

Hierarchical Neural Coding for Controllable CAD Model Generation

ICML 2023

Xiang Xu^{1,2} Pradeep Kumar Jayaraman² Joseph G. Lambourne²
Karl D.D. Willis² Yasutaka Furukawa¹

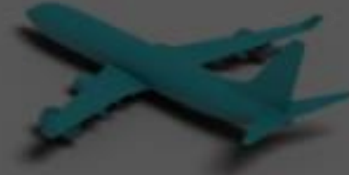
The logo for Simon Fraser University (SFU), consisting of the letters "SFU" in white on a red rectangular background.

¹Simon Fraser University

The Autodesk logo, featuring a stylized "A" icon followed by the word "AUTODESK" in a bold, sans-serif font.

²Autodesk Research



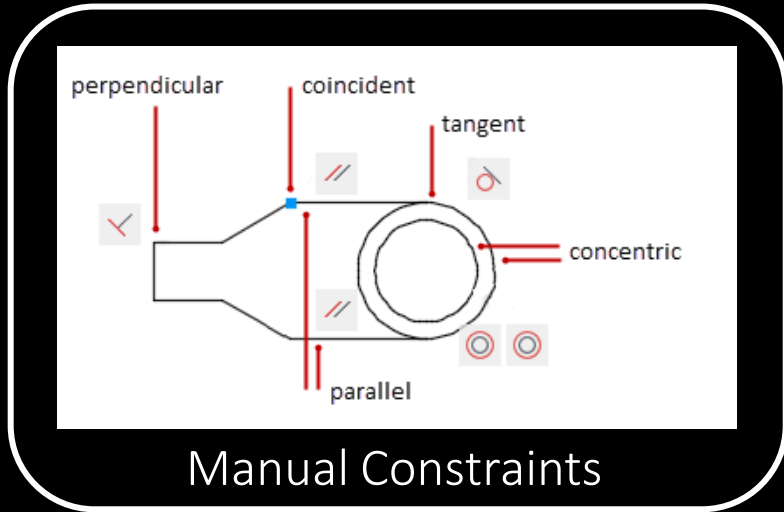


Design intent defines the relationships between different parts of a CAD model

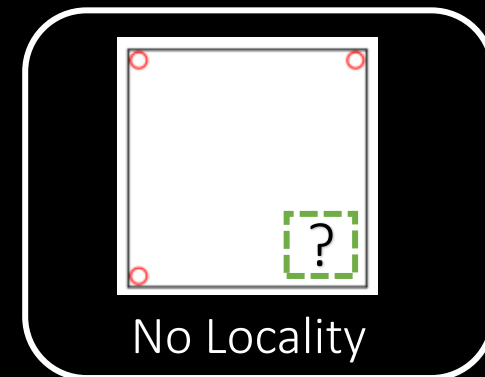
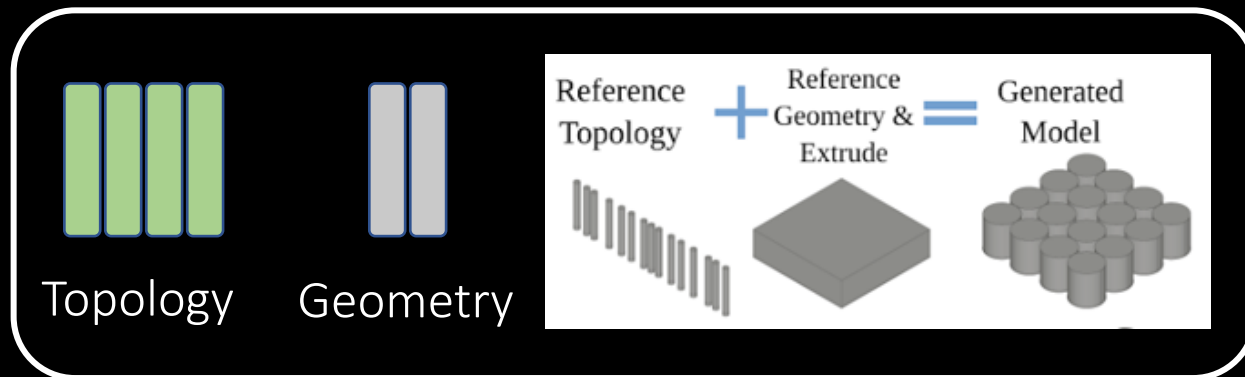


Current Approaches for Controllable CAD Generation

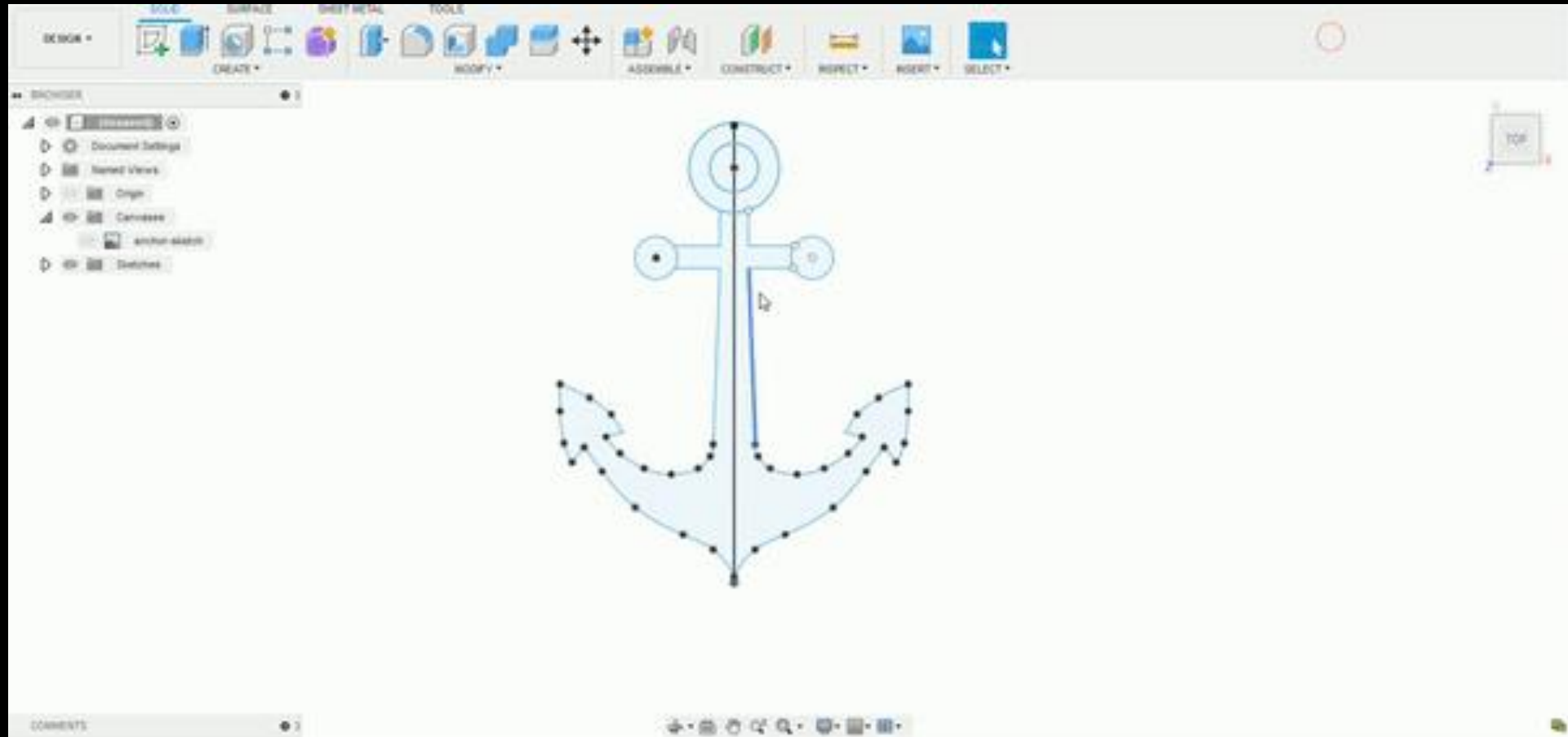
Parametric CAD



SkexGen



Sketch and Extrude Representation

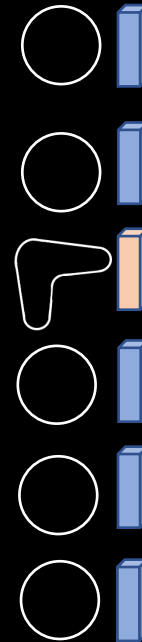


Hierarchical Representation

Solid

Profile

Loop

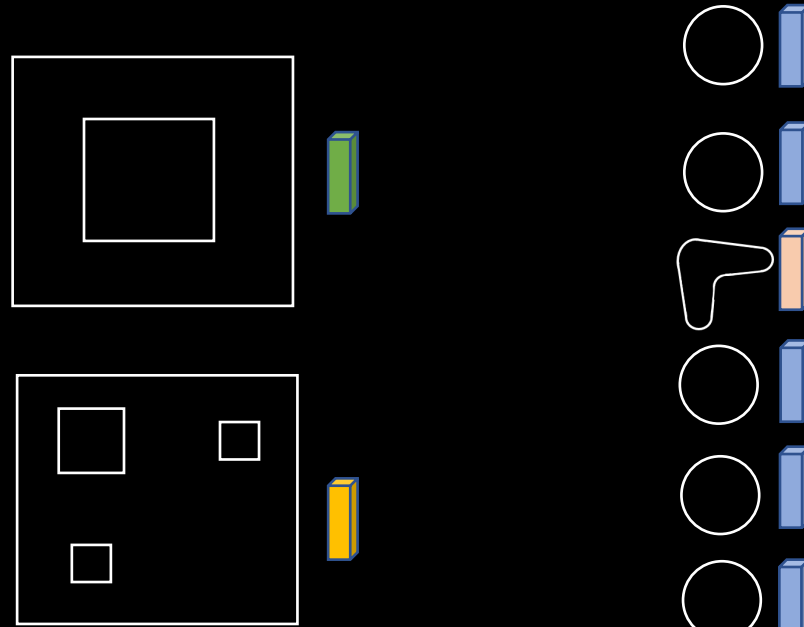


Hierarchical Representation

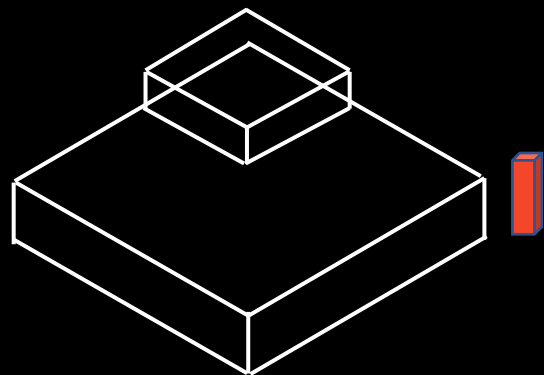
Solid

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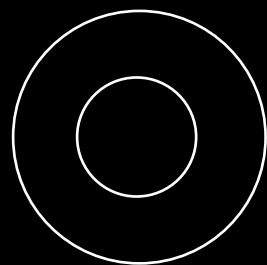
Loop



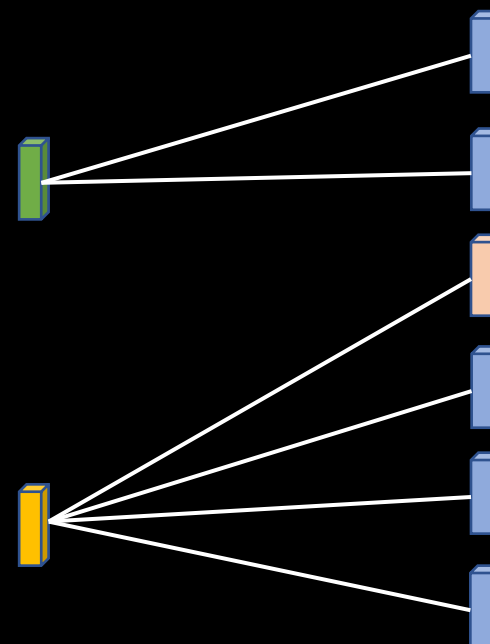
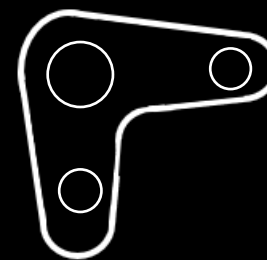
Hierarchical Representation



Solid

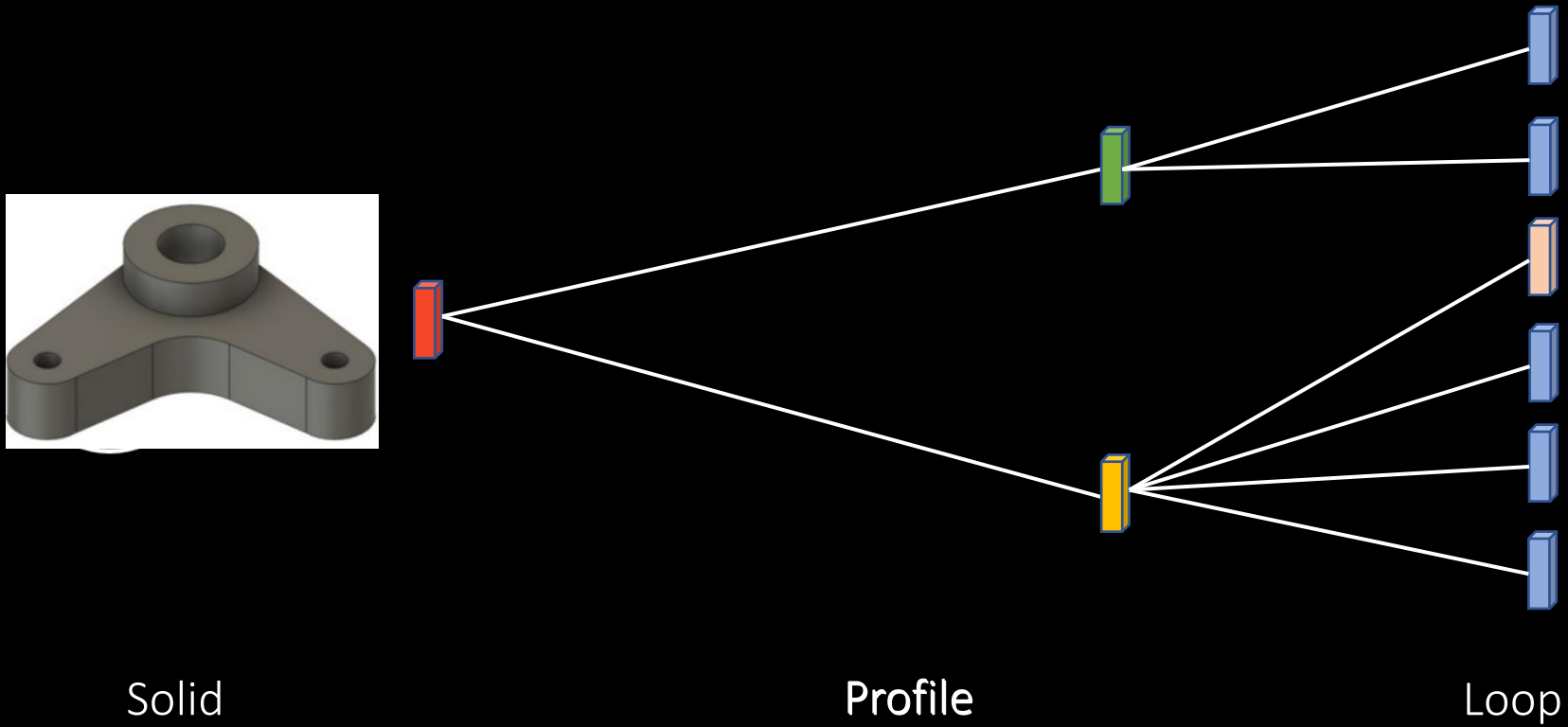


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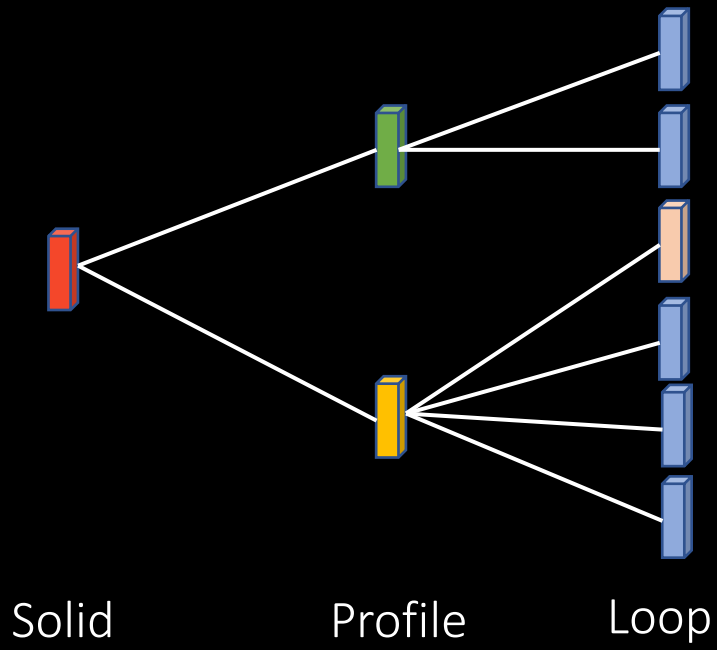


Loop

Hierarchical Representation



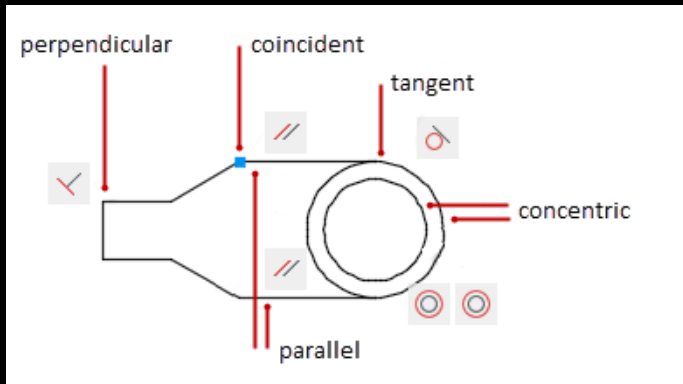
Three-level code tree



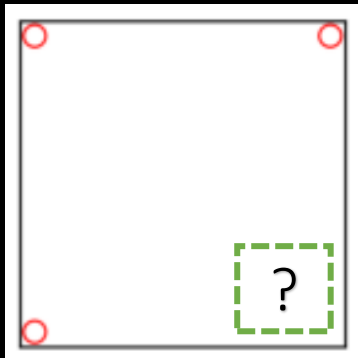
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Manual Constraints

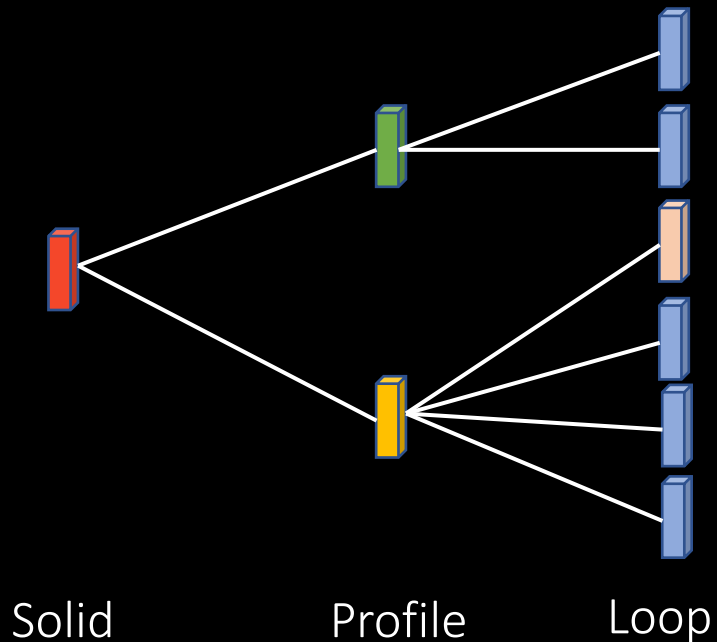


No Locality



Failures After Edit

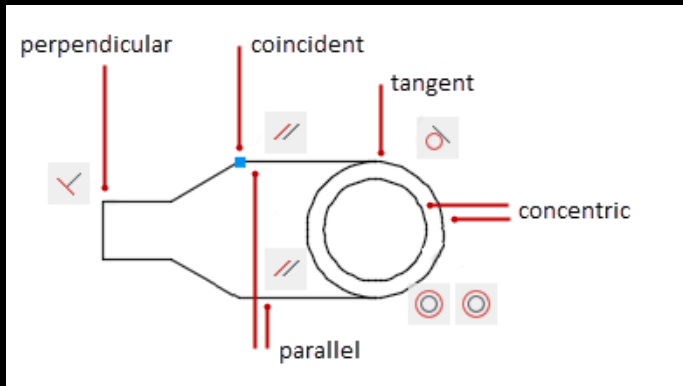
Three-level code tree



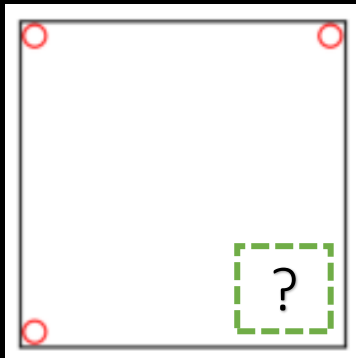
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Manual Constraints

