Search for Concepts: Discovering Visual Concepts Using Direct Optimization

Pradyumna Reddy[1] Paul Guerrero[2] Niloy J. Mitra[1,2]
[1]University College London [2]Adobe Research

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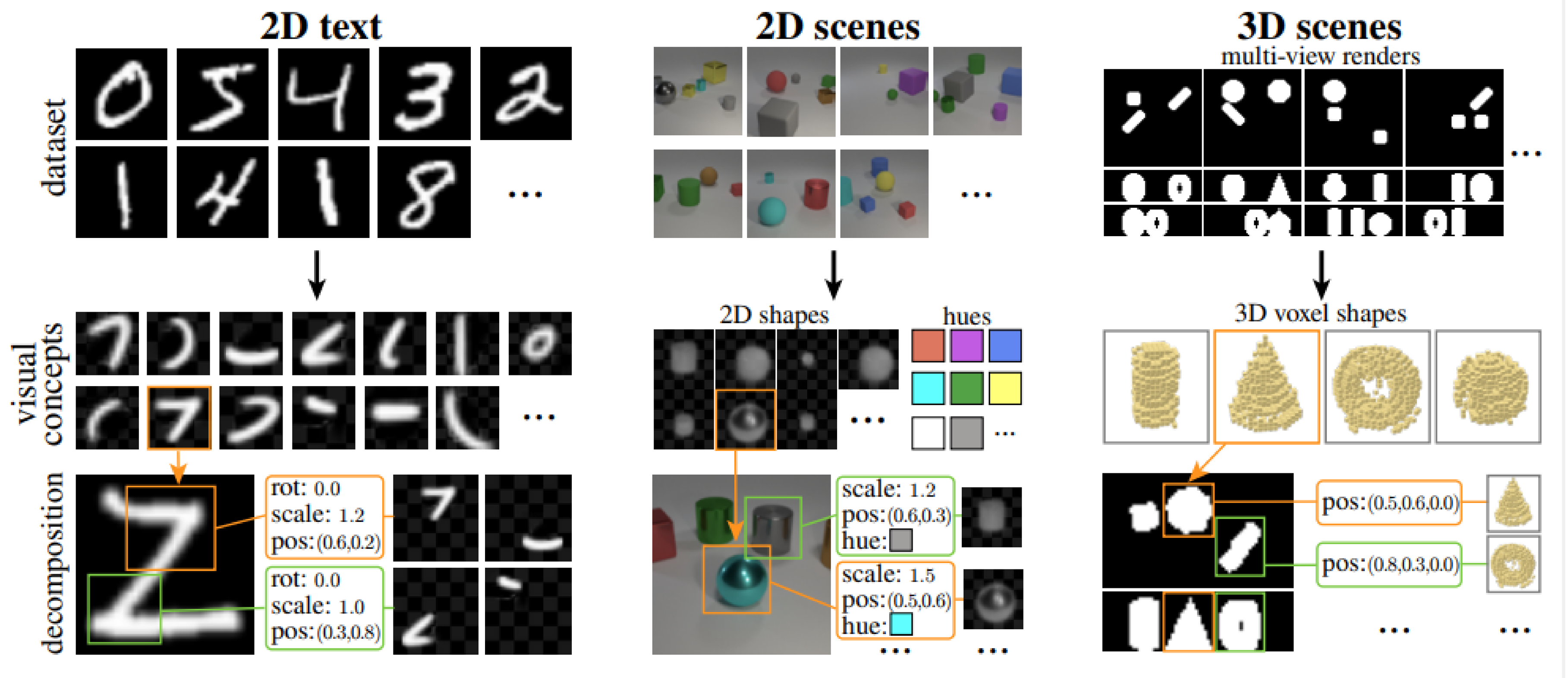
Motivation

Finding an unsupervised decomposition of an image into individual objects is a key step to leverage compositionality and to perform symbolic reasoning. Traditionally, this problem is solved using amortized inference, which does not generalize beyond the scope of the training data, may sometimes miss correct decompositions, and requires large amounts of training data.

We propose finding a decomposition using direct, unamortized optimization, via a combination of a gradient-based optimization for differentiable object properties and global search for non-differentiable properties.



How ??

