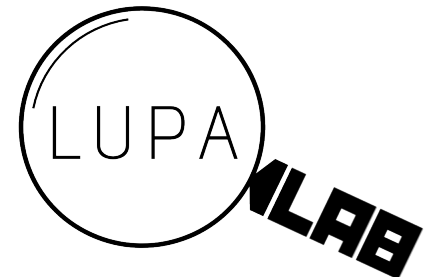


# Partially Observed Exchangeable Modeling

Yang Li, Junier Oliva



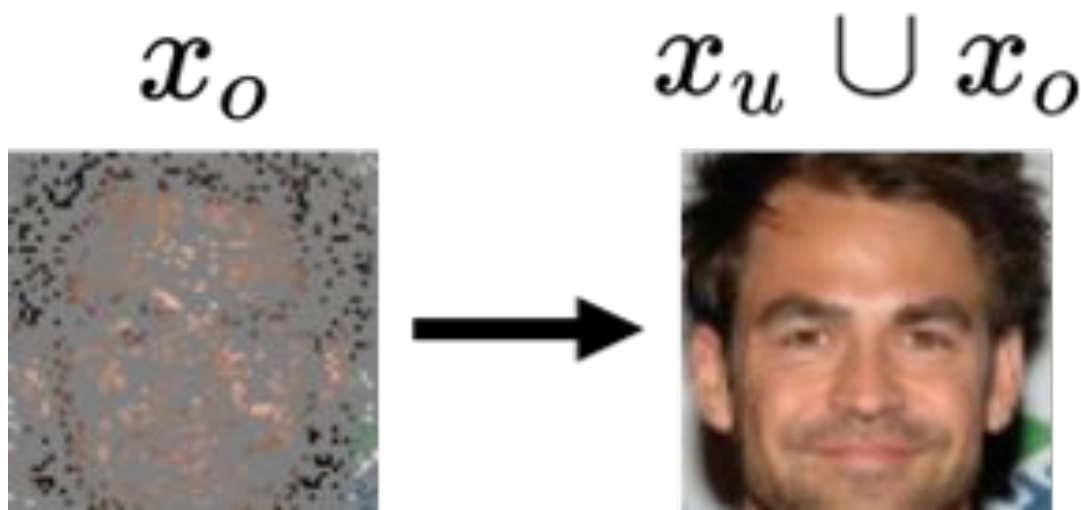
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# Conditional Dependencies