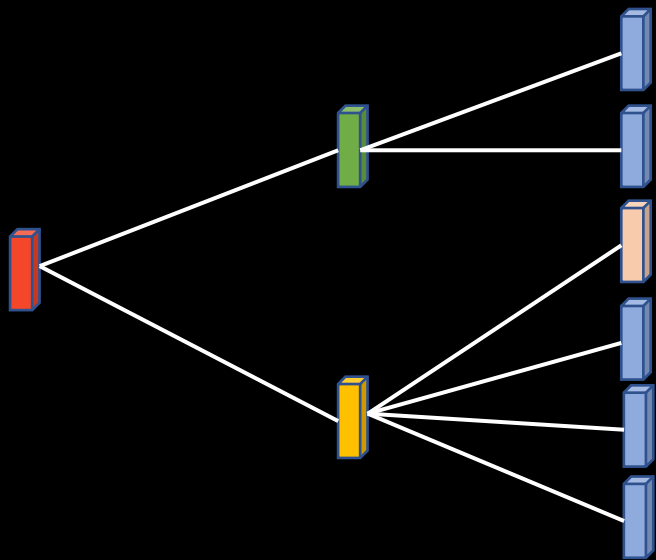


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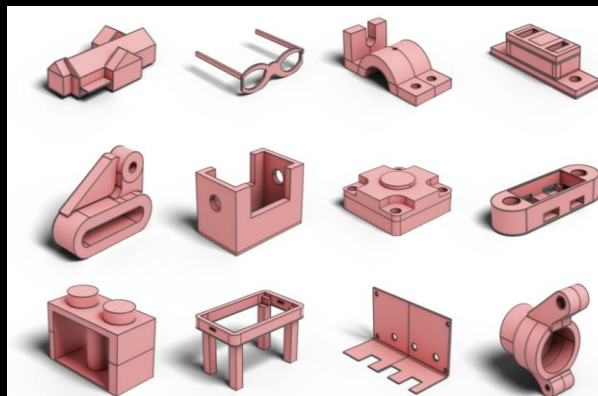
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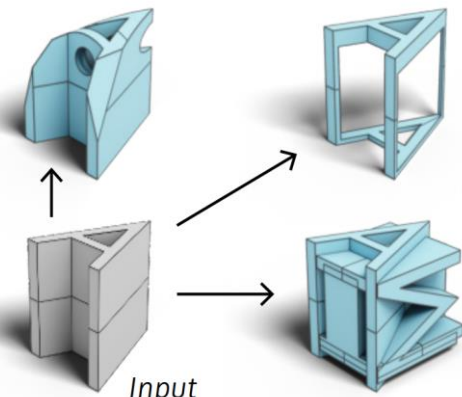
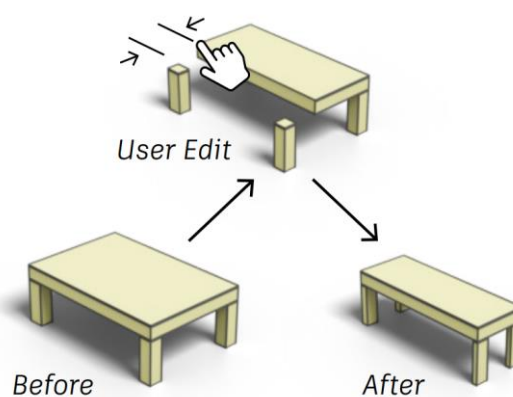
Solid

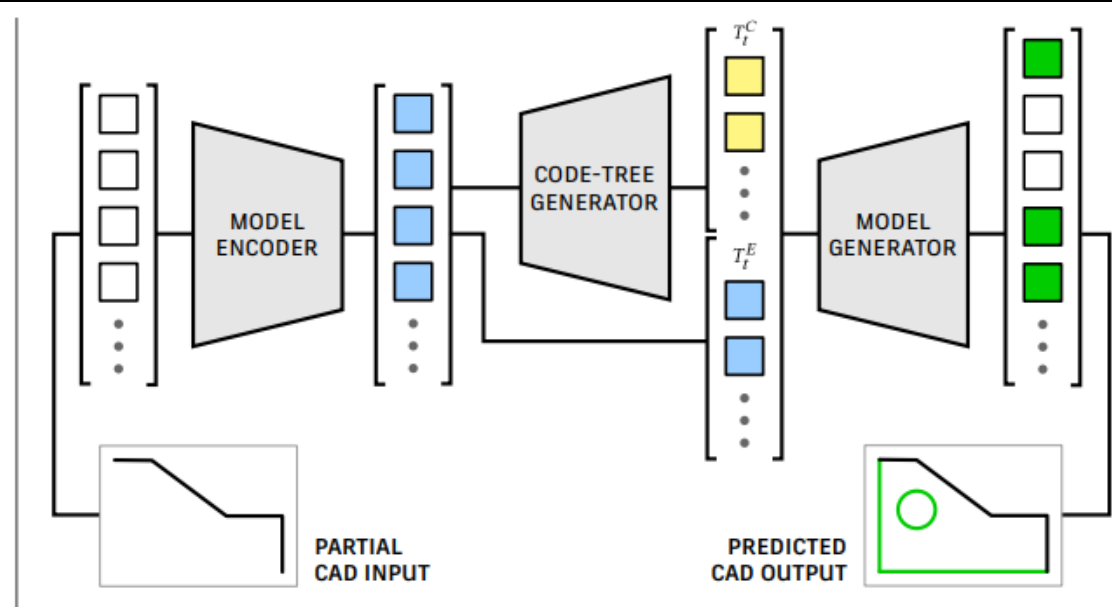
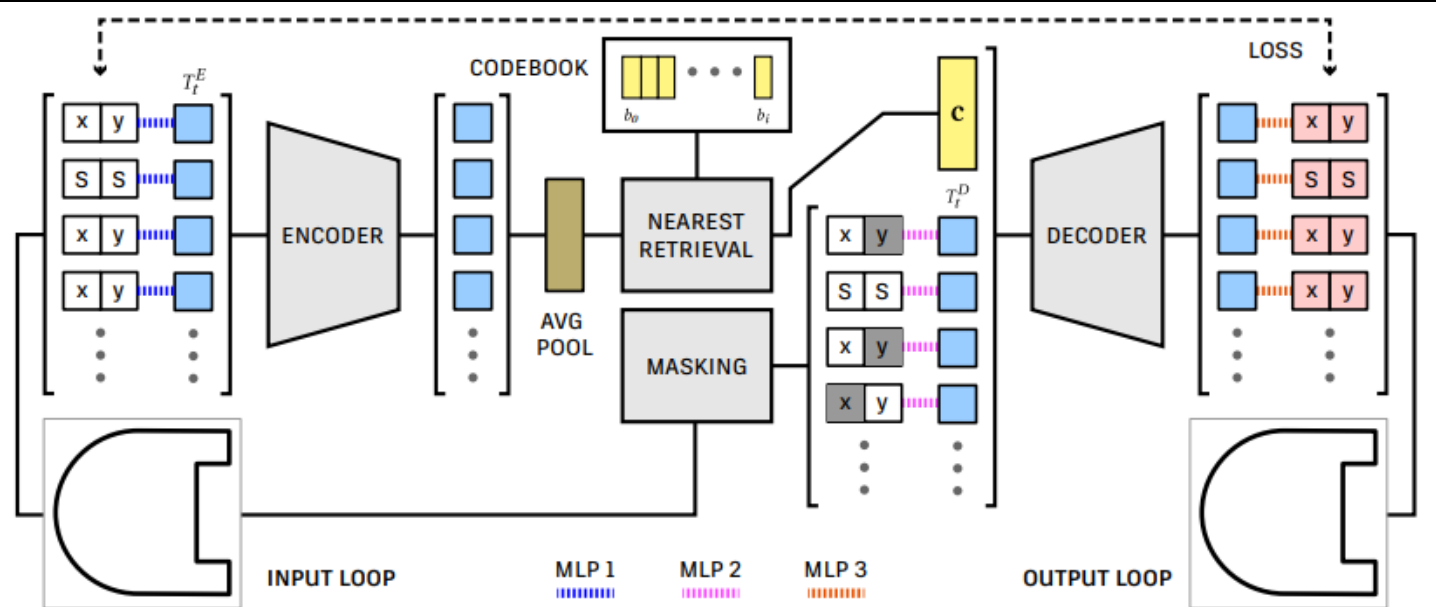
Profile

Loop



RANDOM GENERATION



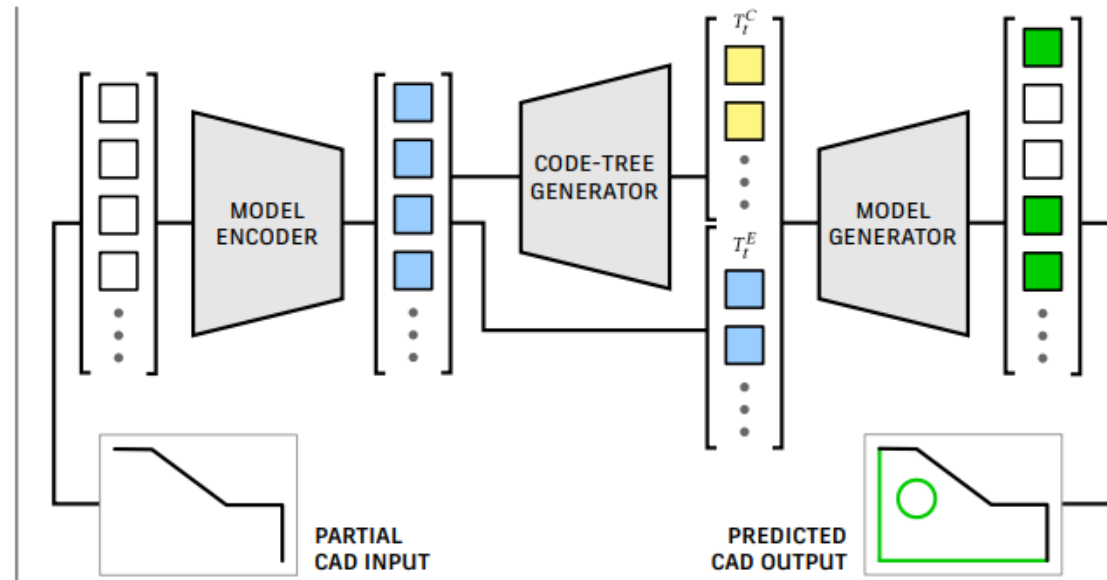
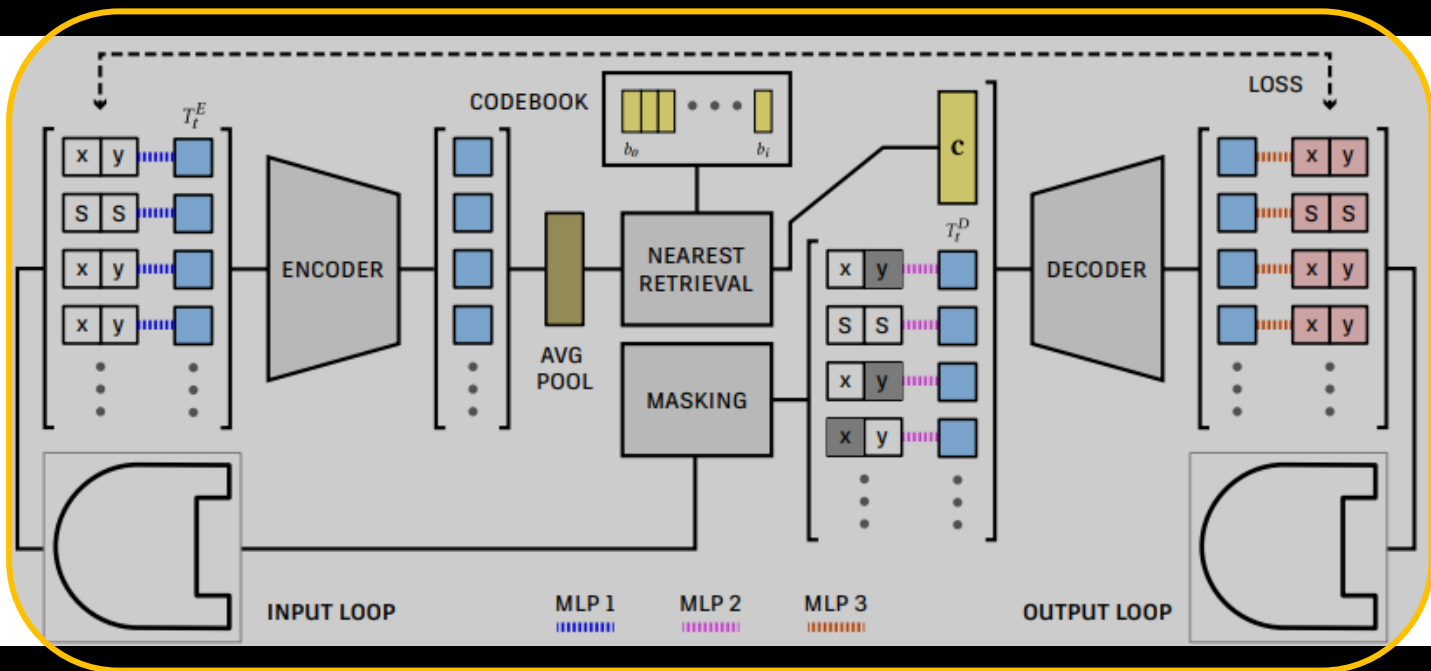


Three-Level Codebook Learning

- Encoder
- Masked skip connection
- Decoder

Controllable CAD Generation

- Model Encoder
- Code-Tree Generator
- Model Generator

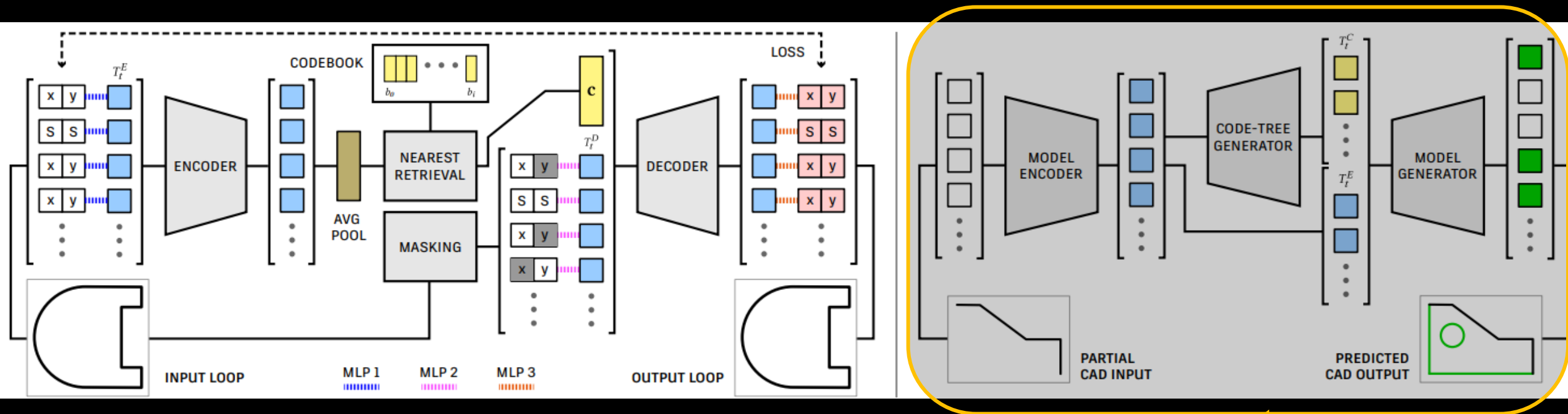


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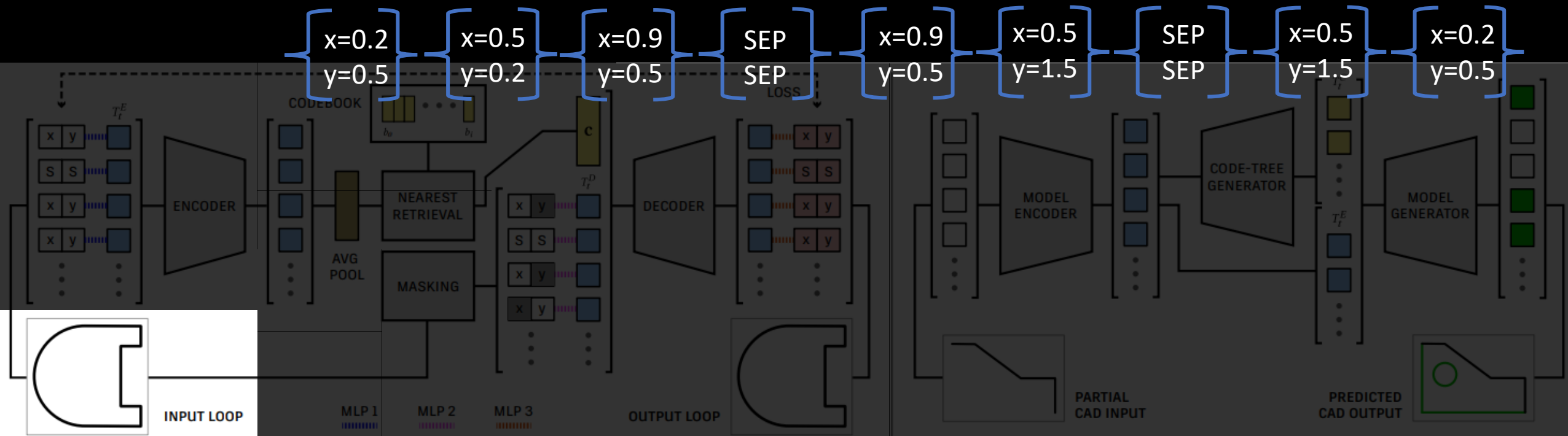


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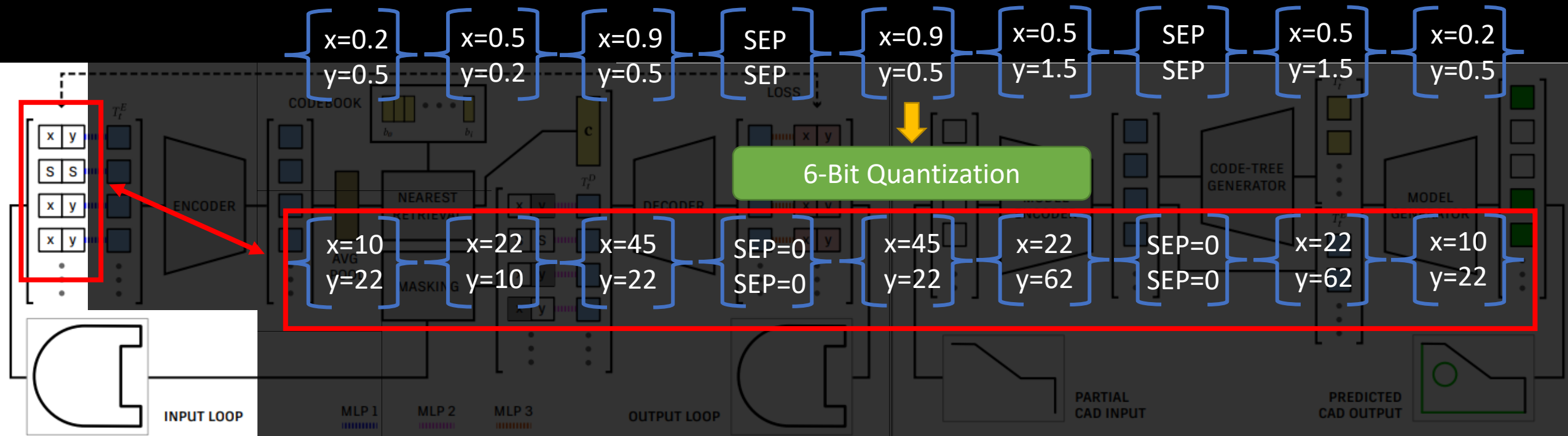


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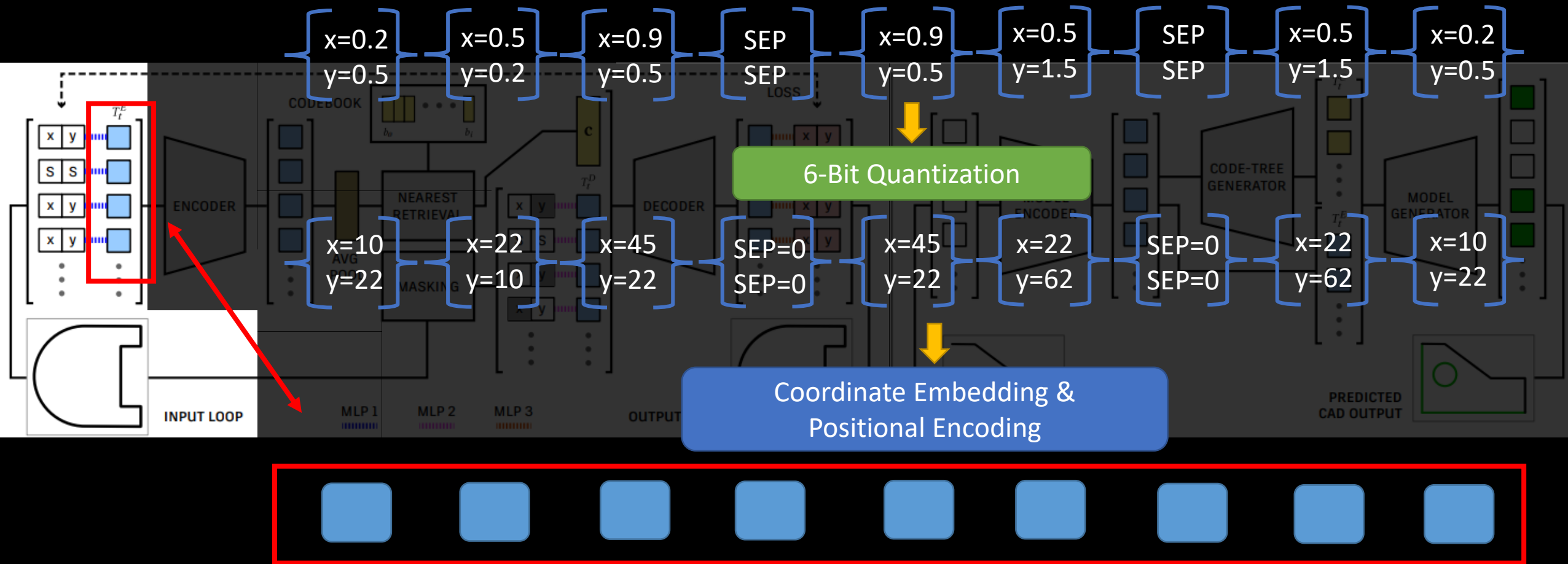


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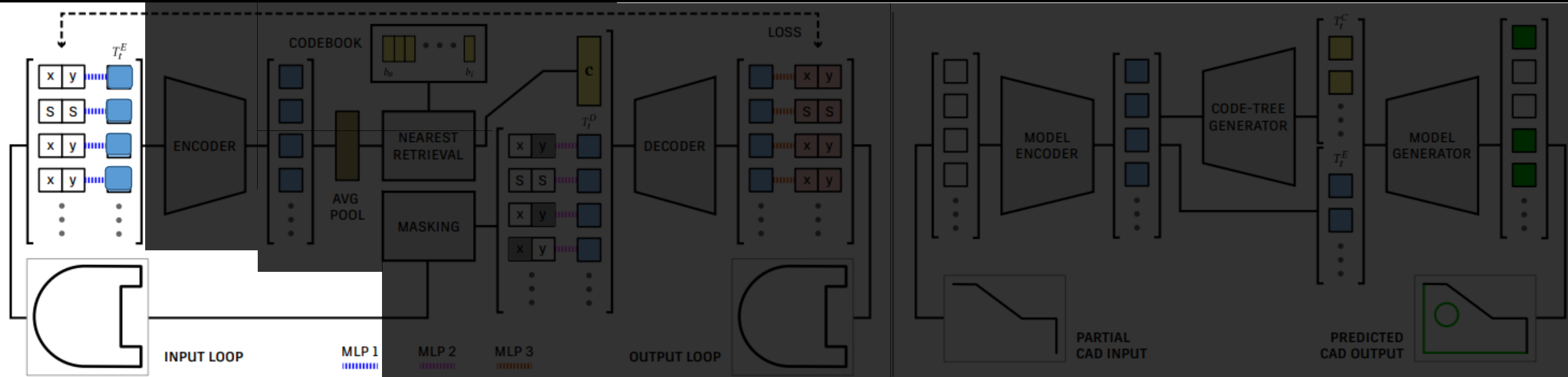