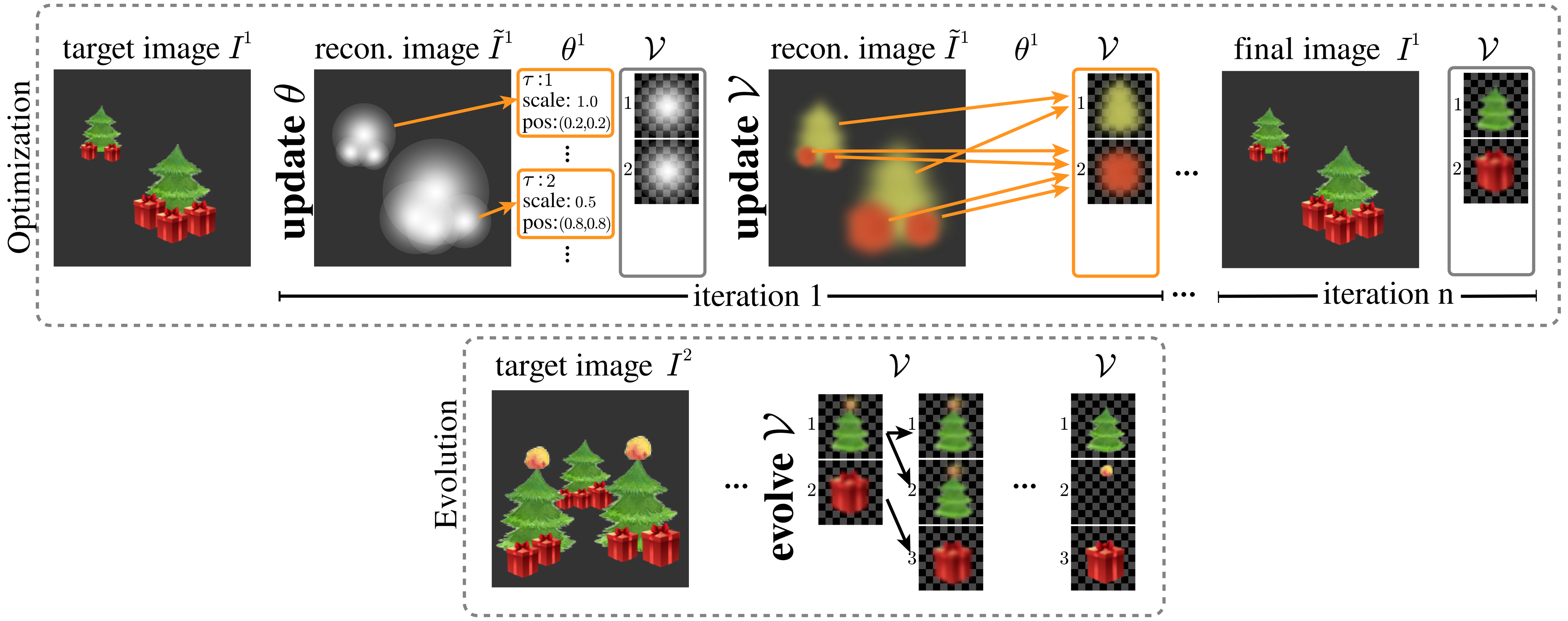
Convolution-based Grid Search: Re-writing normalized cross-correlation based search as convolutions.

$$argmax_{\theta_i} \frac{\sum_p (IC_1)_p + (IC_2 \circledast \hat{E}_i + IC_3 \circledast (1-\hat{E}_i^A))_{t_i}}{\sqrt{\sum_p I_p^2}\ \sqrt{\sum_p (C_1^2)_p + (\mathcal{N}_i)_{t_i}}}$$

$$\text{with } \mathcal{N}_i = C_2^2 \circledast \hat{E}_i^2 + C_3^2 \circledast (1-\hat{E}_i^A)^2 + 2C_1C_2 \circledast \hat{E}_i + 2C_1C_3 \circledast (1-\hat{E}_i^A) + 2C_2C_3 \circledast \hat{E}_i(1-\hat{E}_i^A)$$