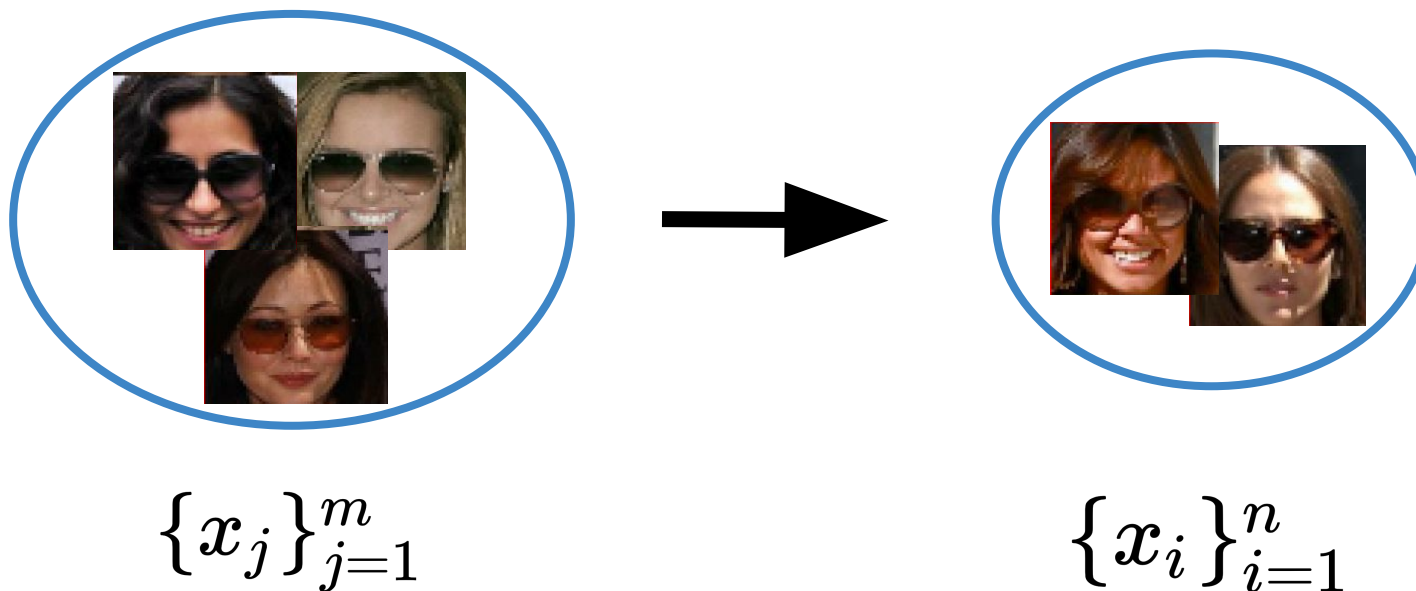
dependencies among features



$$p(x_u \mid x_o) \quad u, o \subseteq \{1, \dots, d\}$$

# Conditional Dependencies

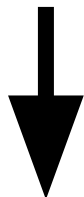
dependencies among instances



$$p(\{x_i\}_{i=1}^n \mid \{x_j\}_{j=1}^m)$$

# Conditional Dependencies

dependencies among features & instances



$$\{x_i^{(o)}\}_{i=1}^n$$

$$\{x_i^{(o \cup u)}\}_{i=1}^n$$

$$p(\{x_i^{(u)}\}_{i=1}^n \mid \{x_i^{(o)}\}_{i=1}^n)$$

# Conditional Dependencies

dependencies among features & instances

May 12, 2020

**Age: 47**  
**Weight: 160**  
**Heart Rate: 104**

**Blood Test:**

Lab Test	Value	Normal Range
WBC (cells/cmm)	8.88	3.5-10.5
Hemoglobin (g)	47	40-54
Lymphocytes (%)	28	20-40
Monocytes (%)	10	2-8
Granulocytes (%)	5	1-5
Eosinophils (%)	0	1-5
RDW (sd)	3.54	4.1-5.7
Hb (g/L)	15.7	13-17
Hematocrit (%)	37	37-47
Platelets (platelets/L)	302	150-450

May 14, 2020

**Age: 47**  
**Weight: 160**  
**Heart Rate: 102**

**X-Ray:**



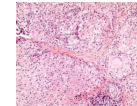
**MRI:**



May 18, 2020

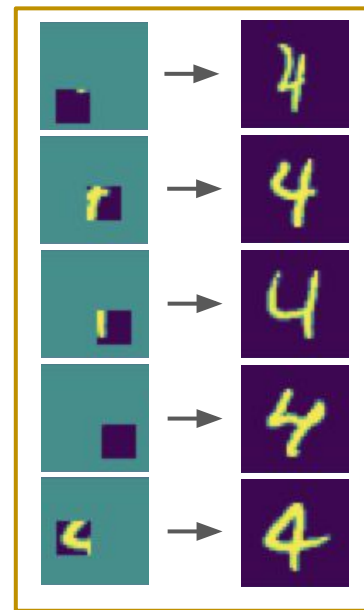
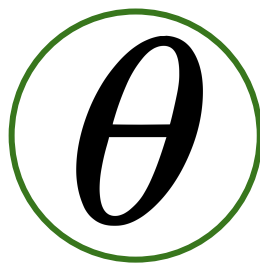
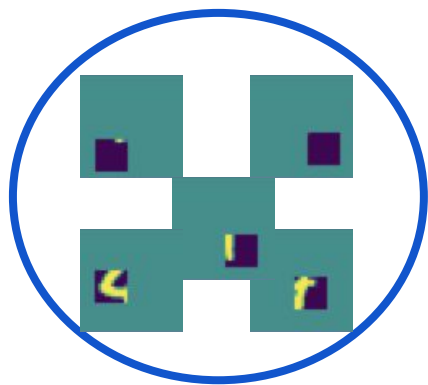
**Age: 47**  
**Weight: 160**  
**Heart Rate: 108**

**Biopsy:**



# Partially Observed Exchangeable Modeling (POEx)

$$p(\{x_i^{(u)}\}_{i=1}^n \mid \{x_i^{(o)}\}_{i=1}^n)$$



$$q(\theta \mid \{x_i^{(o)}\}_{i=1}^n)$$

$$\prod_{i=1}^n p(x_i^{(u)} \mid x_i^{(o)}, \theta)$$

# Applications

## Few-shot Imputation

$$\{x_i^{(u)}\}_{i=1}^n \sim p(\{x_i^{(u)}\}_{i=1}^n \mid \{x_i^{(o)}\}_{i=1}^n)$$

G.T.



observed



imputed



independent



# Applications

## Set Expansion

$$\{x_i^{(u)}\}_{i=1}^n \sim p(\{x_i^{(u)}\}_{i=1}^n \mid \{x_i^{(o)}\}_{i=1}^n)$$