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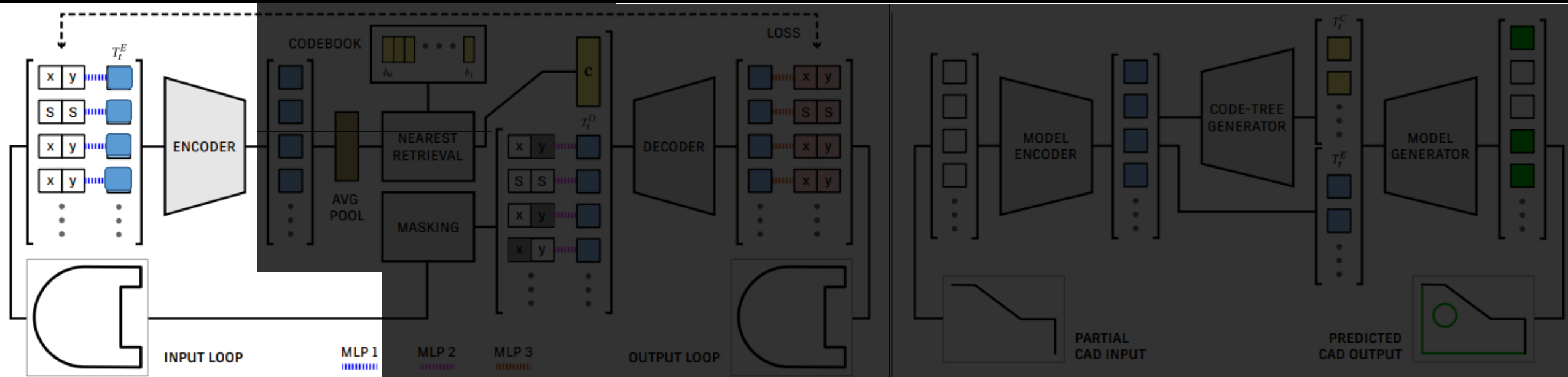


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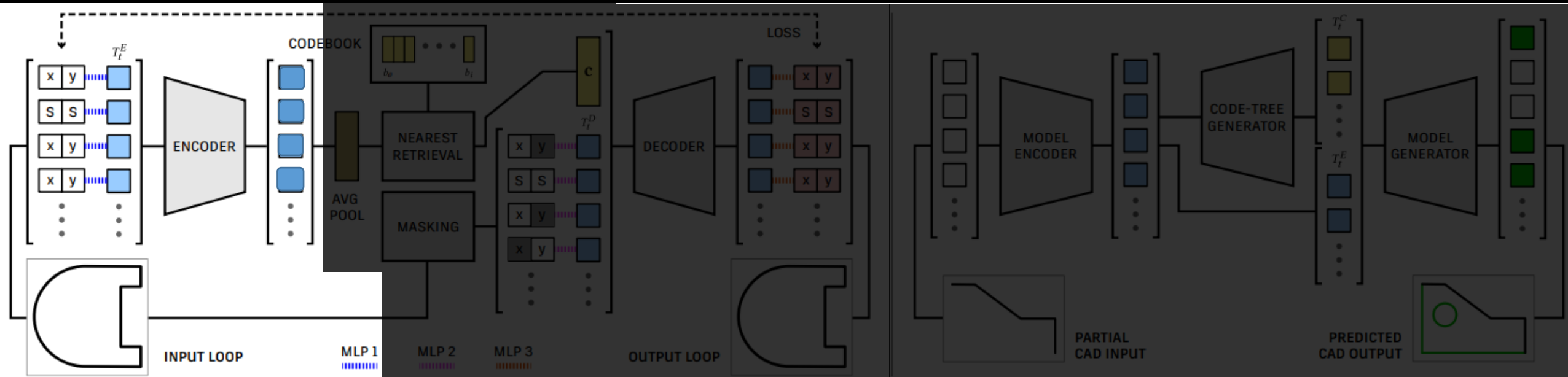


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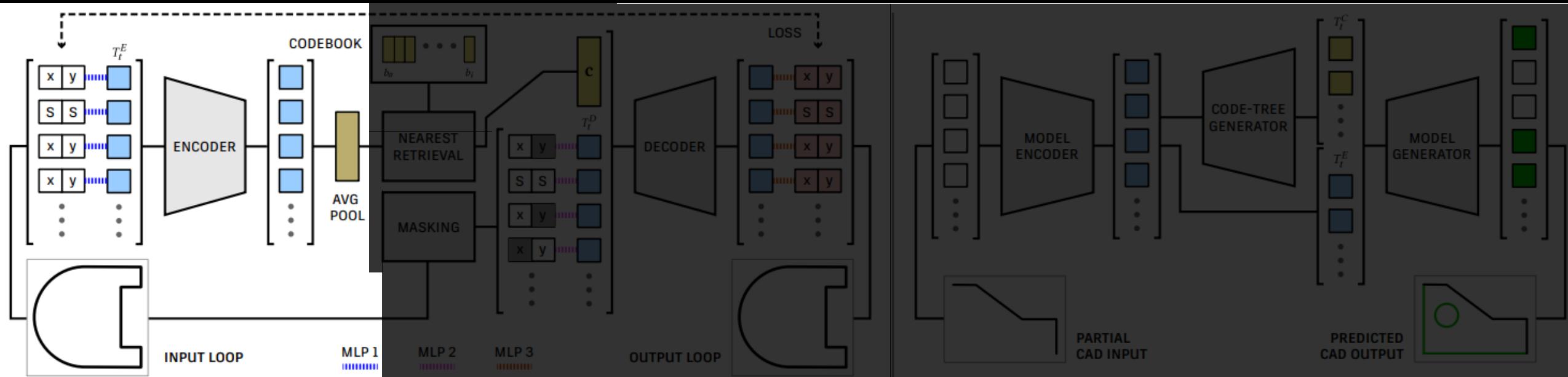


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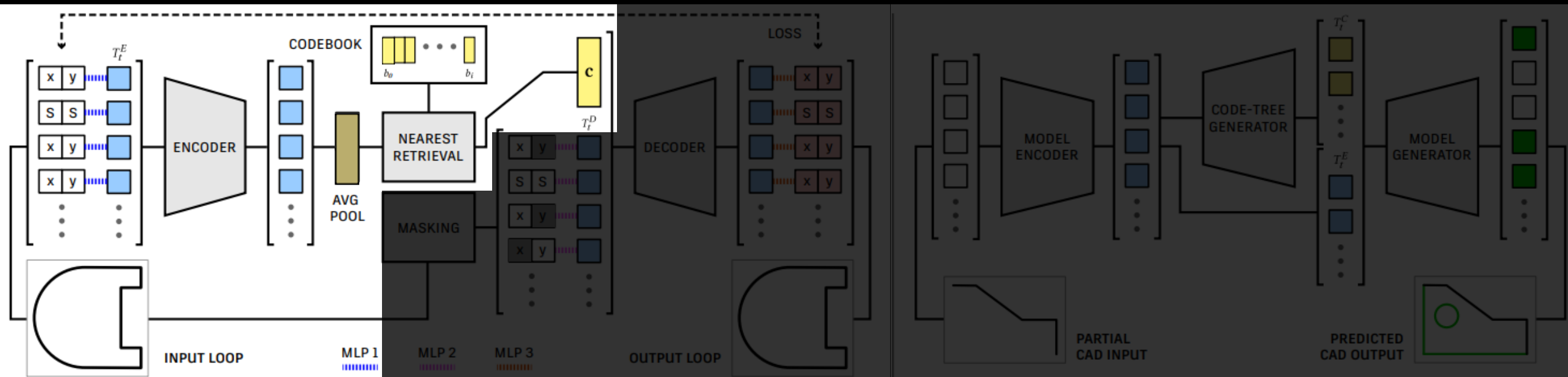


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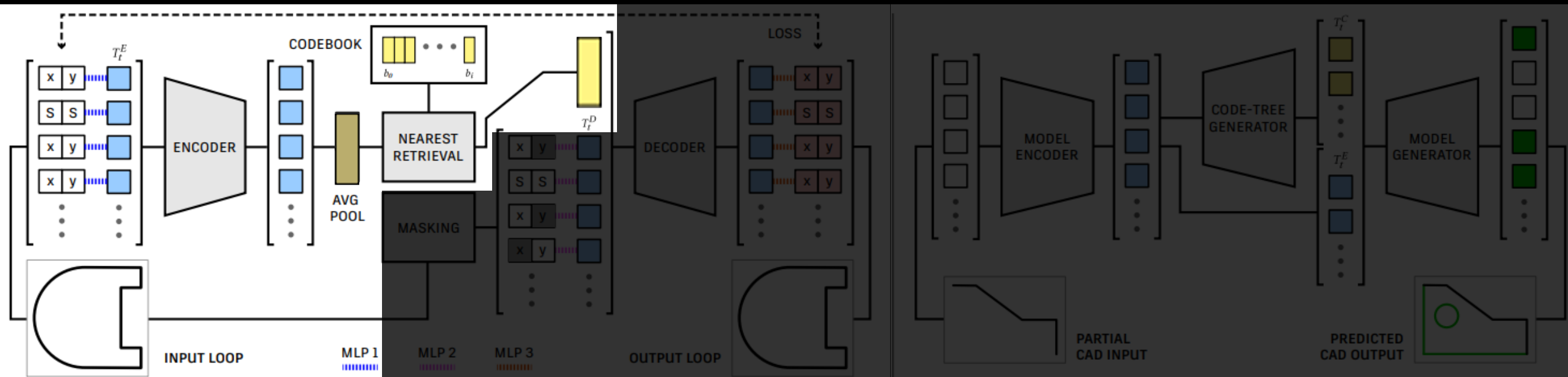


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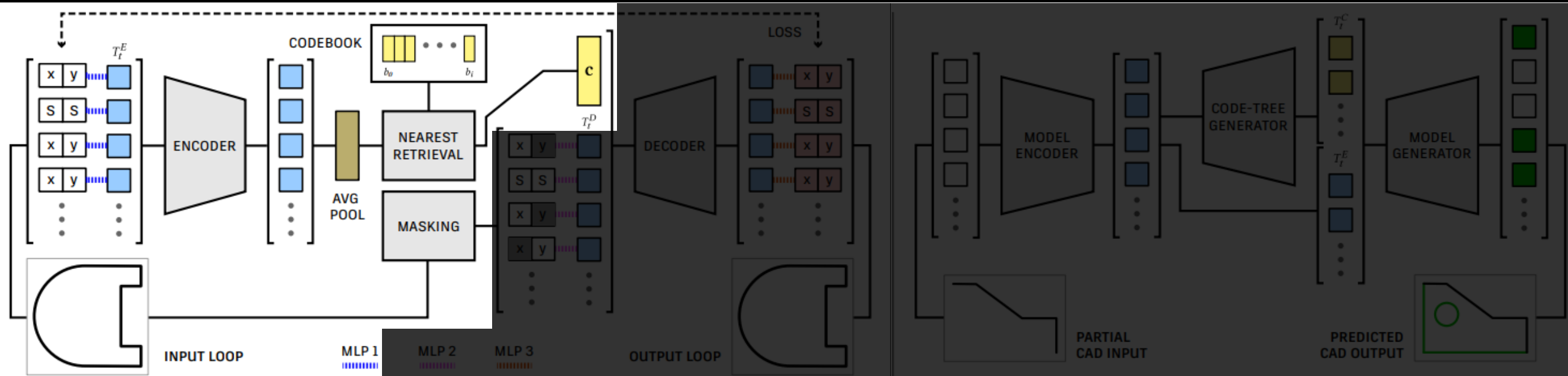


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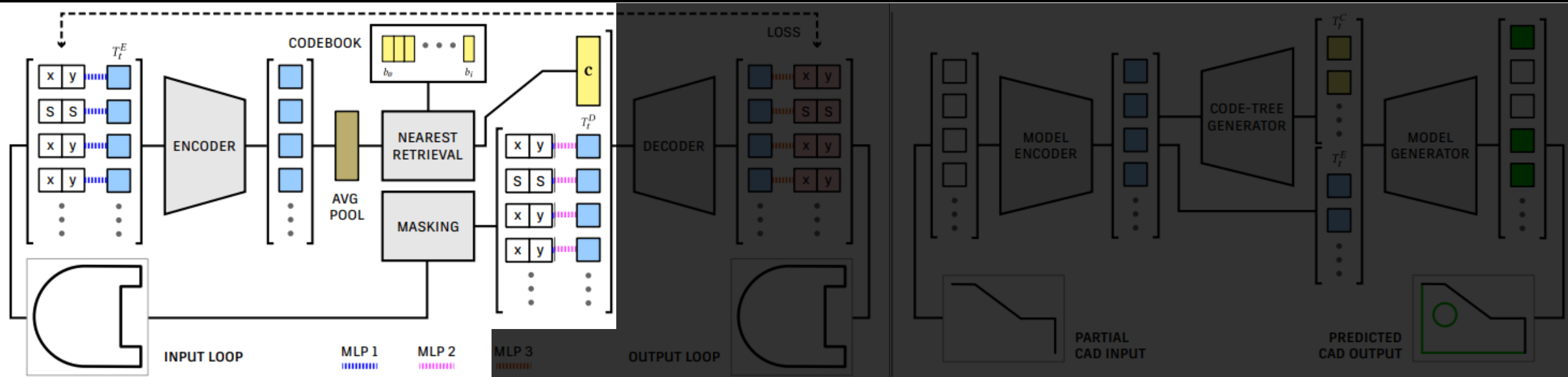


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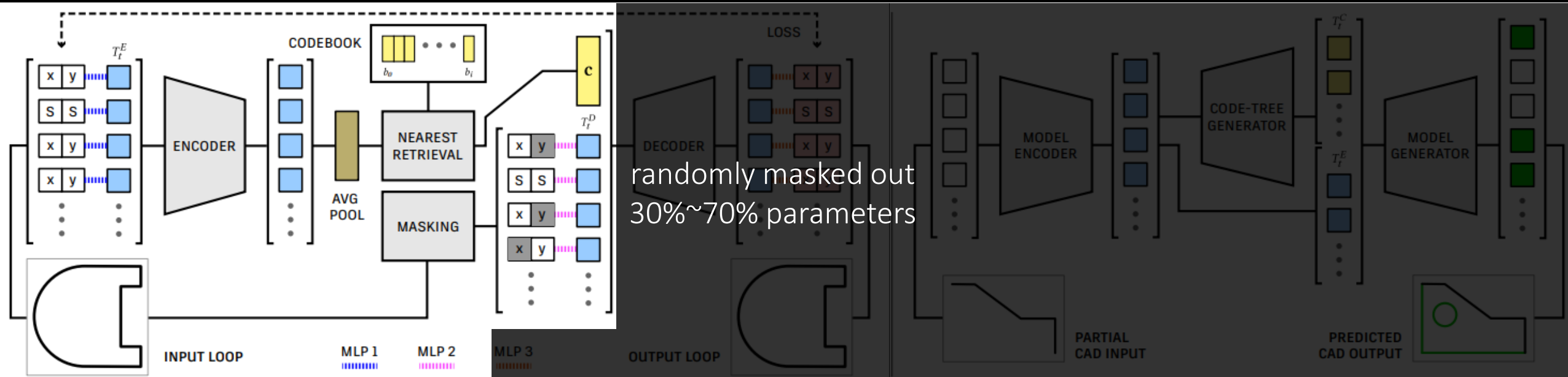


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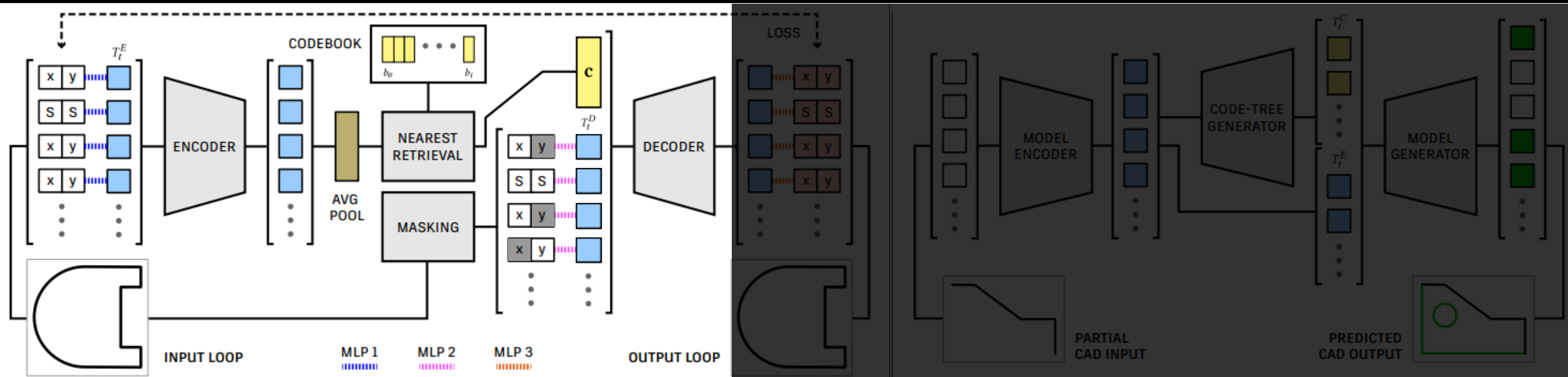


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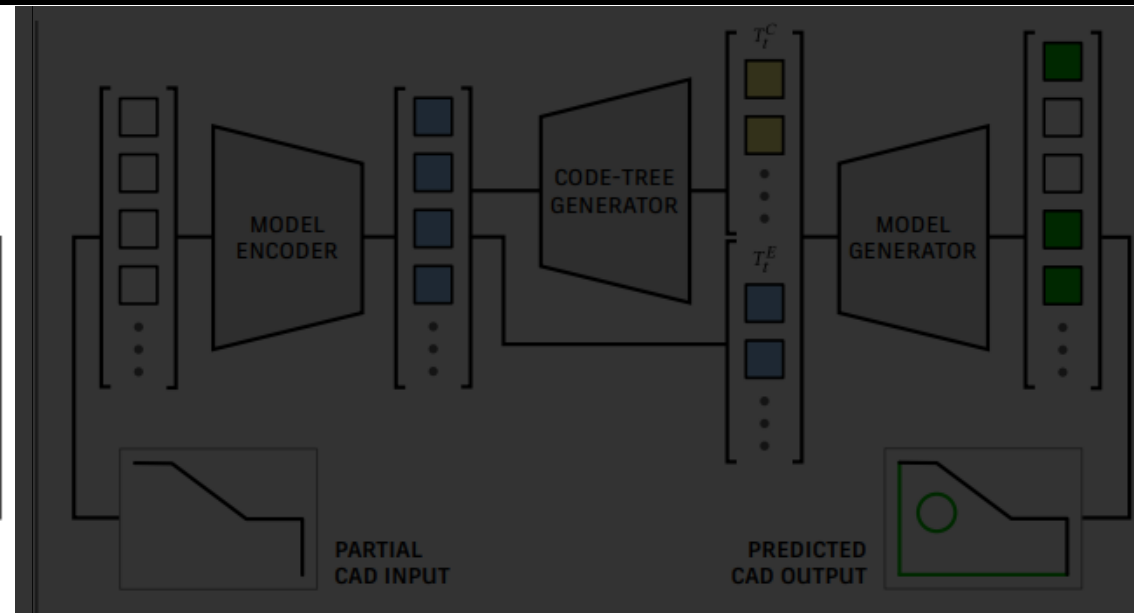
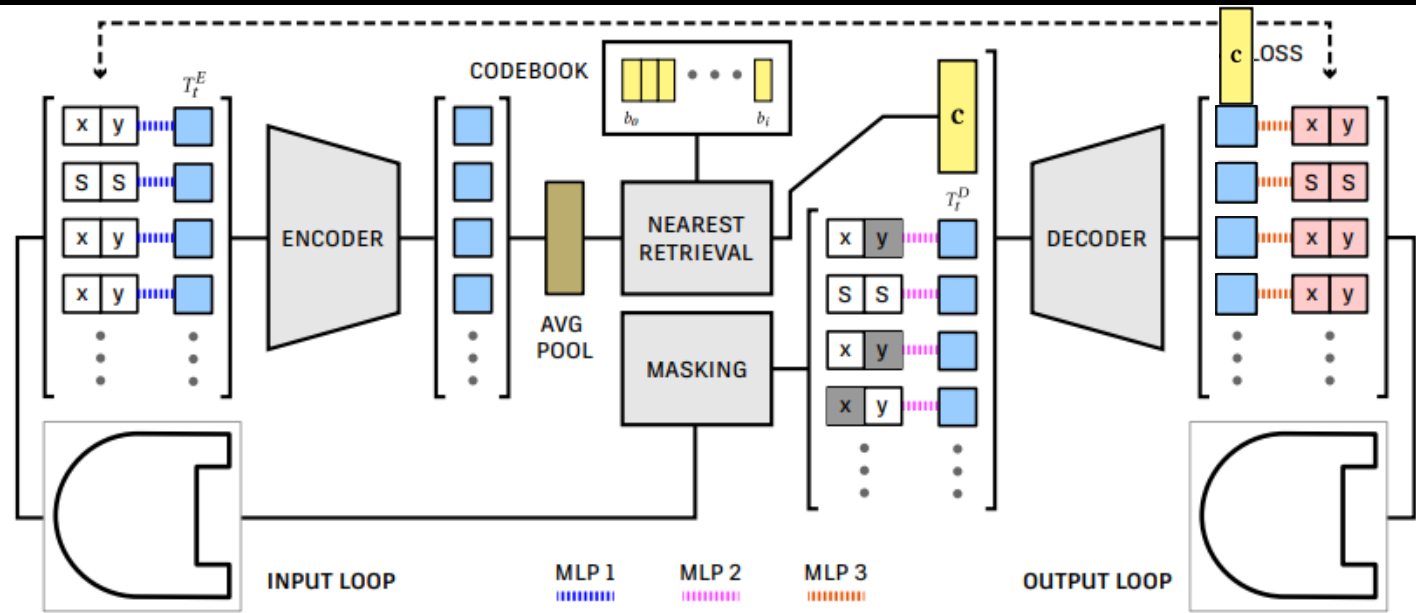