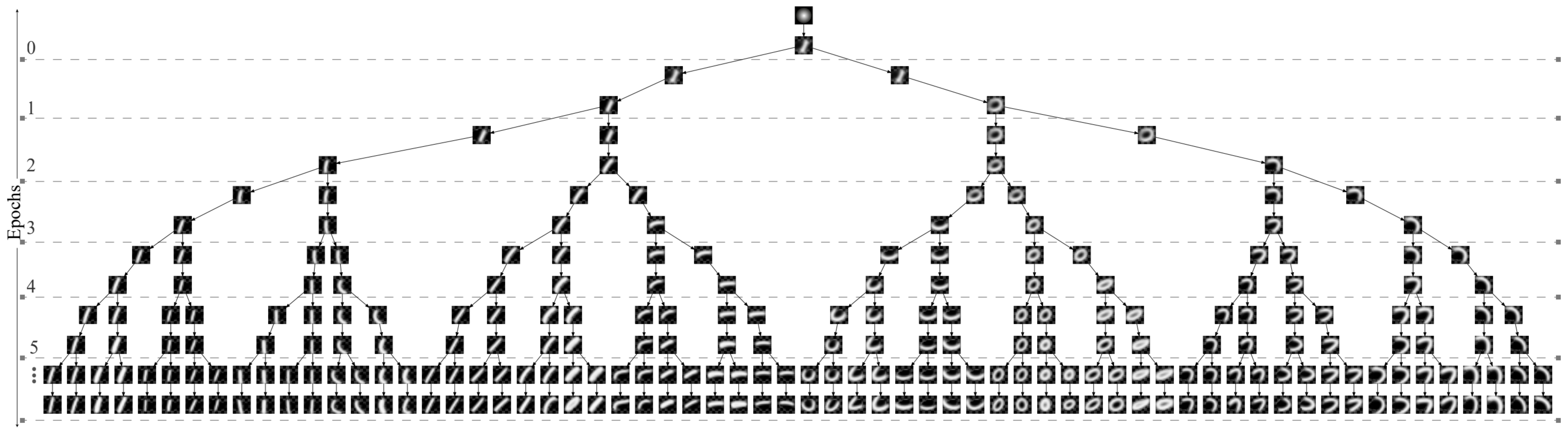
Architecture

Overview of our approach. Given an image dataset I = {I_1, . . . , I_N }, we alternate between updating element parameters θ (such the choice of visual concept τ, its position, scale, etc.) and the visual concepts V. We iterate over multiple target images Ik before evolving V by cloning concepts that are used often and have a large error.