$x_i$  some are fully observed and others are fully unobserved

observed

expanded





# Applications

## Few-shot Generation

generate novel instances given several examples on unseen classes

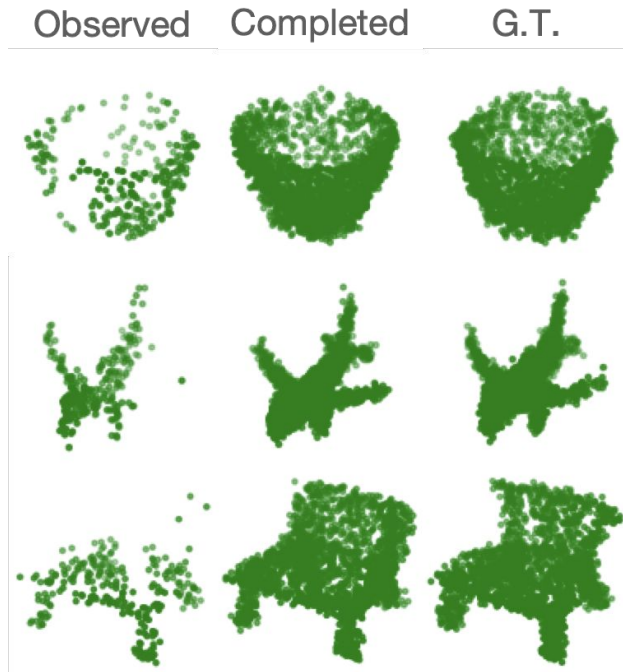
observed

generated

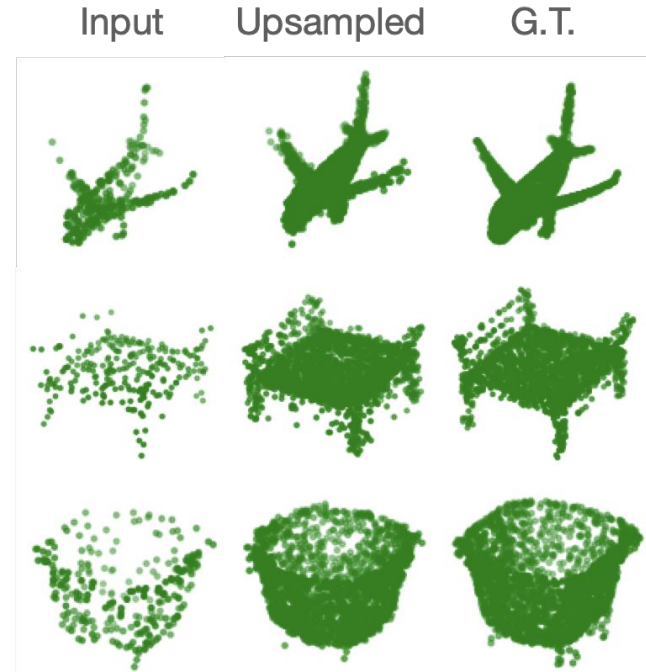


# Applications

## Point Cloud Expansion



point cloud completion



point cloud upsampling

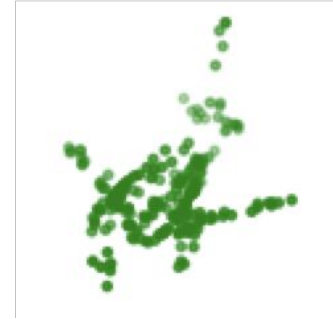
# Applications

## Set Compression

given



select



to represent the underlying geometry

$$o = \emptyset$$

$$\text{while } |o| < K$$

$$i = \operatorname{argmax}_{i \notin o} H(x_i \mid \{x_j; j \in o\})$$

$$o = o \cup \{i\}$$

The next element to select is the **most uncertain** one based on the current selection