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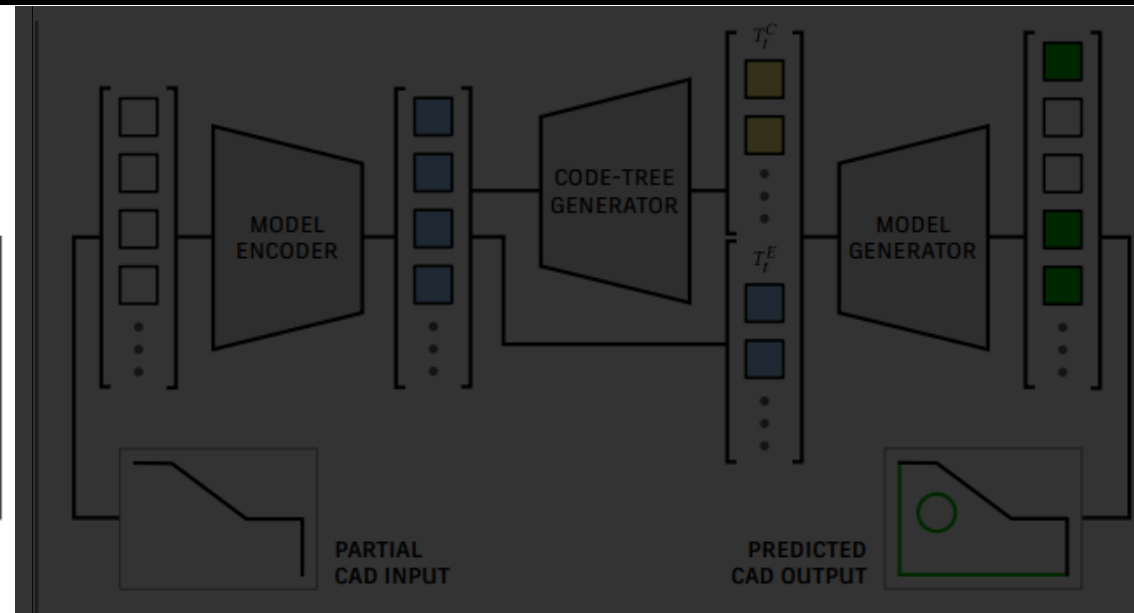
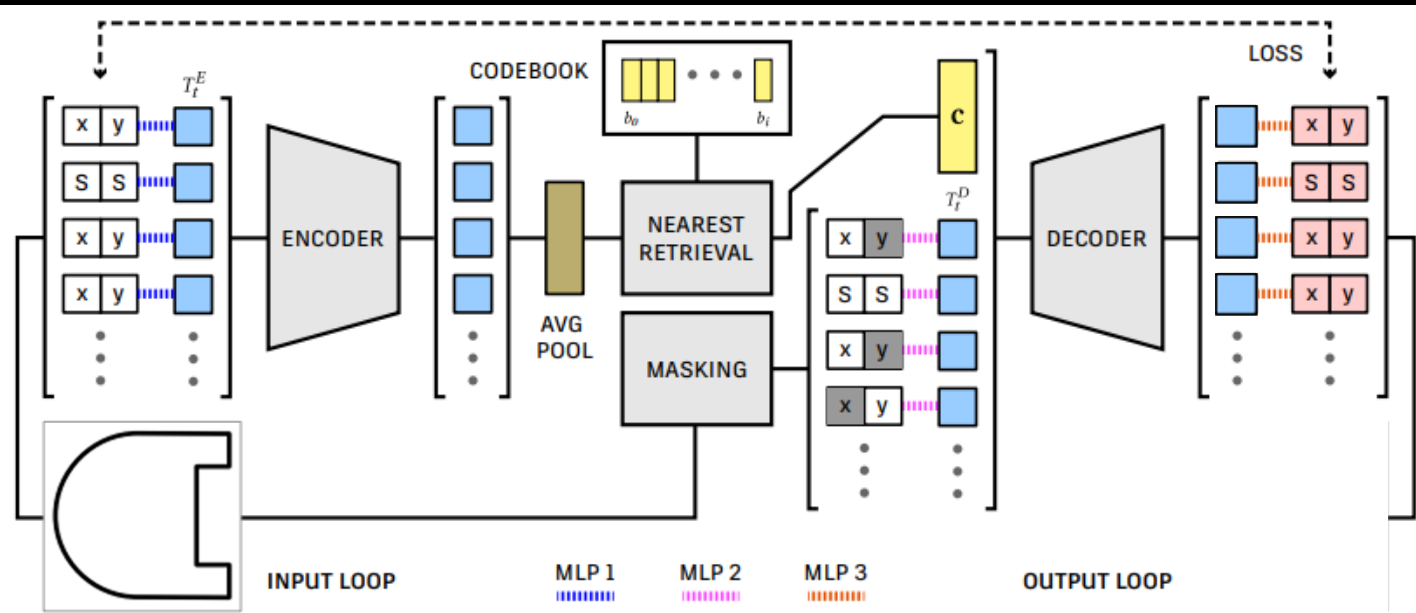


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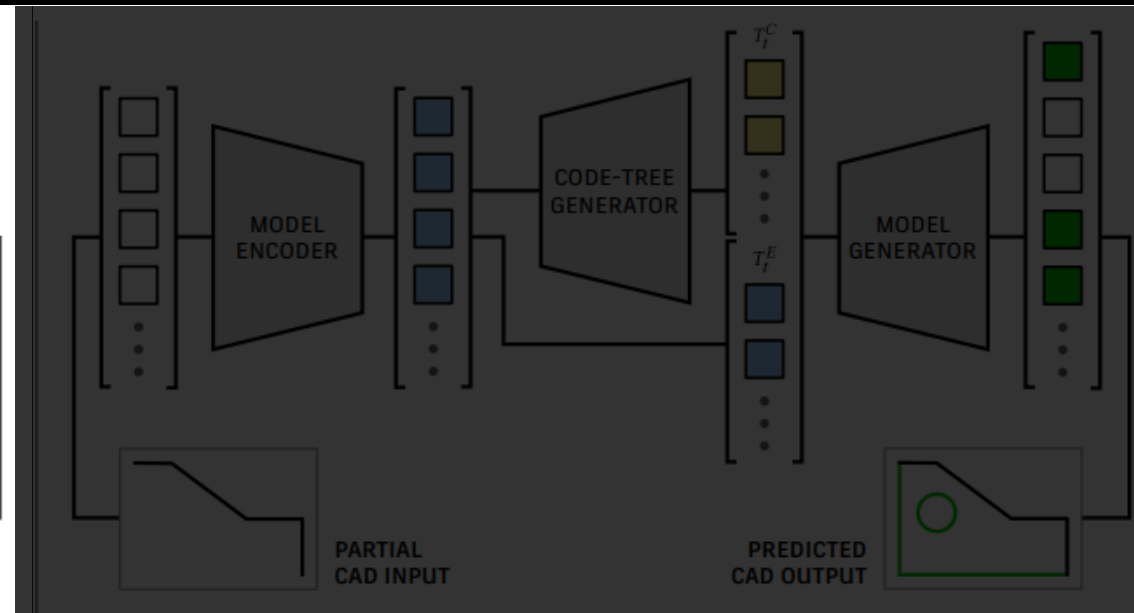
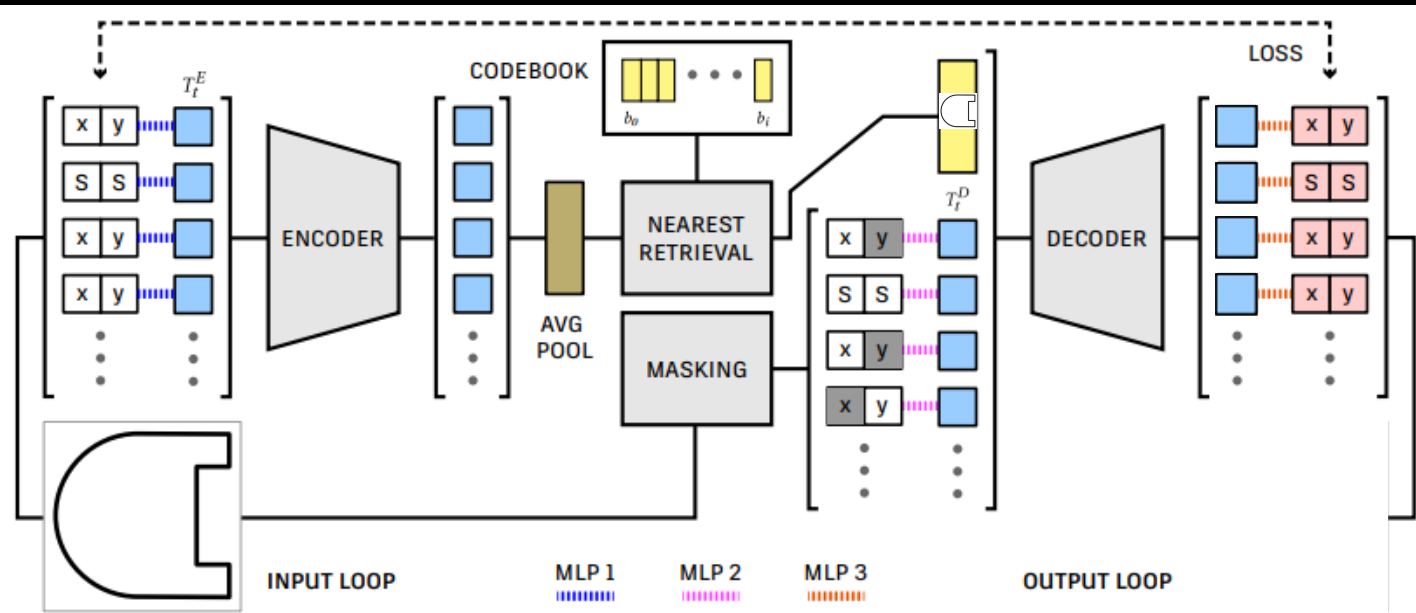


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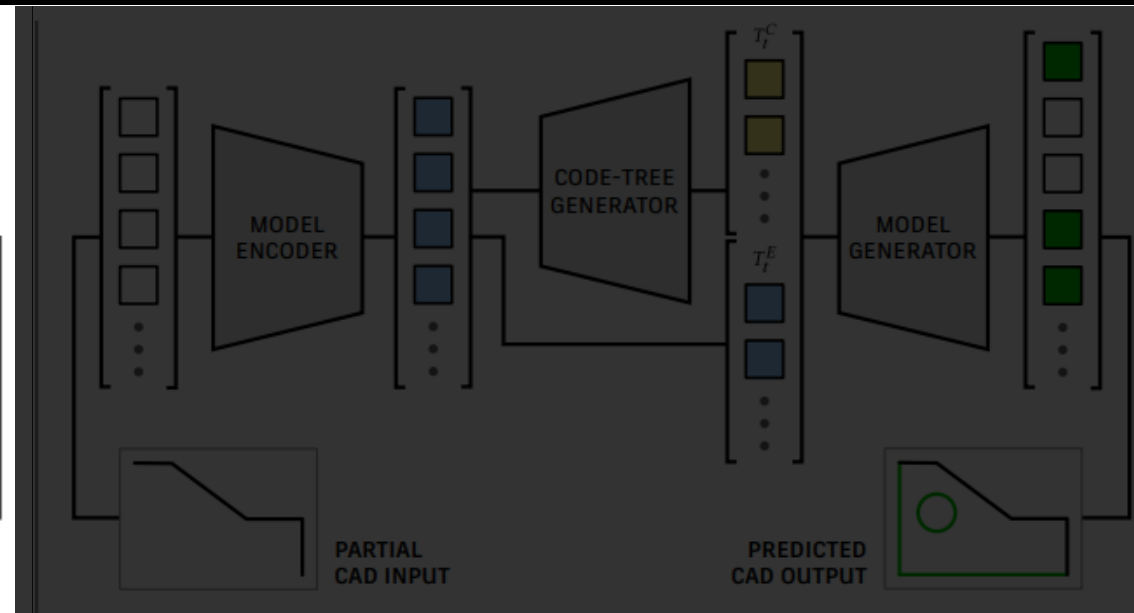
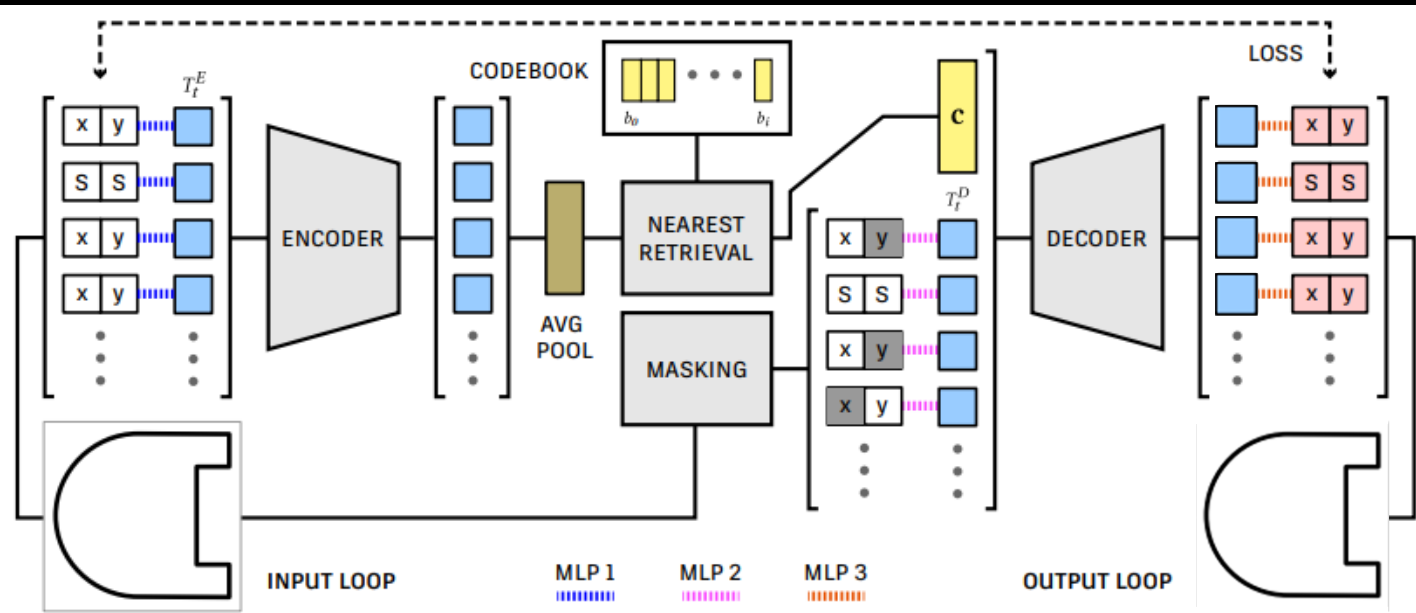


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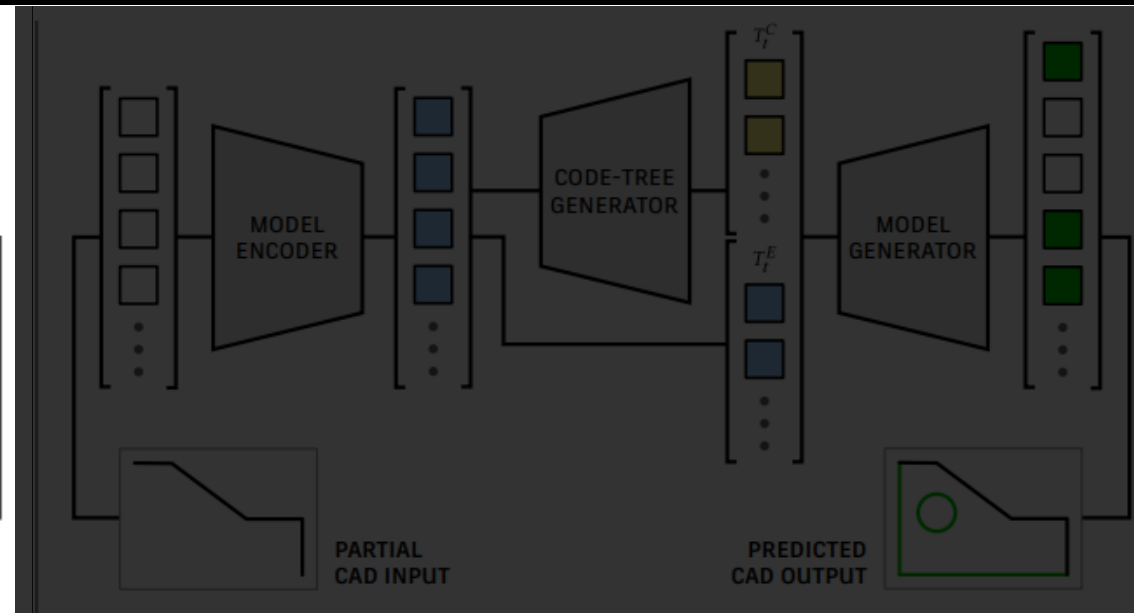
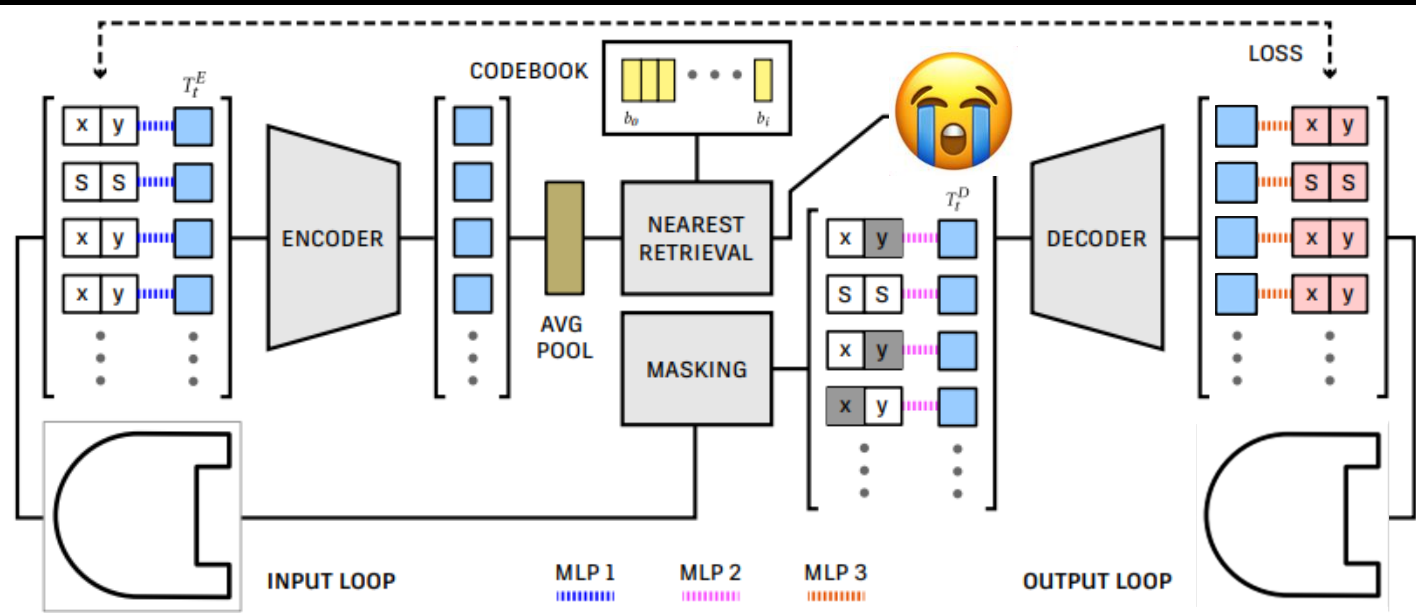


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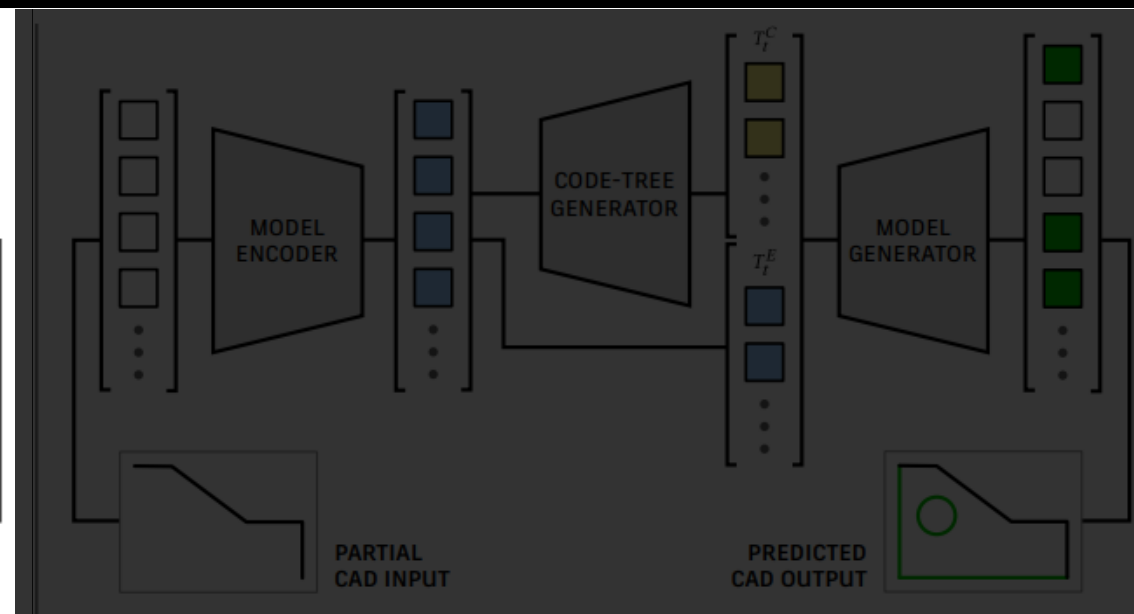
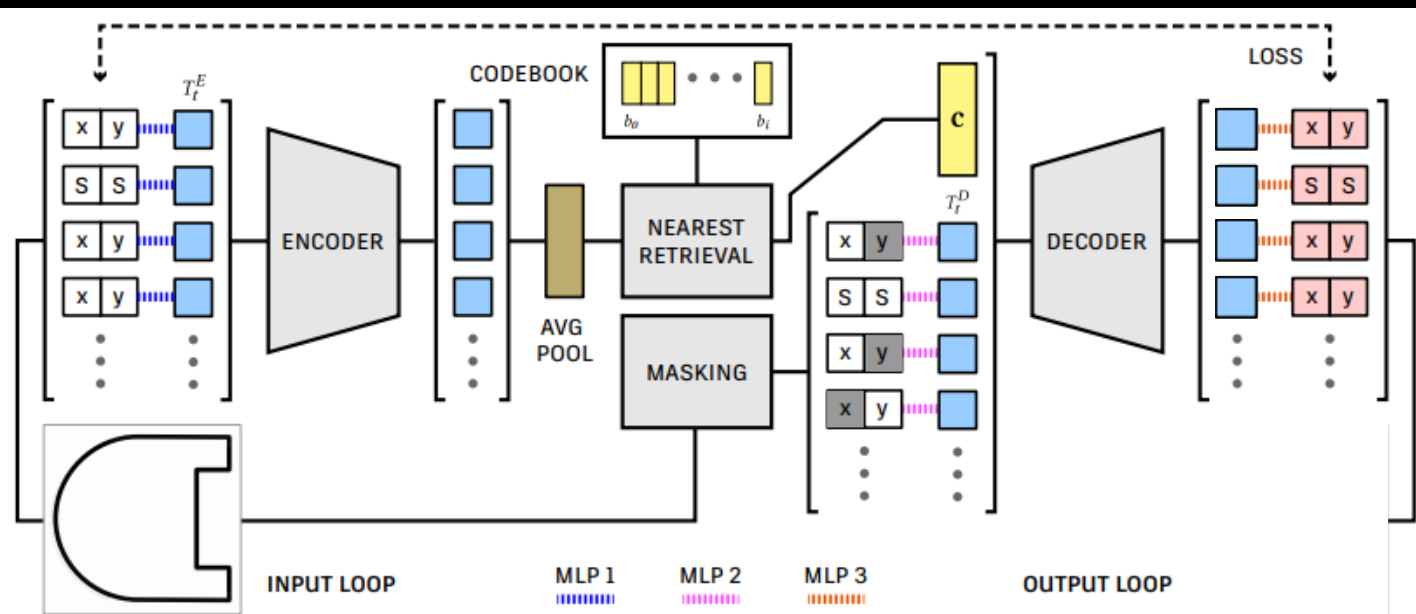