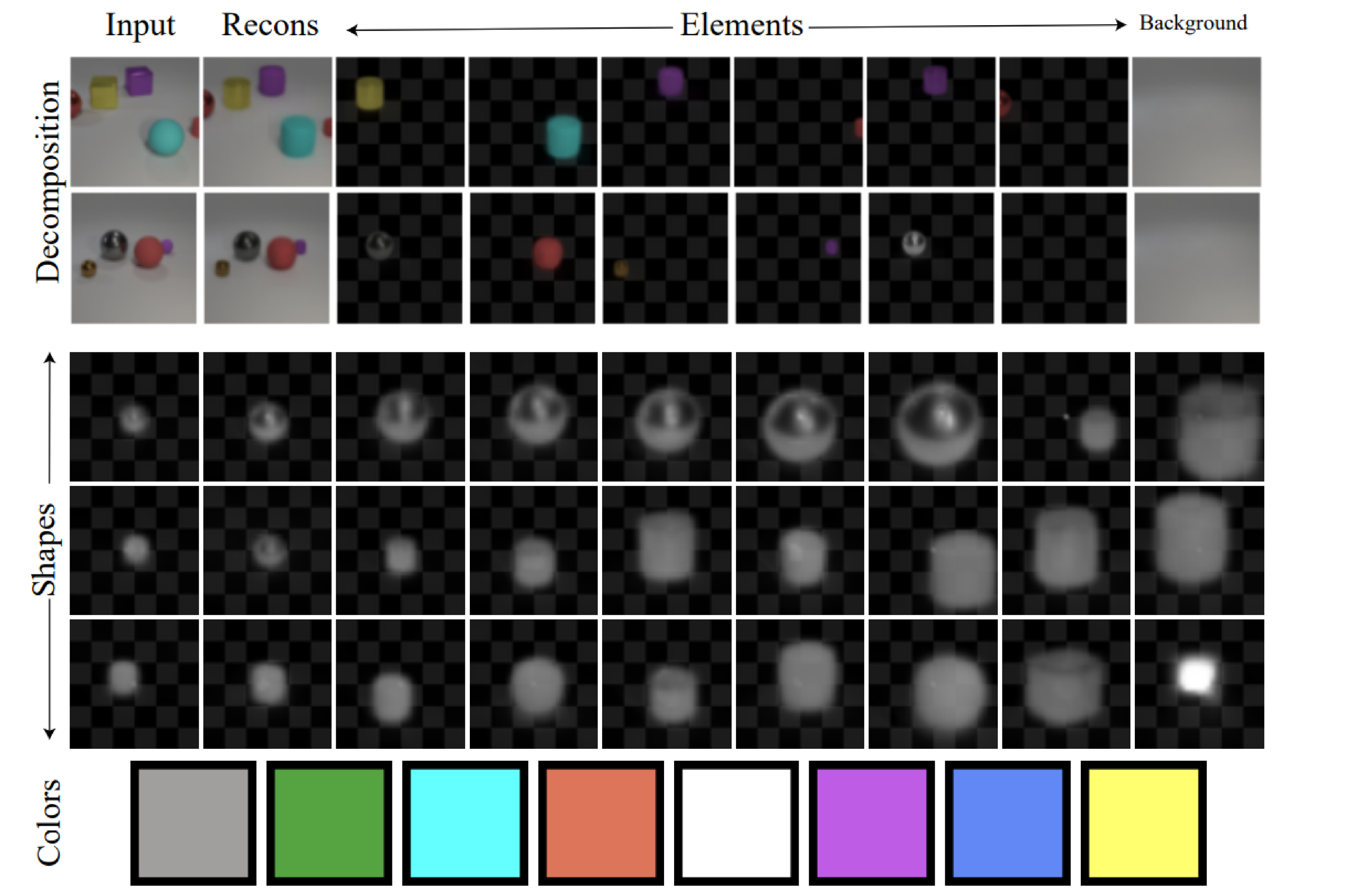
Evolution Graph

Visual concept evolution for the MNIST dataset. Note how the concepts evolve over optimization epochs by specializing to subtle stroke variations.

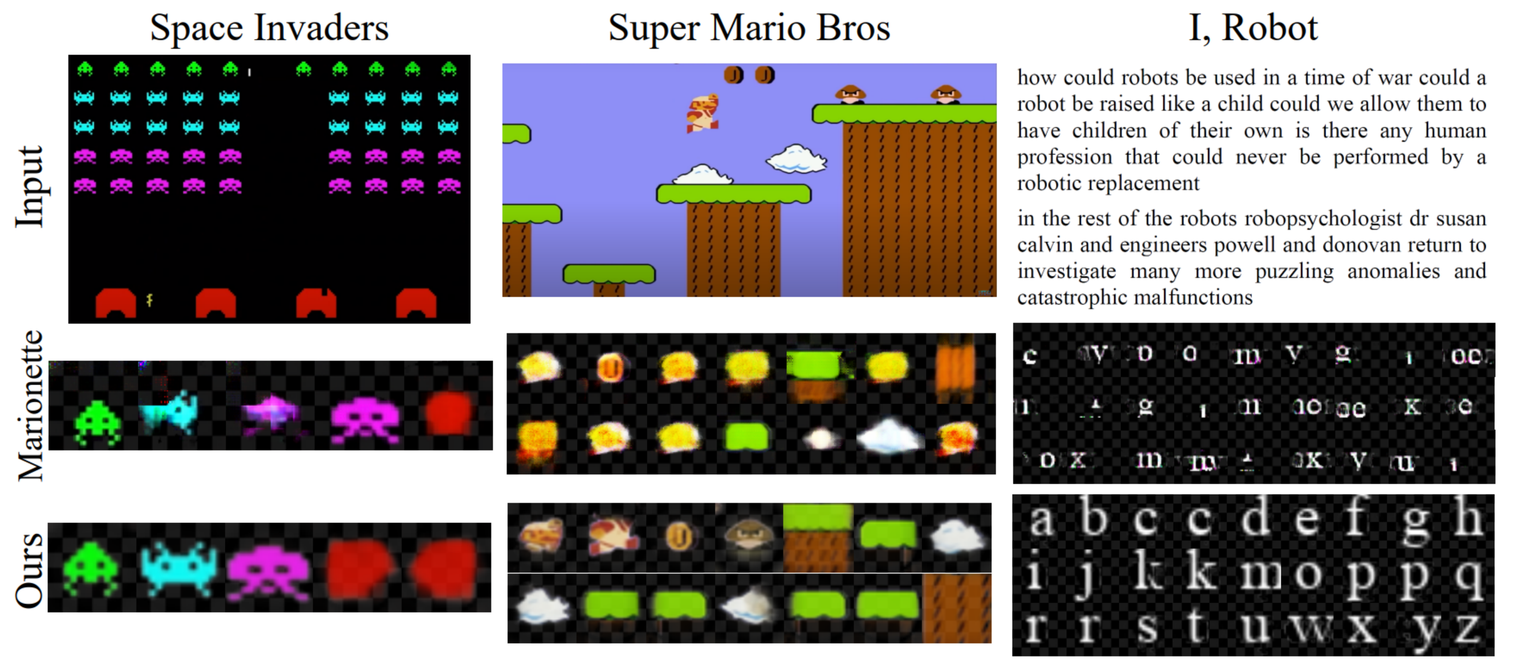


Results

Decomposition result on the Tetris dataset, showing composite concepts consisting of both learned shapes and learned hues



Ours on MarioNette and recovered concepts.



Links

Website: geometry.cs.ucl.ac.uk/projects/2022/SearchForConcepts

Code : github.com/preddy5/SearchForConcepts