# Applications

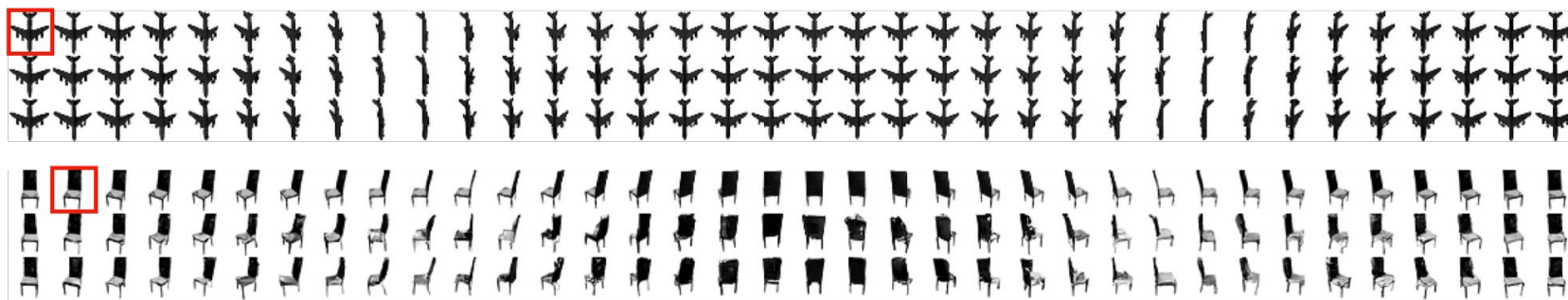
## Neural Processes

Introduce an index variable  $t_i$  for each set element  $x_i$

$$p(\{x_j; j \notin o\} \mid \underbrace{\{t_j; j \notin o\}}_{\text{permutation equivariant}}, \underbrace{\{(t_i, x_i); i \in o\}}_{\text{permutation invariant}})$$

permutation equivariant

permutation invariant



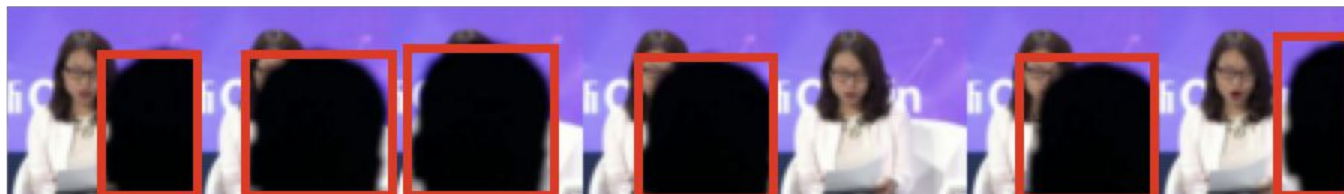
red box indicates the observed context;  $t$  represents the view points (angle)

# Applications

## Video Imputation

$t$  represents the timestamps of each frame

Given



POEx



# Applications

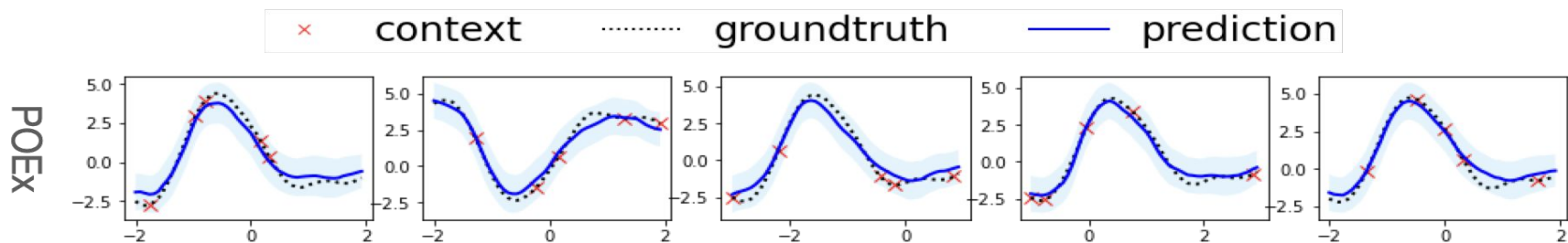
## Set of Functions

model a set of correlated functions using a finite set of input-target pairs from each function

$$p\left(\left\{\left\{y_t\right\}_{t=1}^{N_t}\right\}_{k=1}^K \mid \underbrace{\left\{\left\{x_t\right\}_{t=1}^{N_t}\right\}_{k=1}^K}_{\text{permutation equivariant}}, \underbrace{\left\{\left\{(x_c, y_c)\right\}_{c=1}^{N_c}\right\}_{k=1}^K}_{\text{permutation invariant}}\right)$$

permutation equivariant

permutation invariant



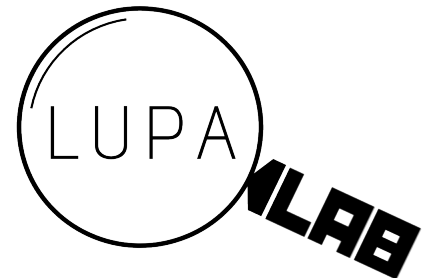
# Summary

- POEx jointly models the intra-instance (among features in a point) and the inter-instance (among multiple points in a set) dependencies in data
- POEx is a general framework that encompasses many existing tasks such as point cloud expansion and few-shot generation
- POEx enables imputation model to leverage information from multiple instances
- POEx can be extended to model a set of correlated functions

# Thanks!



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