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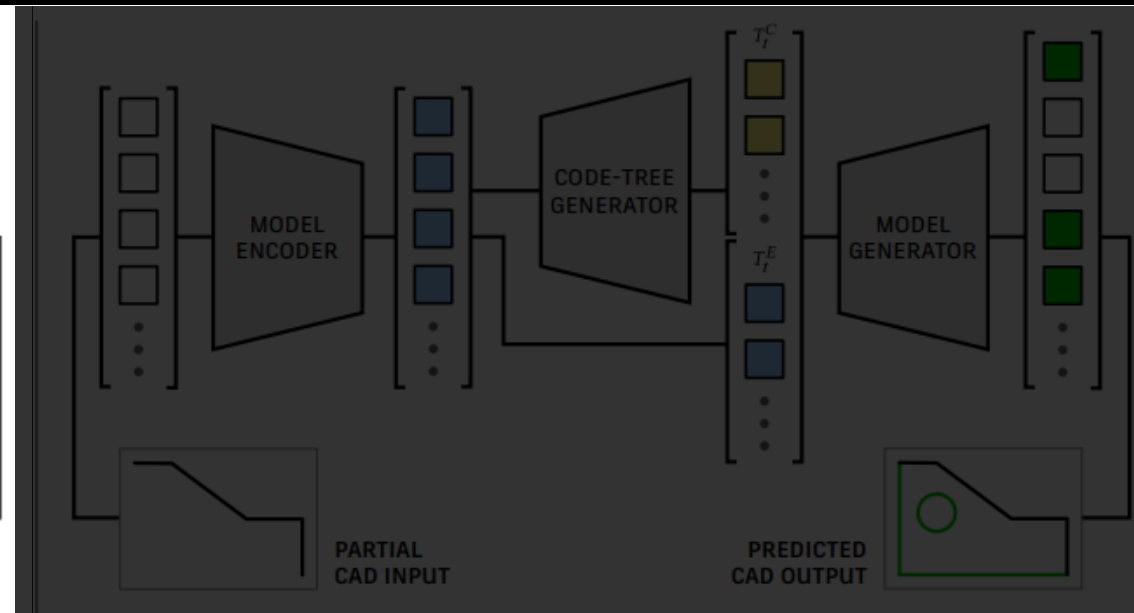
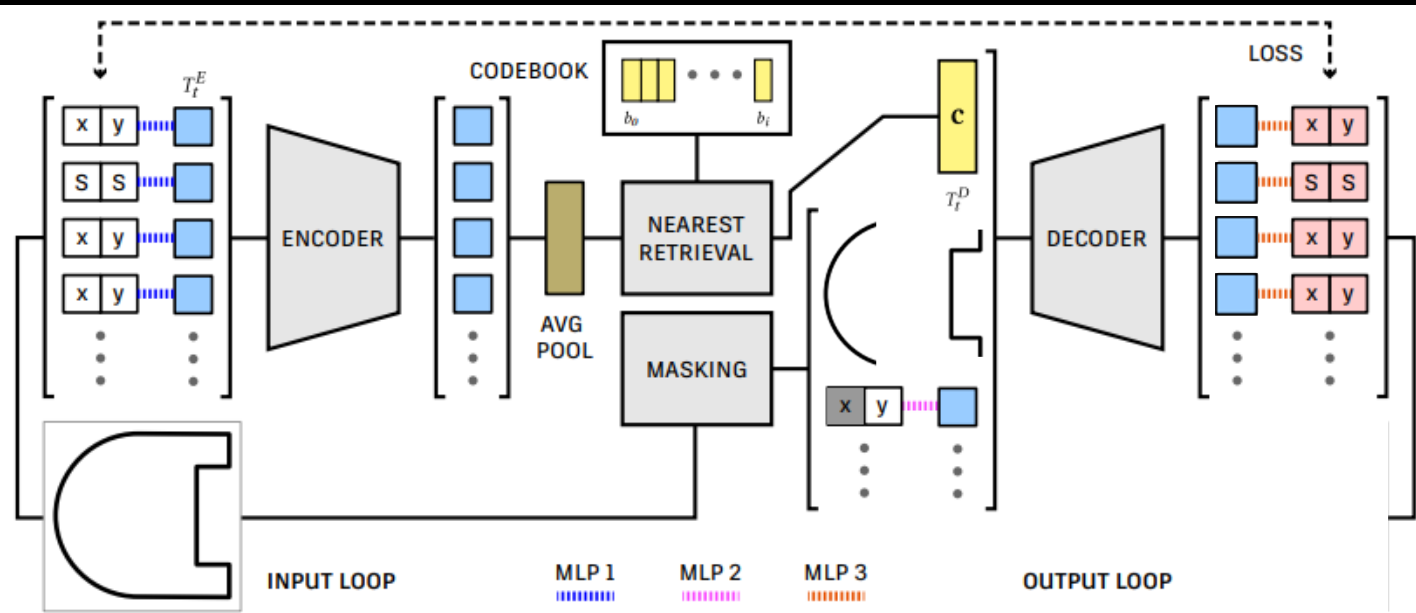


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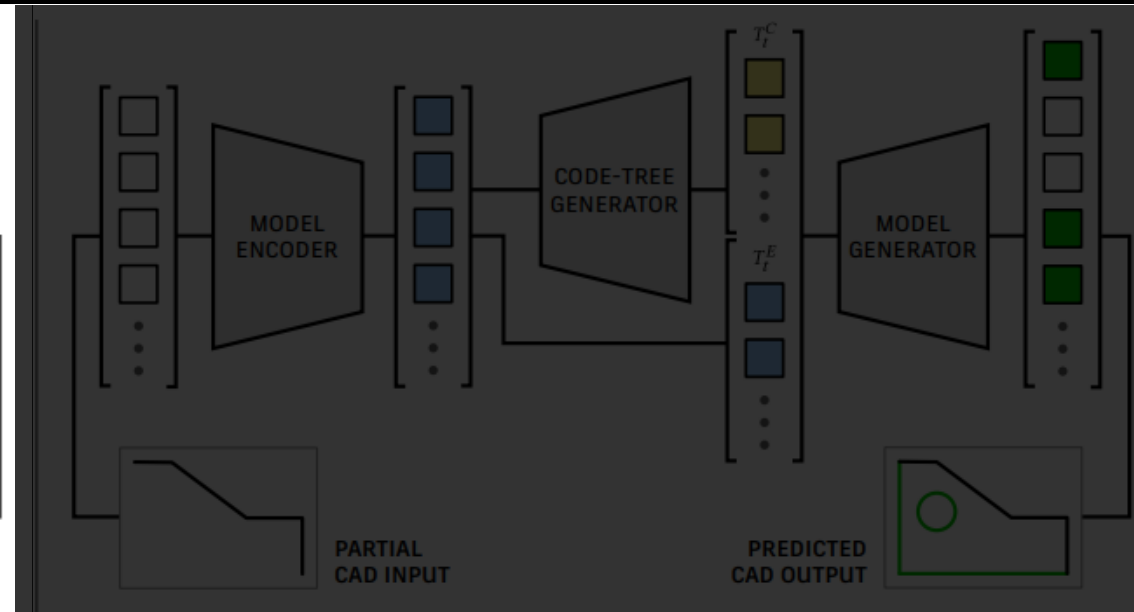
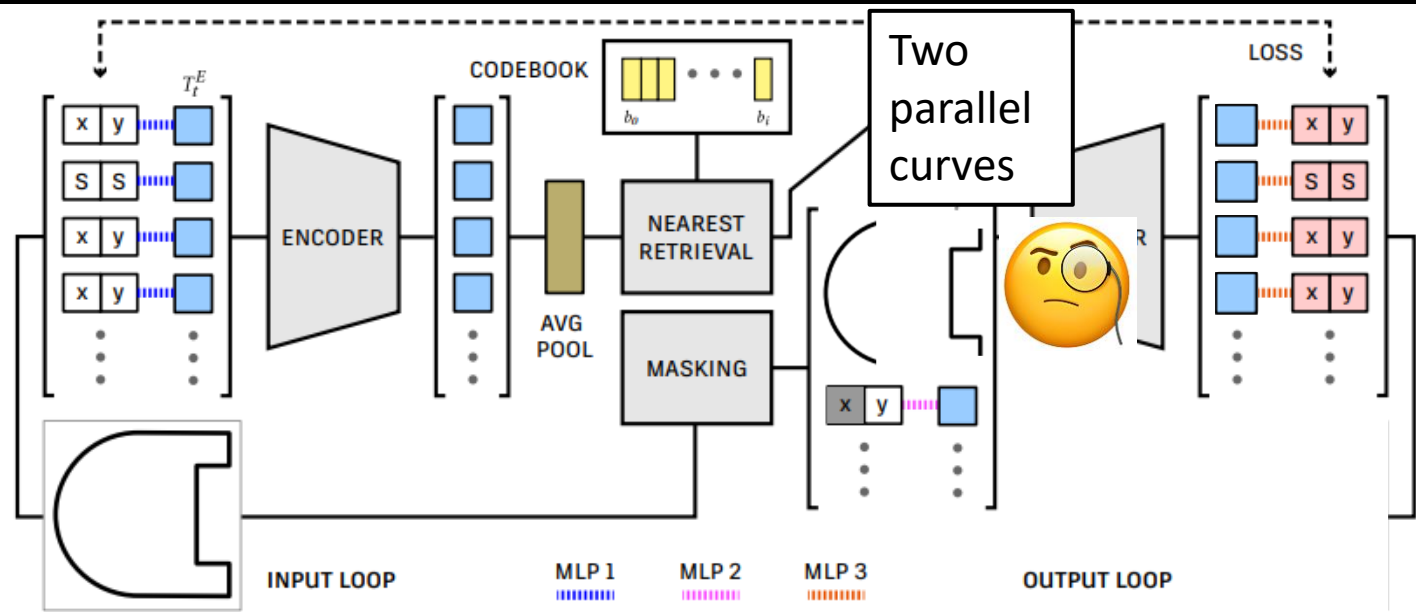


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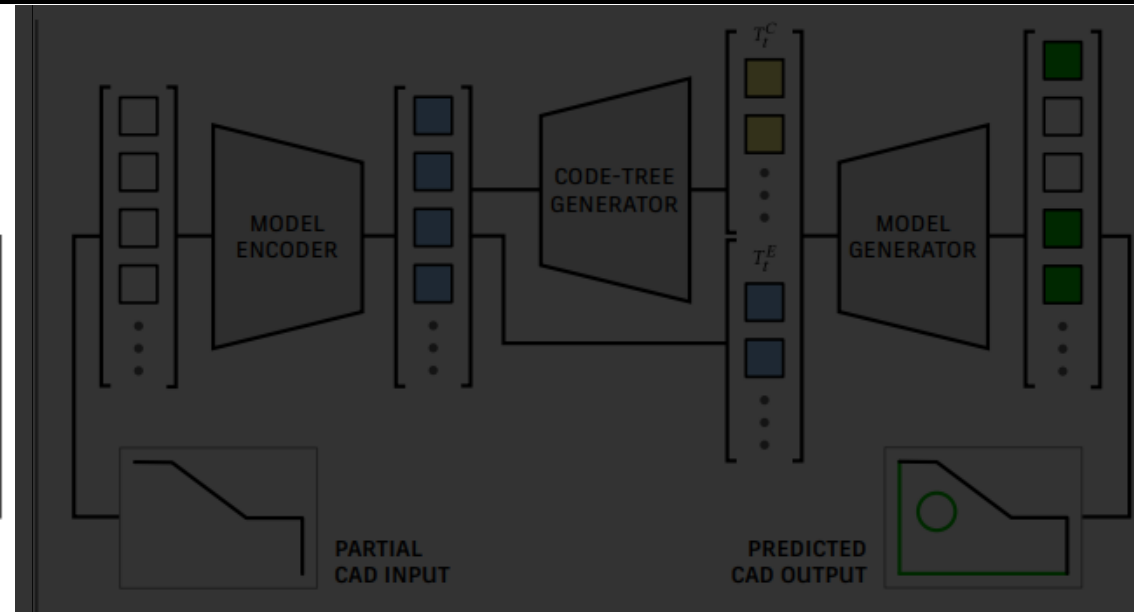
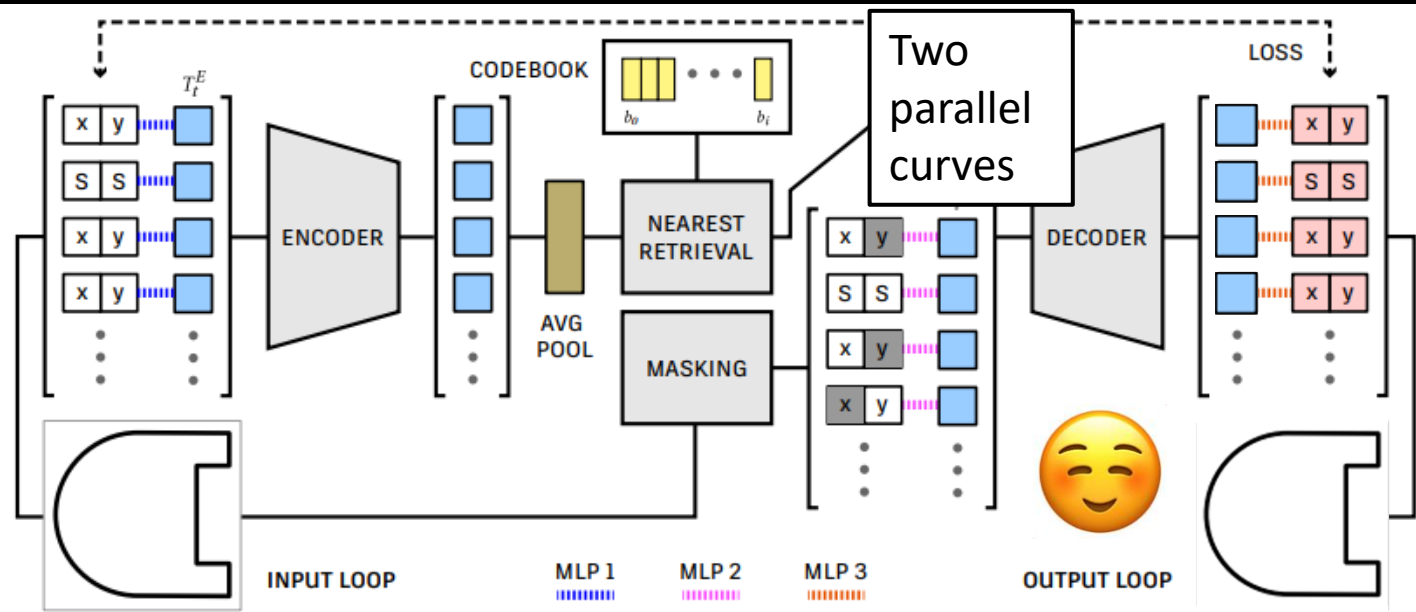


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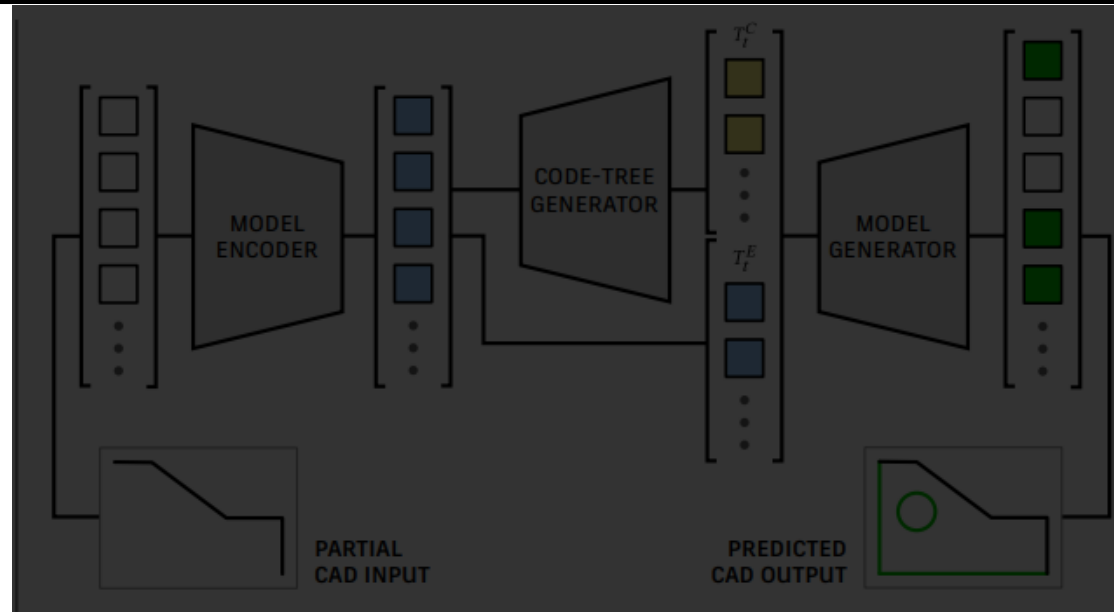
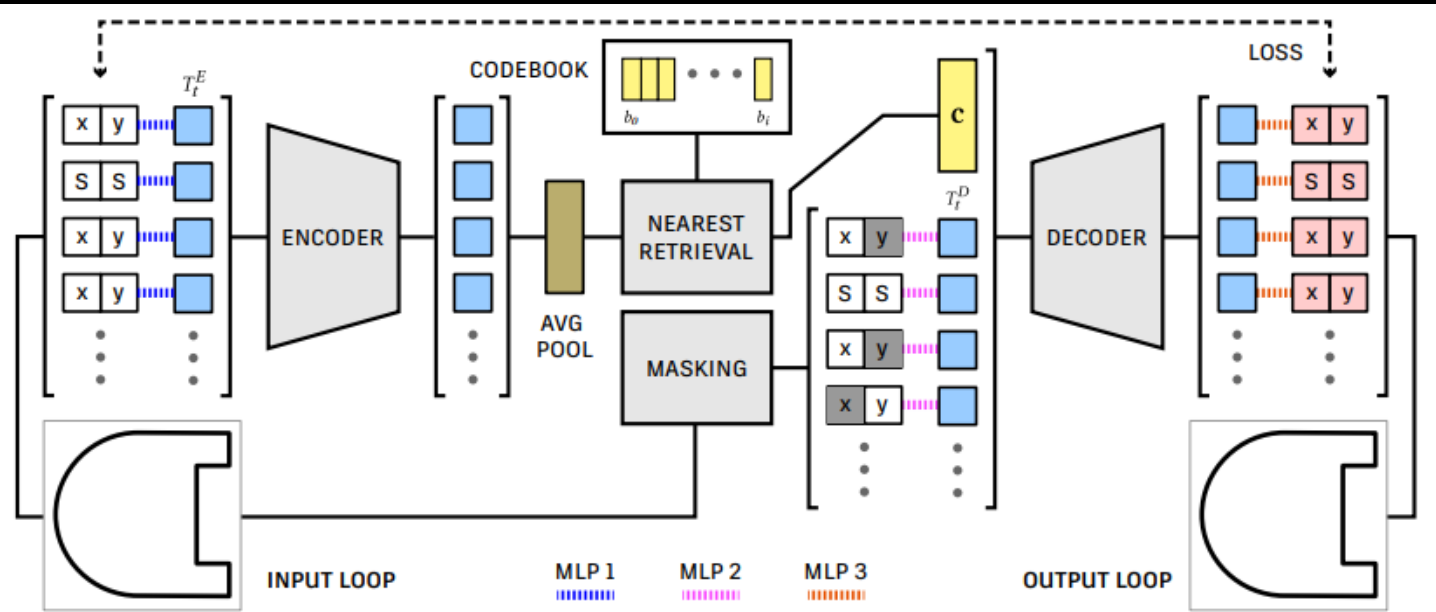


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$$\sum_t \text{EMD}(D(\mathbf{c}, \{T_t^D\}), \mathbb{1}_{T_t^E}) +$$

