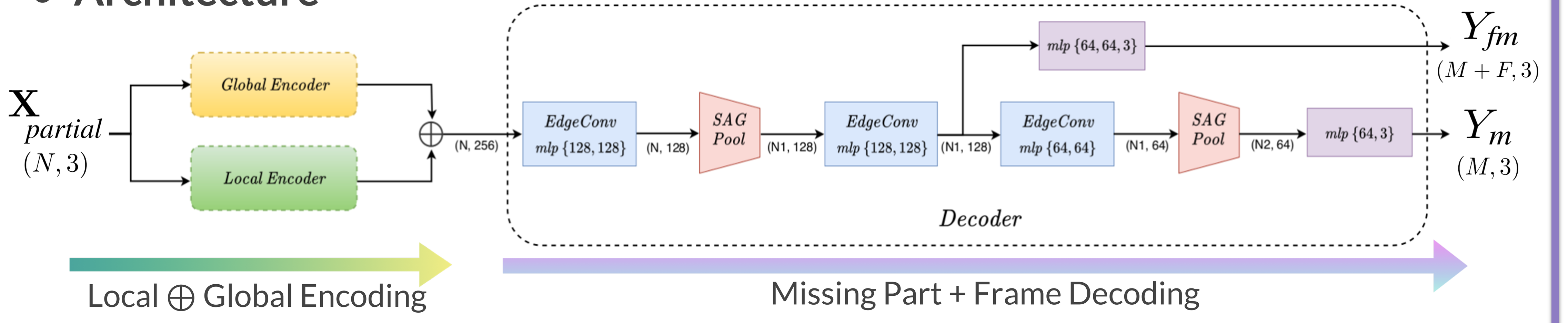
X: noiseless ground truths

$$\mathcal{L}_{MSE} = \frac{1}{N+M} \sum_{\substack{\tilde{x} \in \tilde{X} \\ x \in X}} \|\tilde{x} - x\|^2$$

- **Contrast**
  - At a *global level*: the set $\mathcal{P}(i)$ of partial observations of the same i-th shape should encode similar information

$$\mathcal{L}_{NT-Xent} = \frac{-1}{|\mathcal{P}(i)|} \sum_{j \in \mathcal{P}(i)} \log \frac{\exp(\text{sim}(z_i, z_j)/\tau)}{\sum_{k=1}^{4K} \mathbb{1}_{[k \neq i]} \exp(\text{sim}(z_i, z_k)/\tau)}$$

- **Frame Regularization**
  - Intermediate strategy between whole shape reconstruction and missing part prediction
  - Better blend the generated part with the partial observation
- **Architecture**



- **Completion Training loss**

X_m : missing part ground truths, X_{fm} : frame + missing ground truths

$$\mathcal{L}_{CD} = \frac{1}{2M}\Big\{ \sum_{x \in X_m} \min_{y \in Y_m} \|x - y\|_2^2 + \sum_{y \in Y_m} \min_{x \in X_m} \|y - x\|_2^2 \Big\} + \frac{1}{2(M+F)}\Big\{ \sum_{x \in X_{fm}} \min_{y \in Y_{fm}} \|x - y\|_2^2 + \sum_{y \in Y_{fm}} \min_{x \in X_{fm}} \|y - x\|_2^2 \Big\}$$