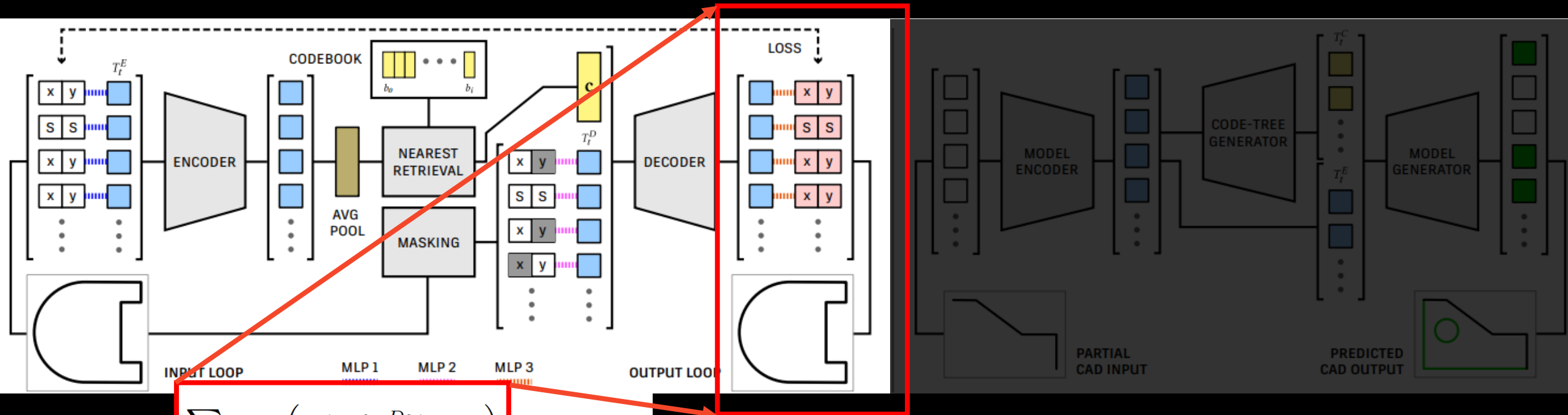
$$\|sg[\bar{E}(T^E)] - \mathbf{c}\|_2^2 + \beta \|\bar{E}(T^E) - sg[\mathbf{c}]\|_2^2$$

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$$\sum_t \text{EMD}(D(\mathbf{c}, \{T_t^D\}), \mathbb{1}_{T_t}) + \left\| \text{sg}[\overline{E}(T^E)] - \mathbf{c} \right\|_2^2 + \beta \left\| \overline{E}(T^E) - \text{sg}[\mathbf{c}] \right\|_2^2$$

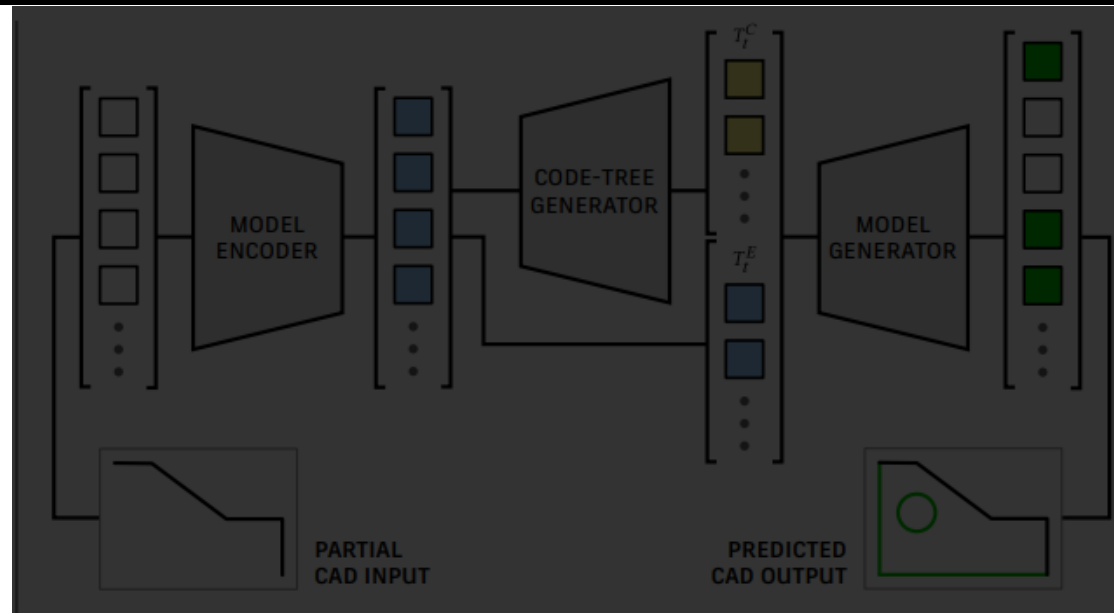
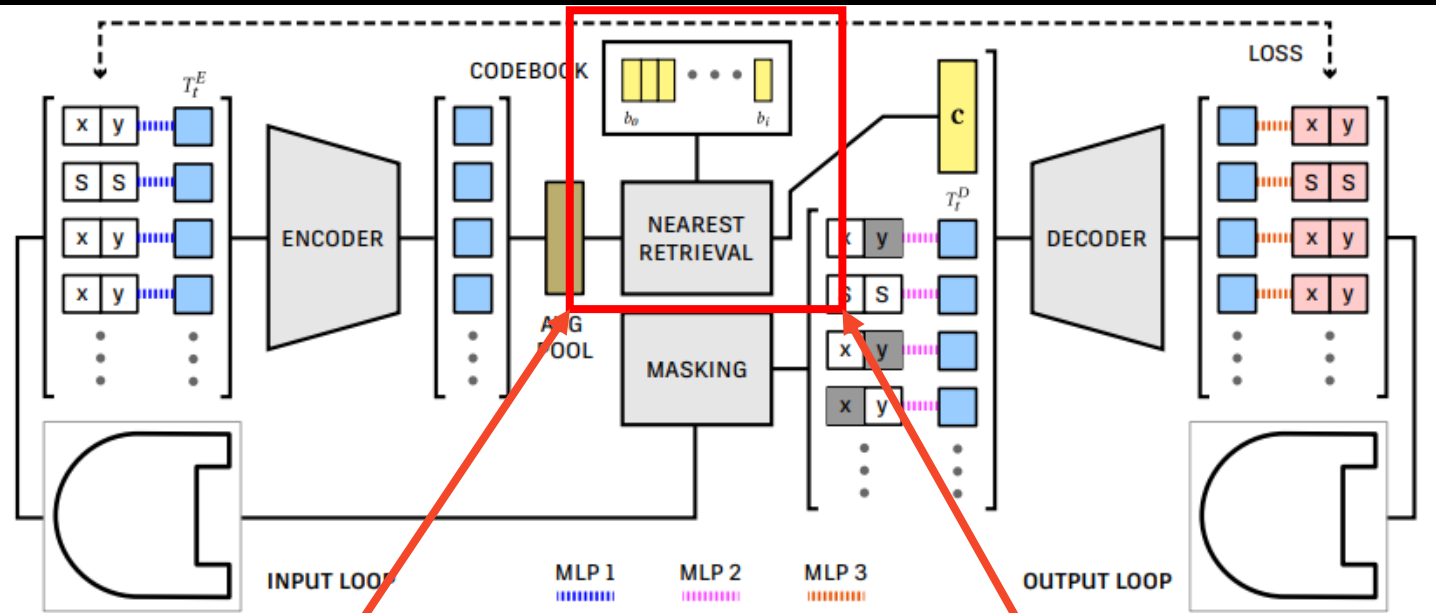
Reconstruction Loss
(Earth Mover's Distance)

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Codebook Losses

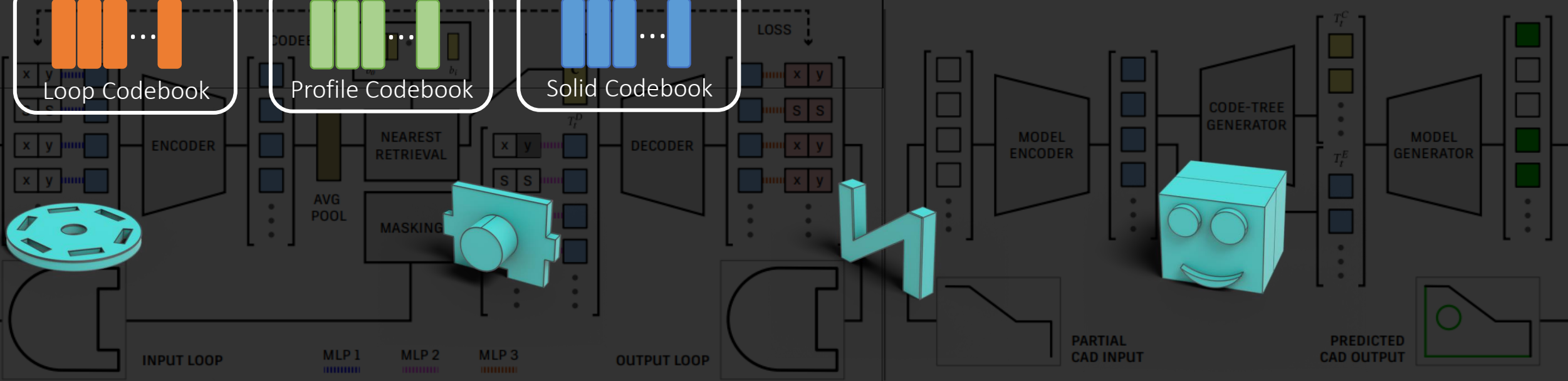
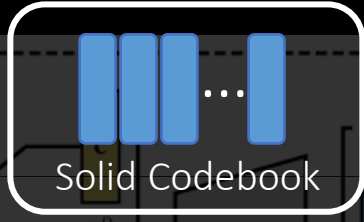
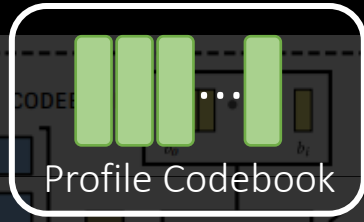
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Loop – Profile – Solid Tree



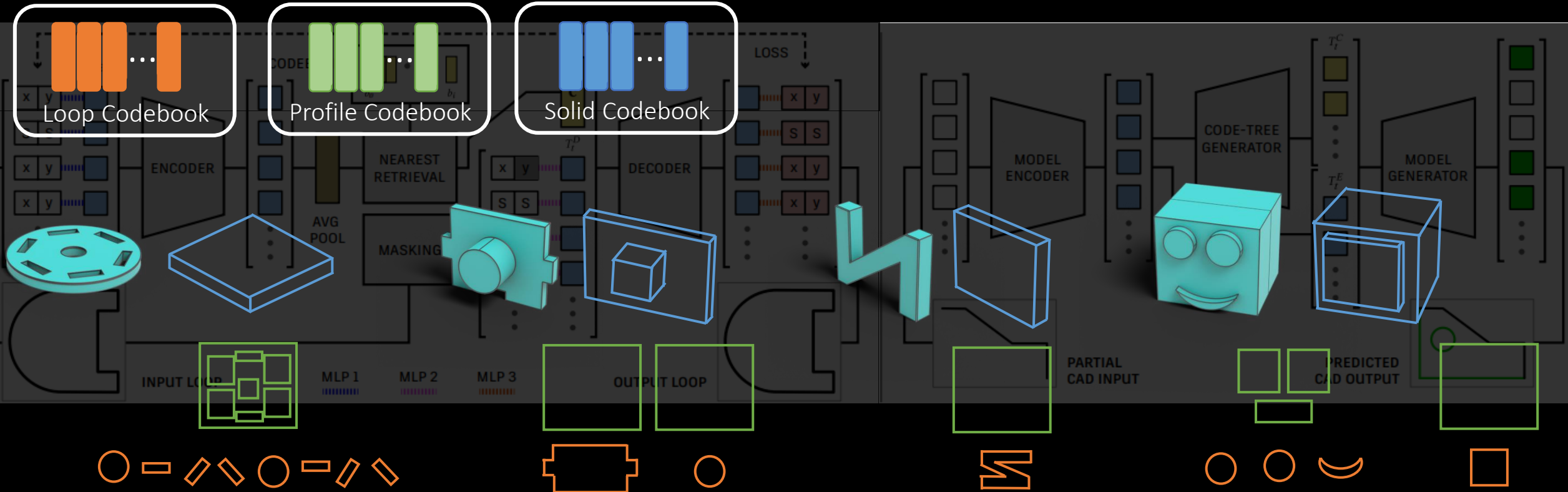
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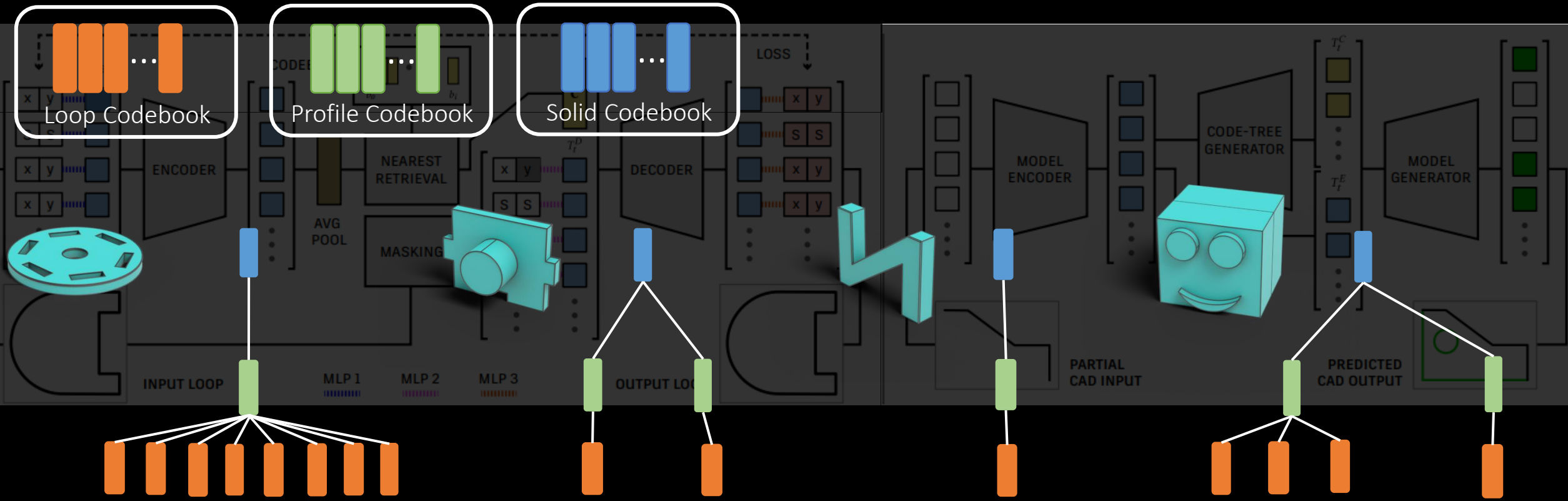
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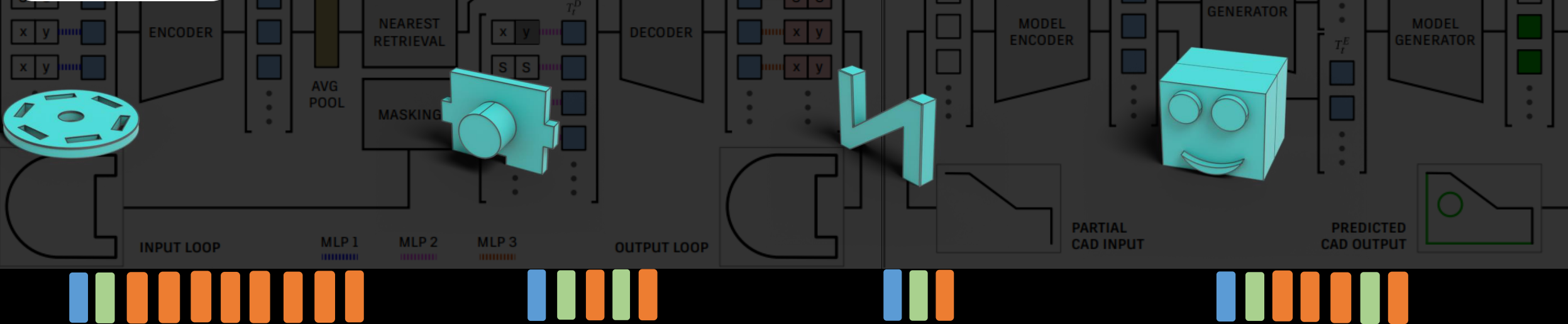
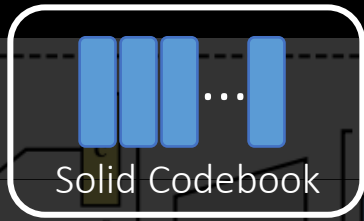
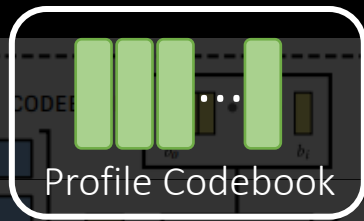
Three-Level Codebook Learning

- Encoder
- Masked skip connection
- Decoder

Controllable CAD Generation

- Model Encoder
- Code-Tree Generator
- Model Generator

Flatten Code Tree (depth first traverse)



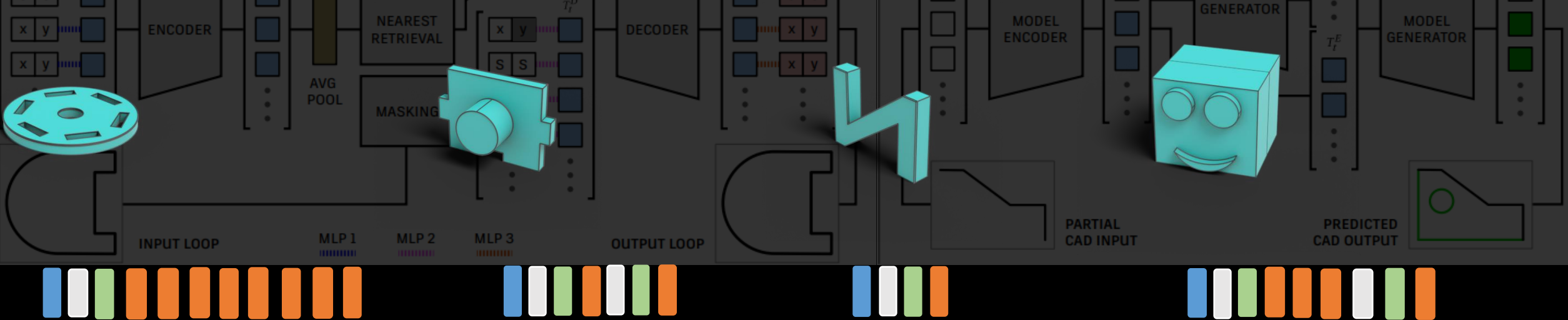
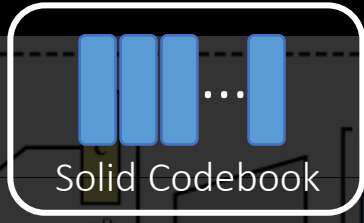
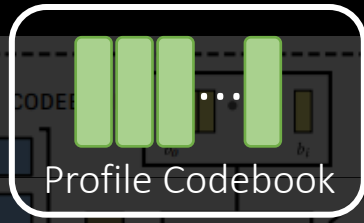
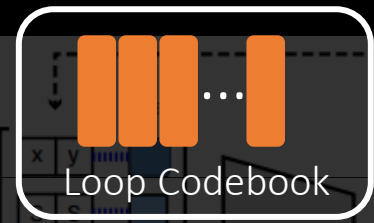
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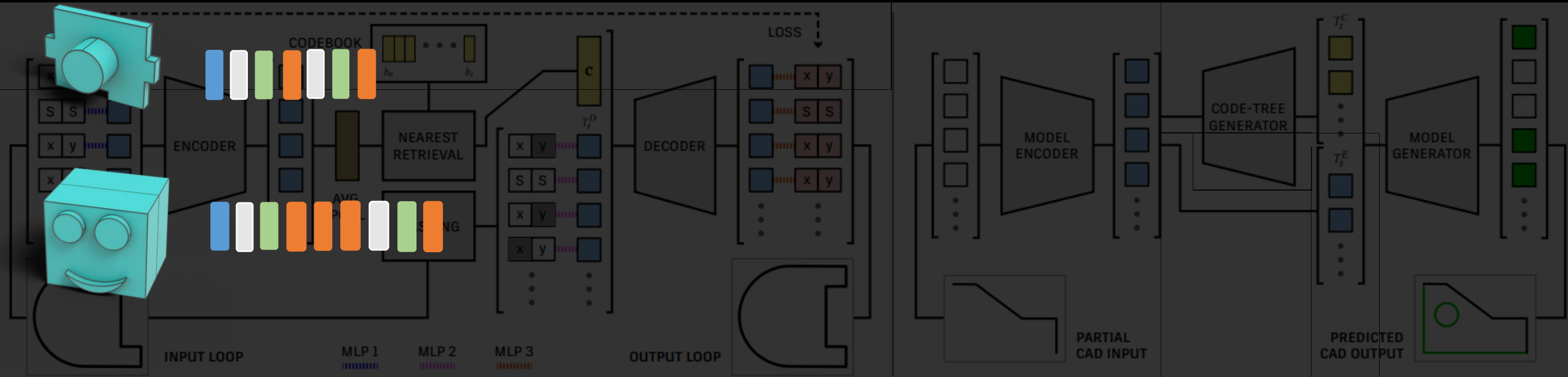


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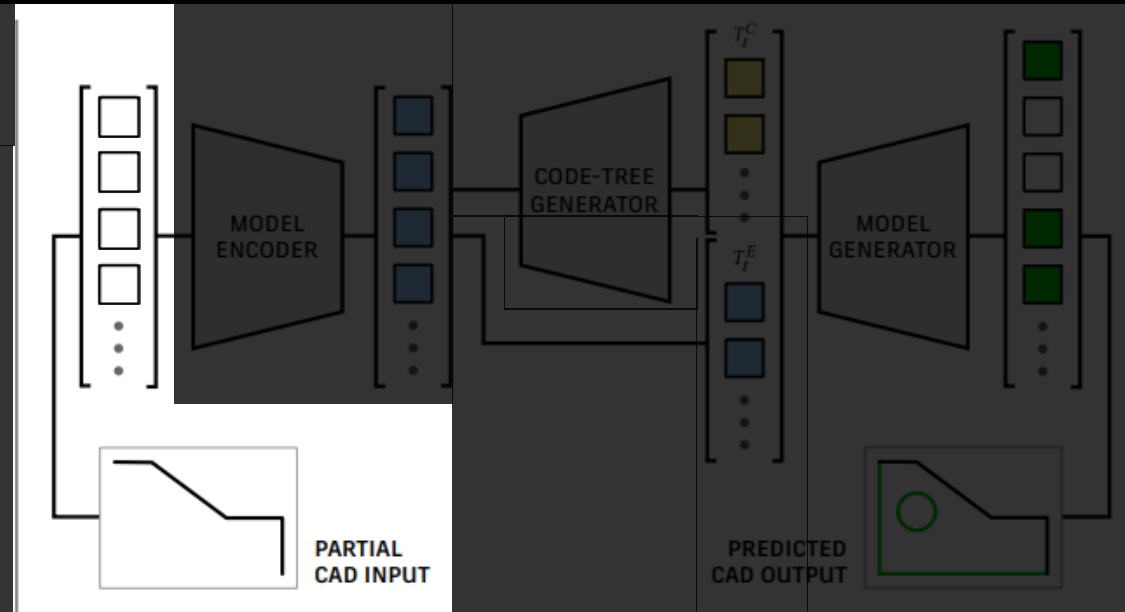
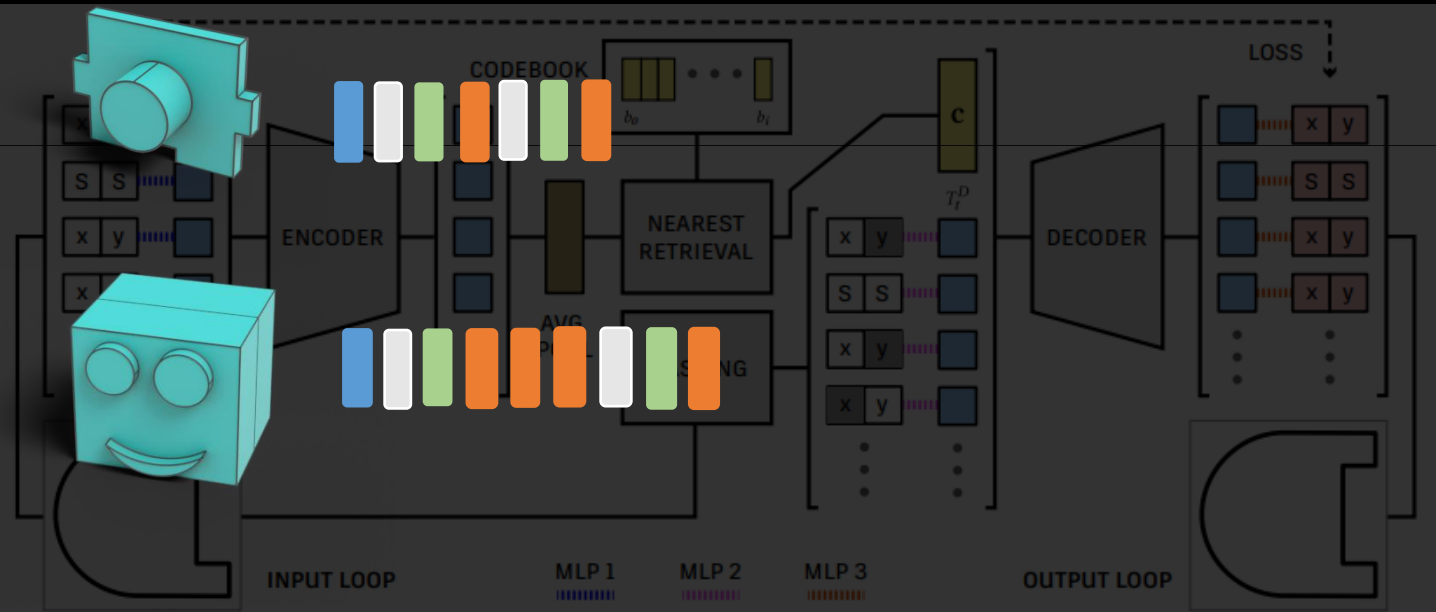


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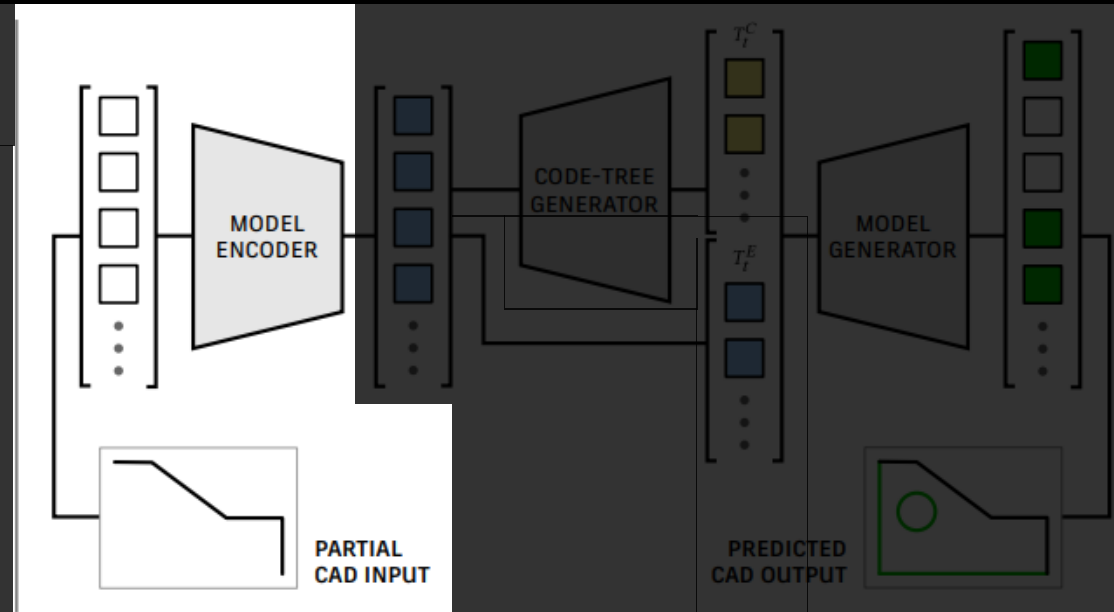
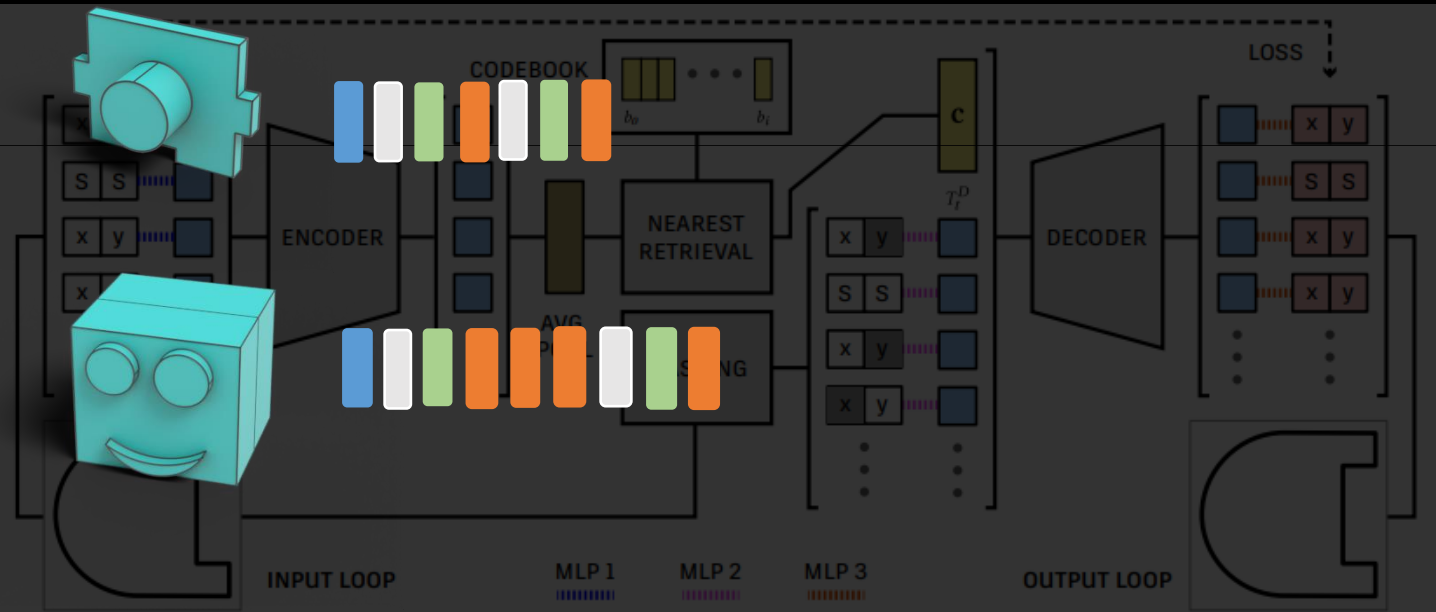


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Controllable CAD Generation

- **Model Encoder**
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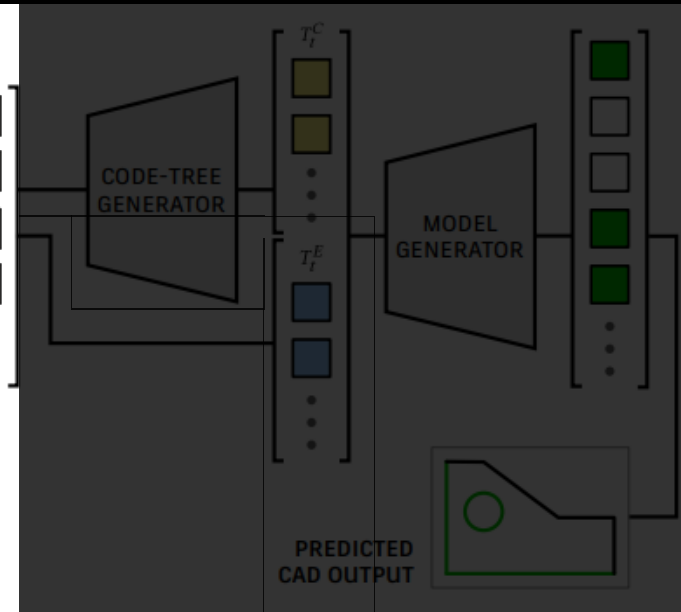
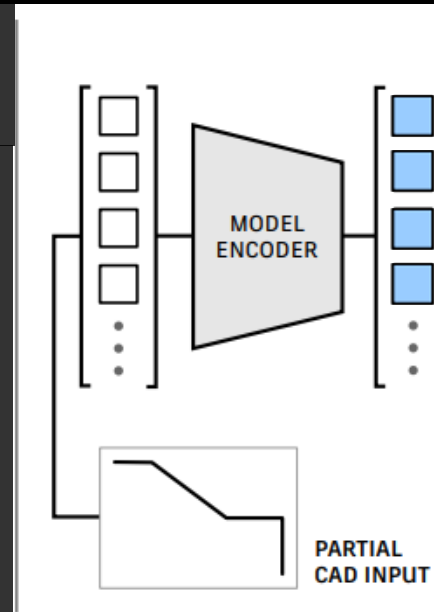
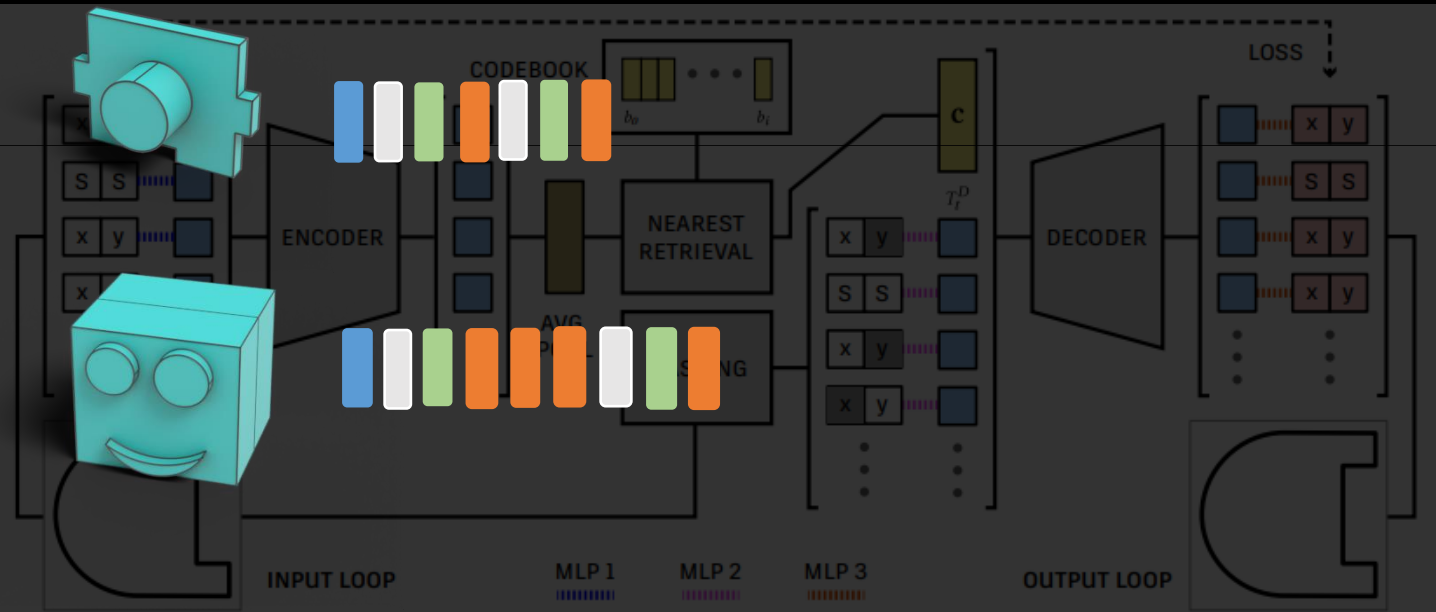


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Controllable CAD Generation

- **Model Encoder**
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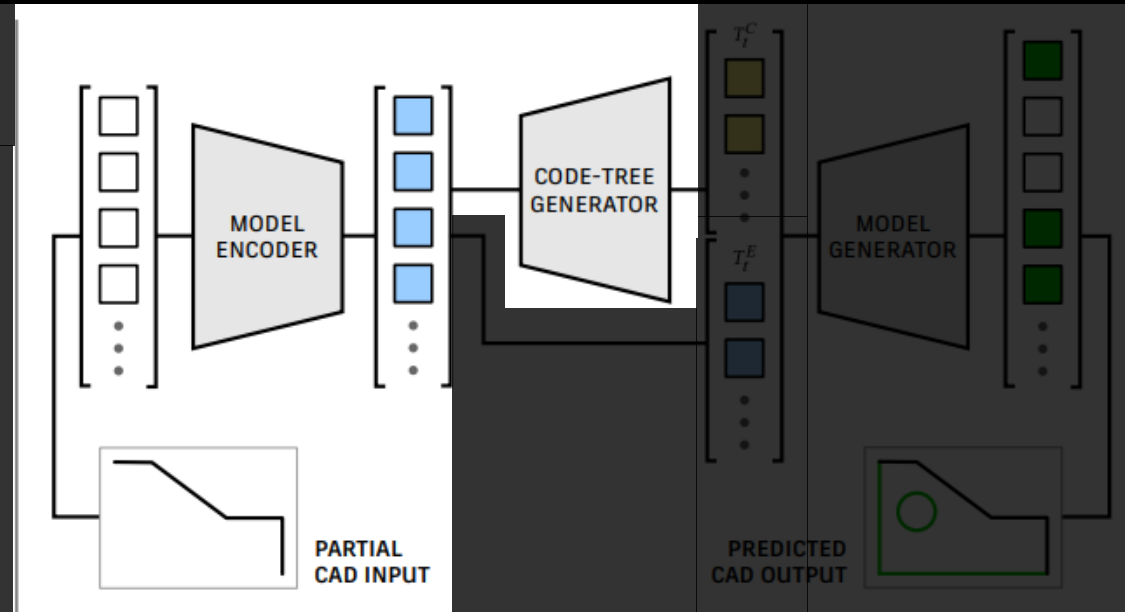
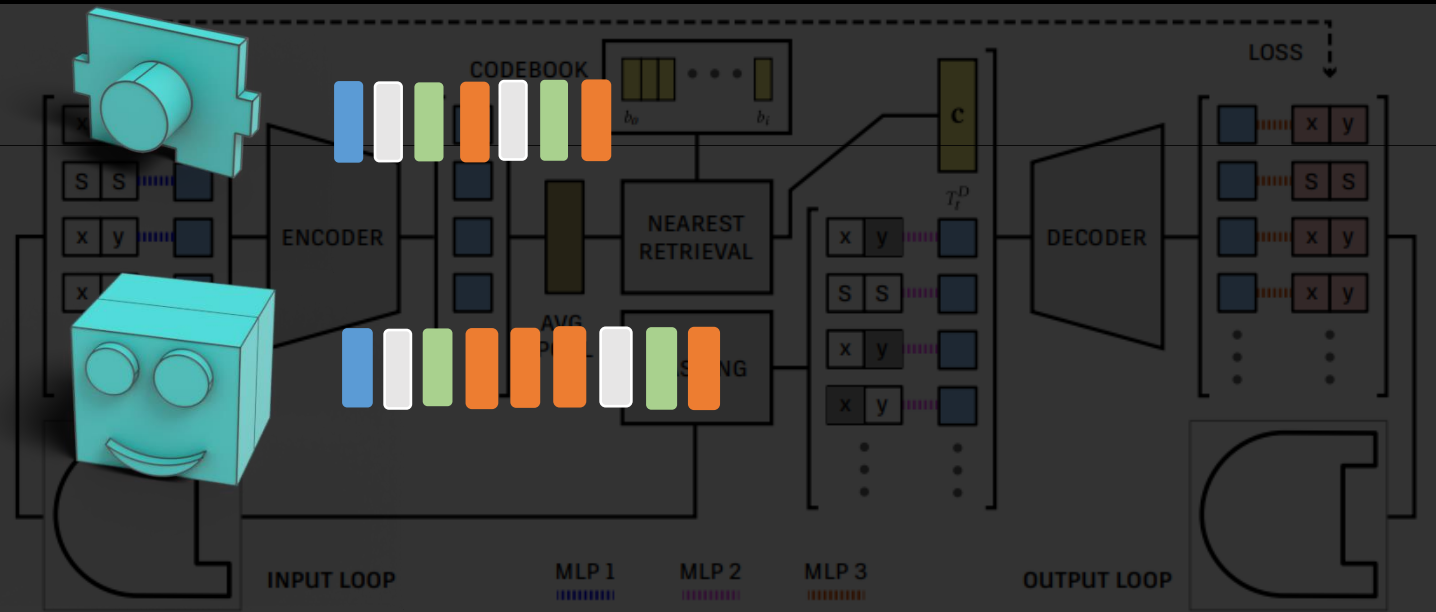


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Controllable CAD Generation

- **Model Encoder**
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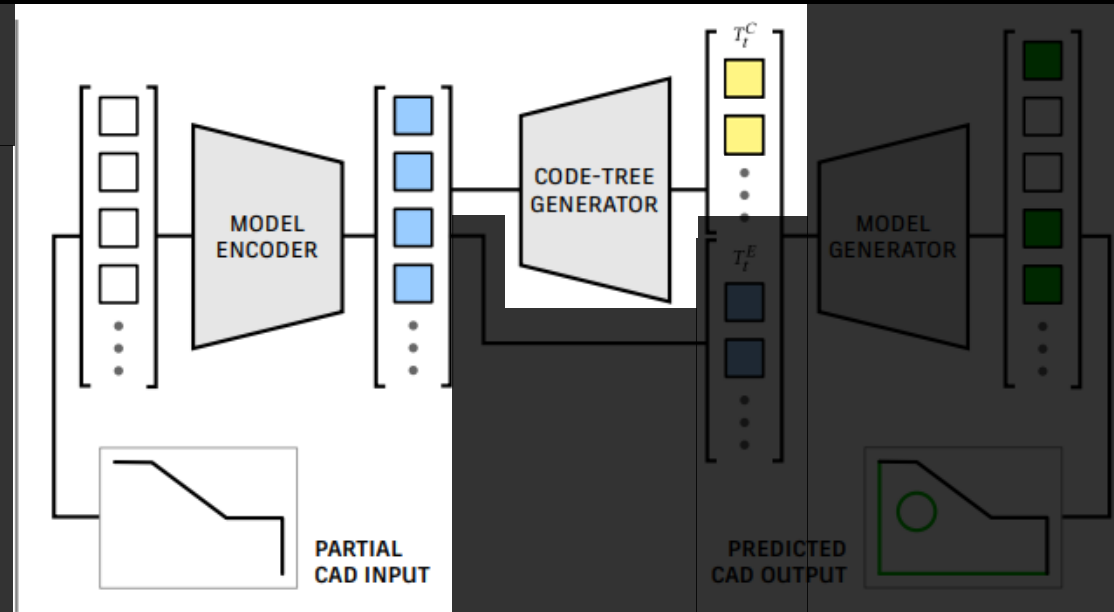
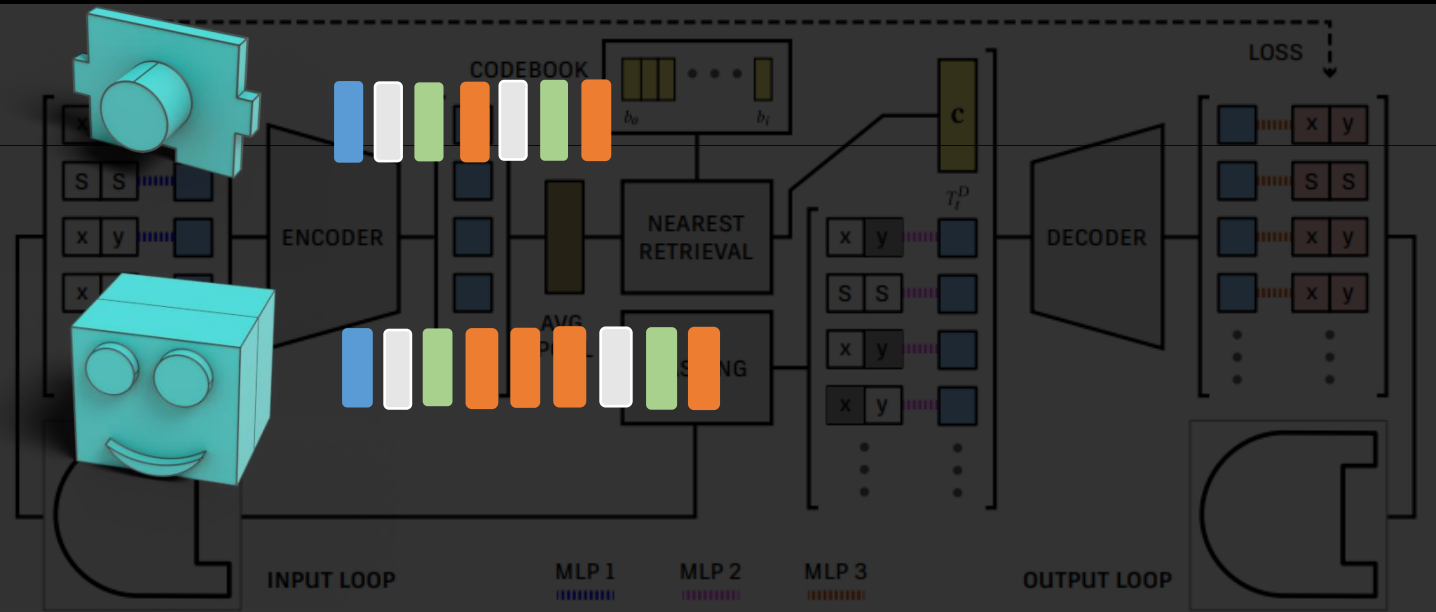