Results

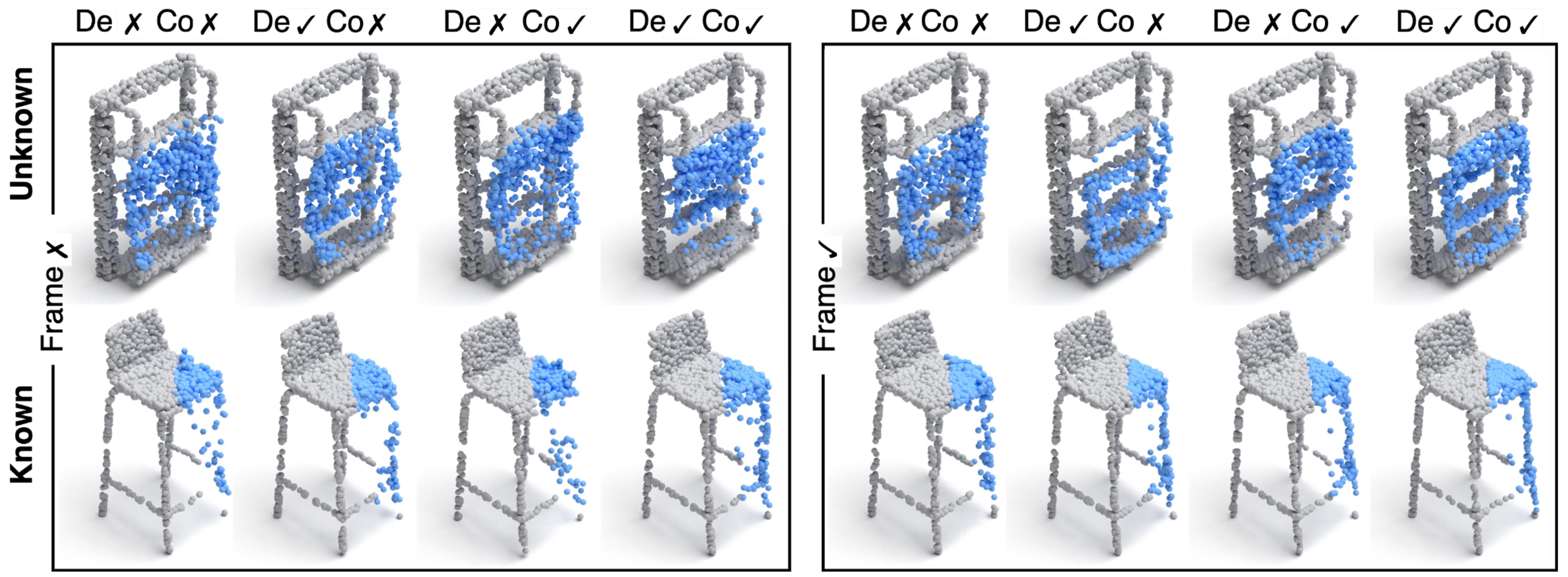
Known Categories

Category	PCN [39]	MSN [16]	CRN [30]	PF-Net vanilla [11]	PF-Net [11]	DeCo
Airplane	31.515	15.907	39.334	11.015	10.805	**10.003**
Bag	37.825	59.185	33.593	40.000	38.485	**28.508**
Cap	66.275	40.276	53.146	49.945	50.450	**36.436**
Car	24.320	24.176	39.537	21.925	**21.640**	22.963
Chair	31.265	20.751	28.688	19.130	19.490	**16.428**
Lamp	93.745	41.094	30.207	41.555	42.910	**24.150**
Laptop	22.460	11.718	26.393	11.520	**11.220**	12.706
Motorbike	34.420	21.276	41.292	20.525	19.905	**19.136**
Mug	35.905	57.007	41.153	32.800	**31.880**	34.239
Pistol	29.490	14.560	26.845	11.395	**10.885**	12.266
Skateboard	23.815	14.146	34.358	12.275	12.365	**9.861**
Table	24.775	22.103	23.953	20.560	20.845	**17.120**
Guitar	10.540	6.959	15.224	4.350	**4.425**	4.482
Overall	34.095	22.410	29.044	20.209	20.445	**16.517**

Unknown Categories

Categories	MSN [16]	CRN [30]	PF-Net vanilla [11]	PF-Net [11]	DeCo
Similar					
Bicycle	47.423	64.275	49.779	47.186	39.684
Basket	48.100	50.692	58.866	57.066	**34.613**
Helmet	71.161	57.851	63.742	69.849	**47.412**
Bowl	52.002	63.357	97.316	78.793	**35.209**
Rifle	34.712	47.239	25.438	28.684	**12.004**
Vessel	30.948	41.418	27.122	31.114	**18.836**
Overall	35.544	46.166	31.232	33.844	**17.680**
Dissimilar					
Piano	62.969	61.643	62.131	62.994	**49.429**
Bookshelf	48.397	44.738	58.920	55.123	**34.681**
Bottle	29.580	20.134	25.543	24.578	**20.002**
Clock	57.222	38.132	50.964	48.373	**32.826**
Microwave	53.354	56.259	61.702	56.152	**41.877**
Telephone	38.032	25.554	38.085	32.063	**20.106**
Overall	45.049	34.625	45.014	41.449	**28.403**

Visual Ablation



Conclusion

We propose **DeCo** for point cloud completion in which:

- **Local and global feature encoding** is enforced by (1) specific **architectural choices** and (2) the use of **tailored pretext tasks**
- **Framing strategy** allows us to blend the generated output with the partial obs.

Achieving **SOTA** for both **Known and Unknown classes**

Code: github.com/antoalli/Deco