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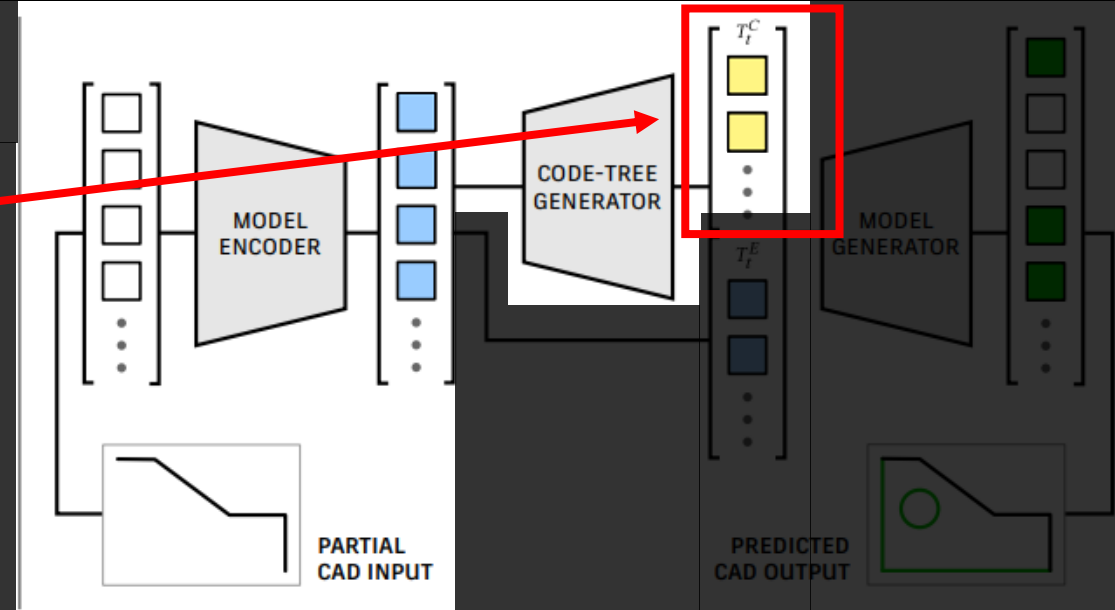
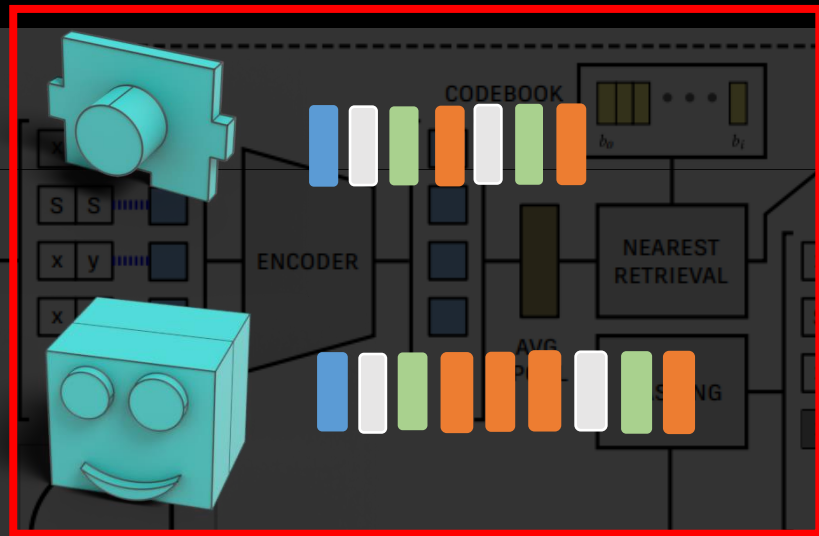


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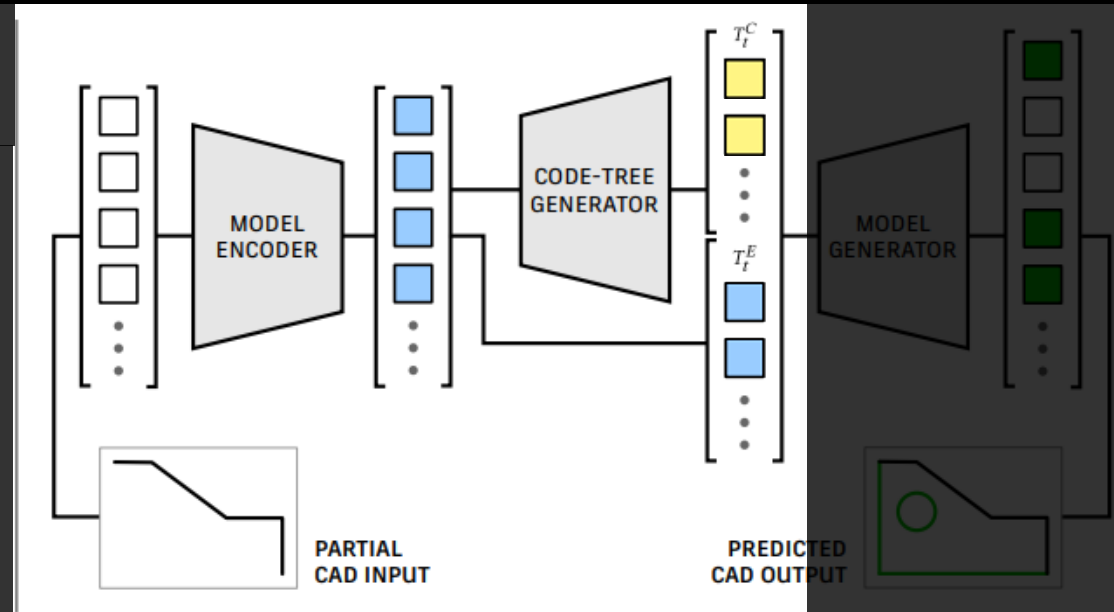
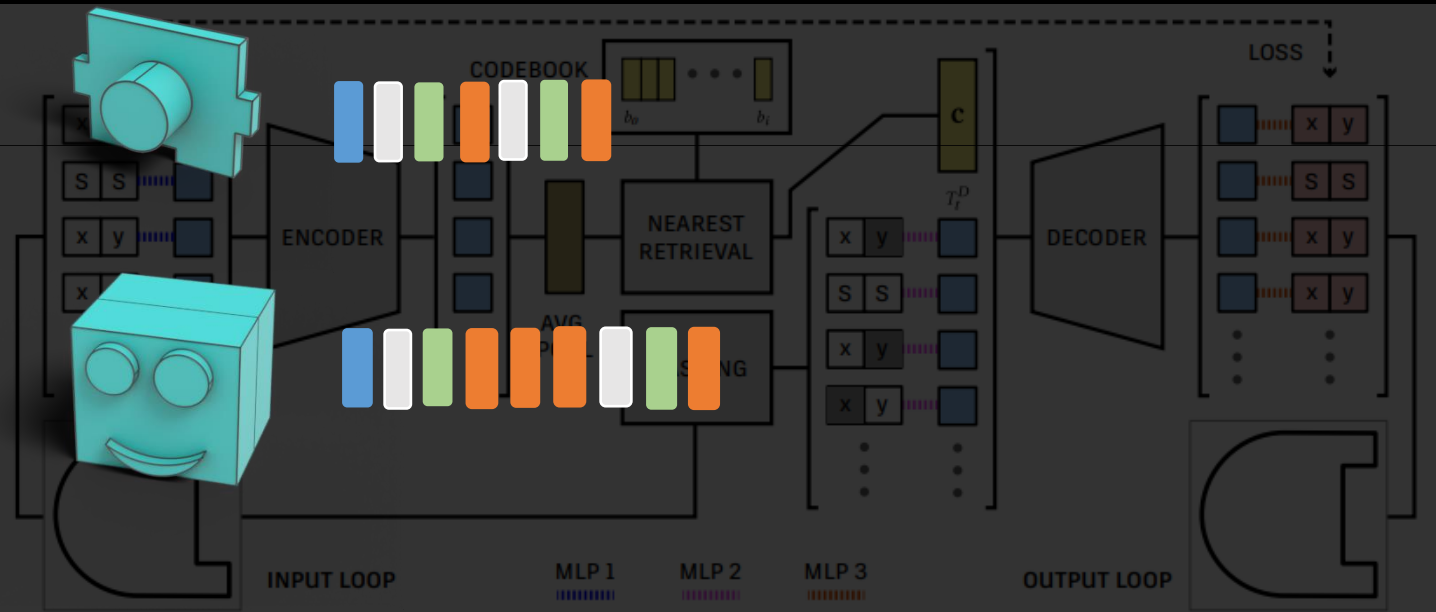


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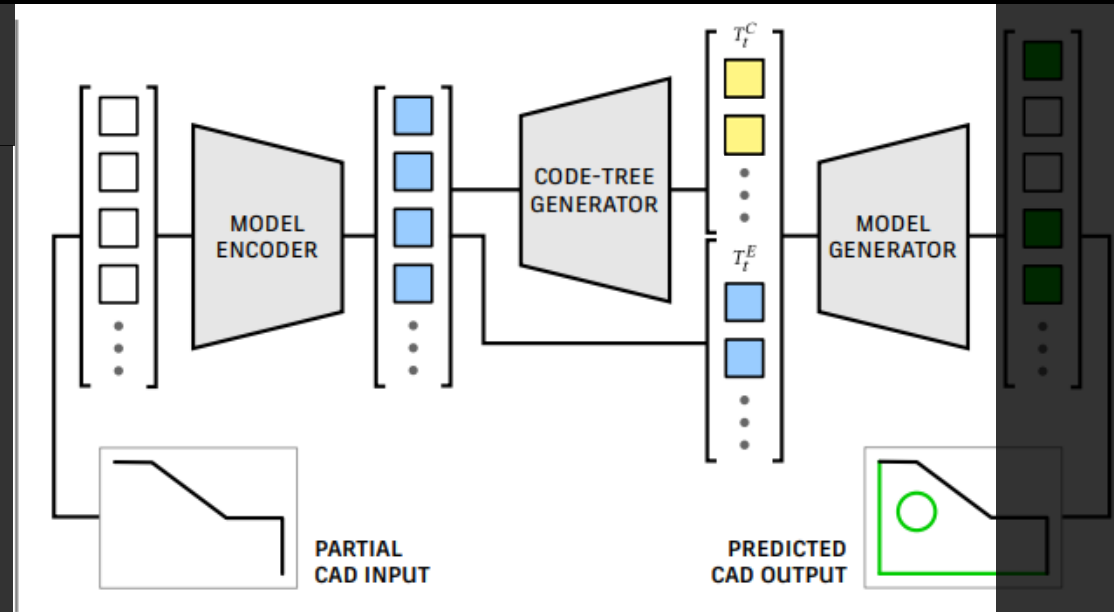
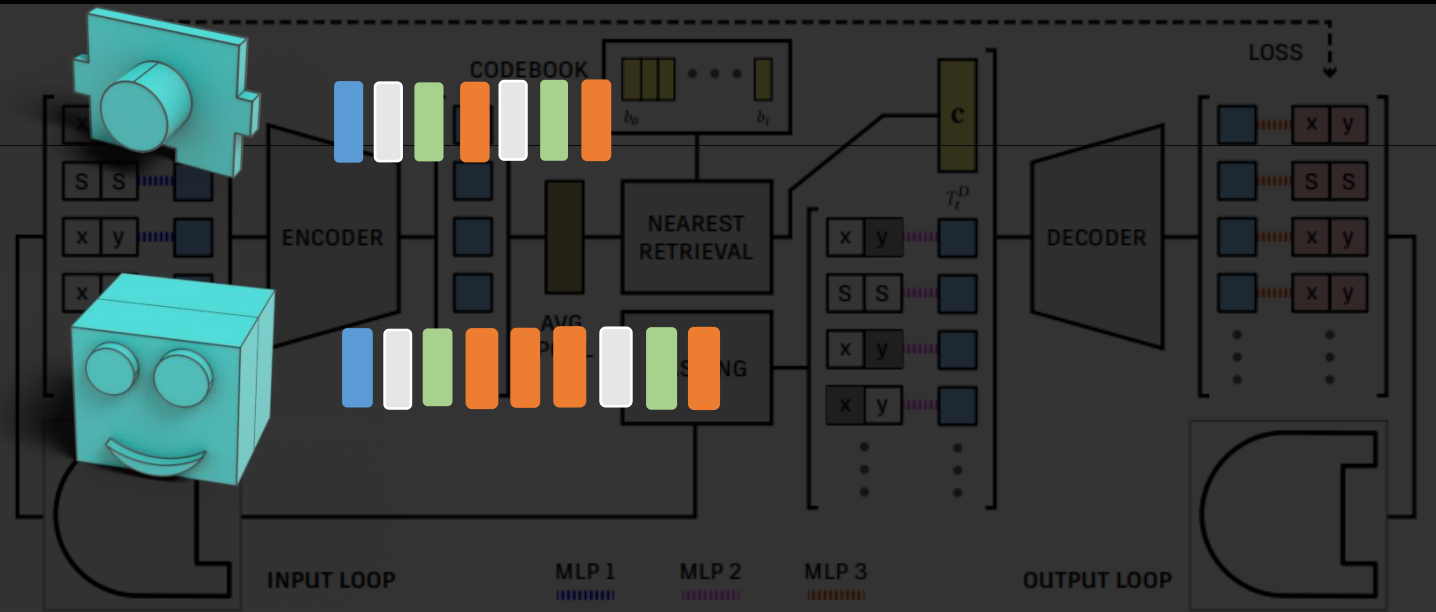


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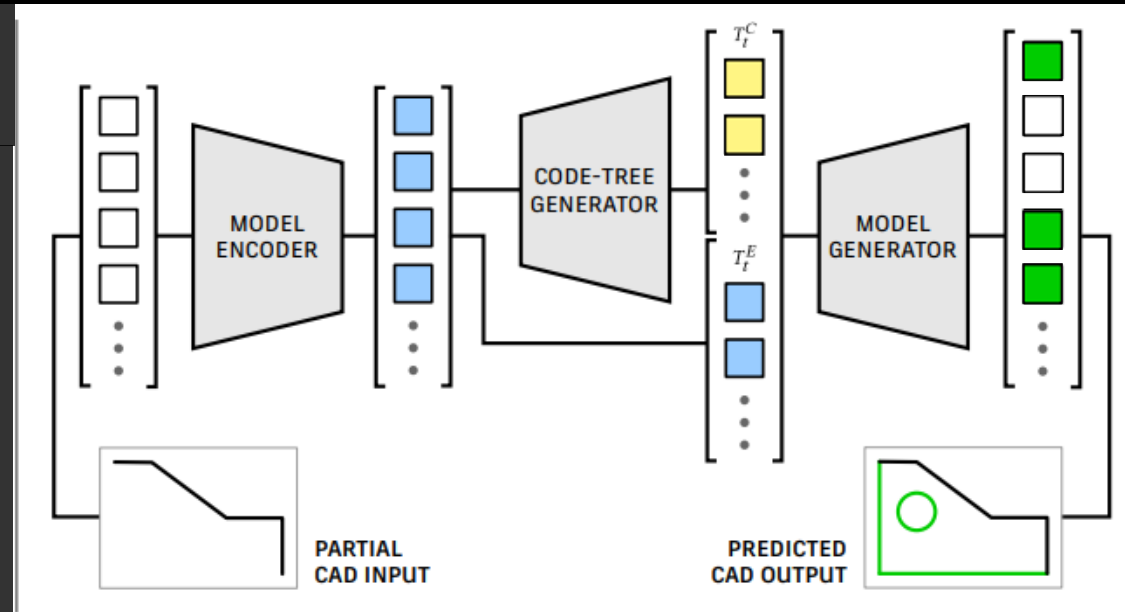
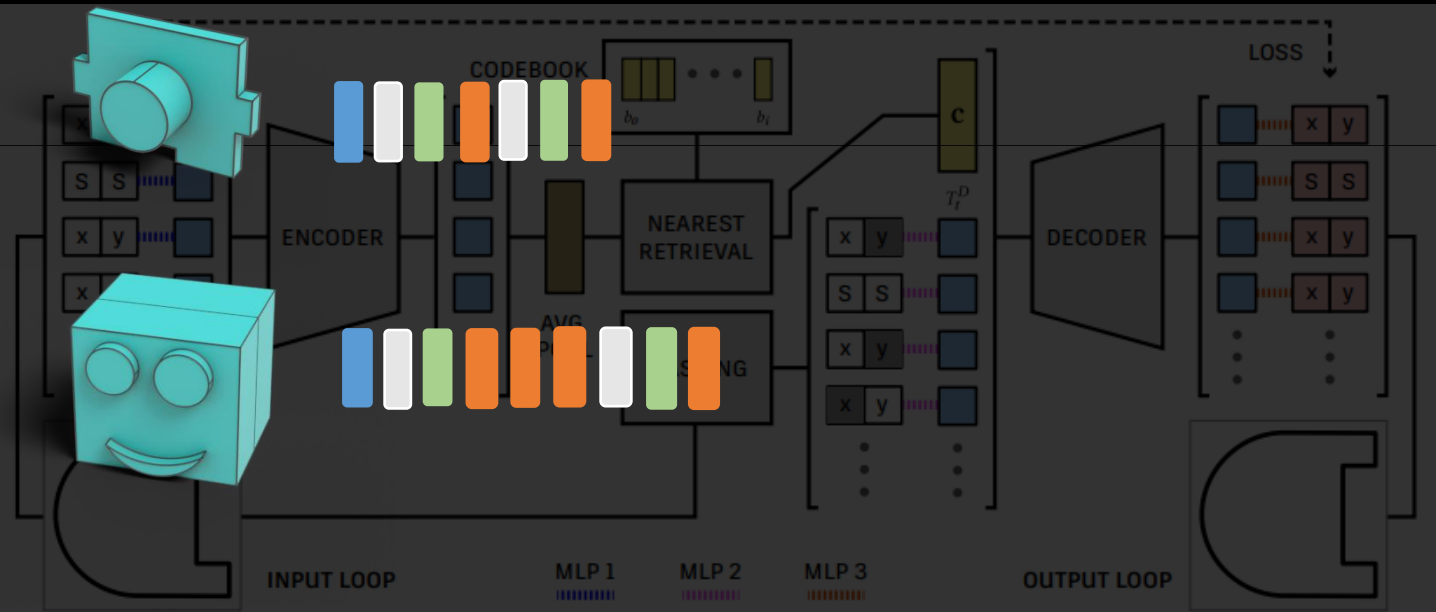


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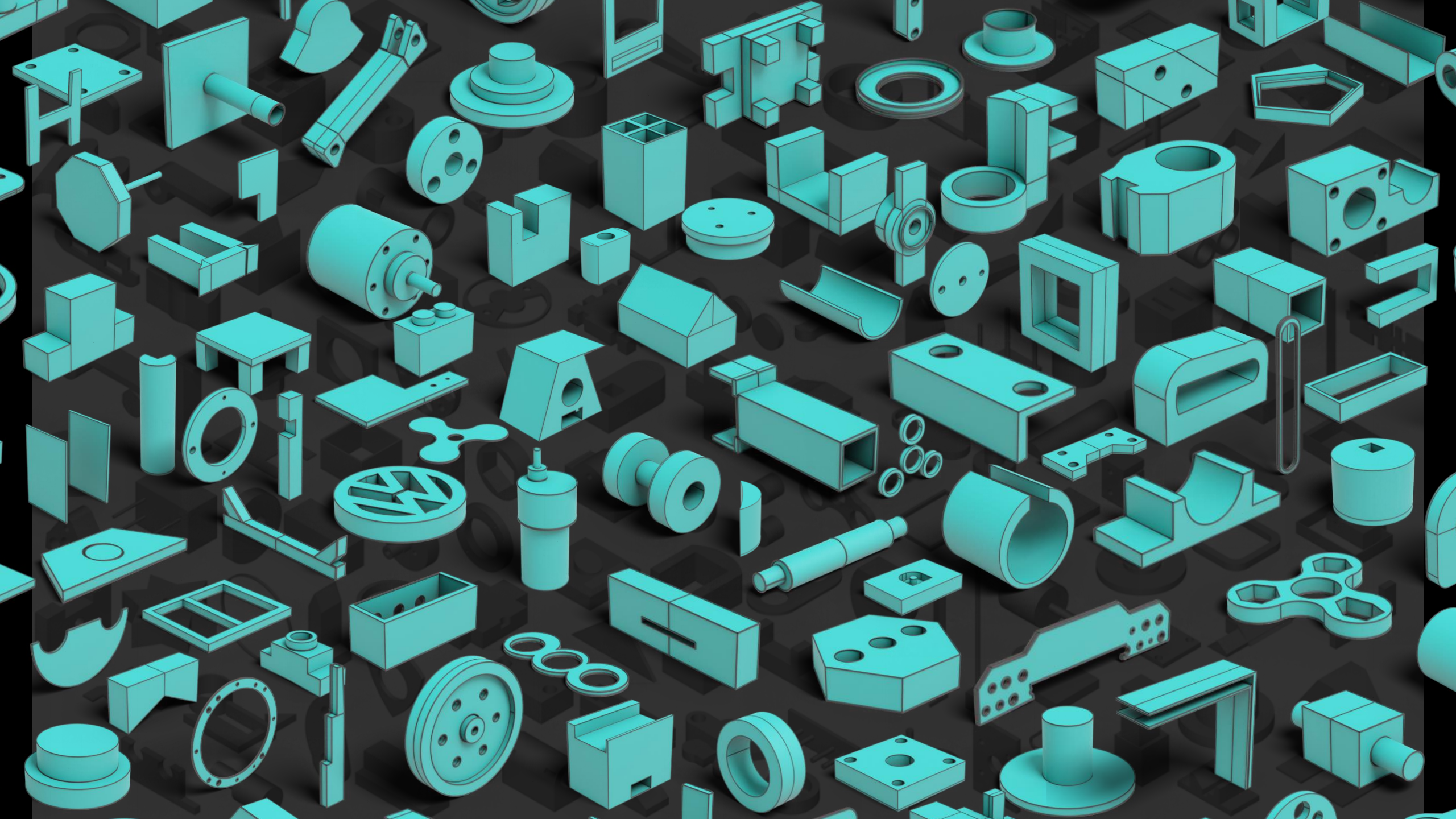


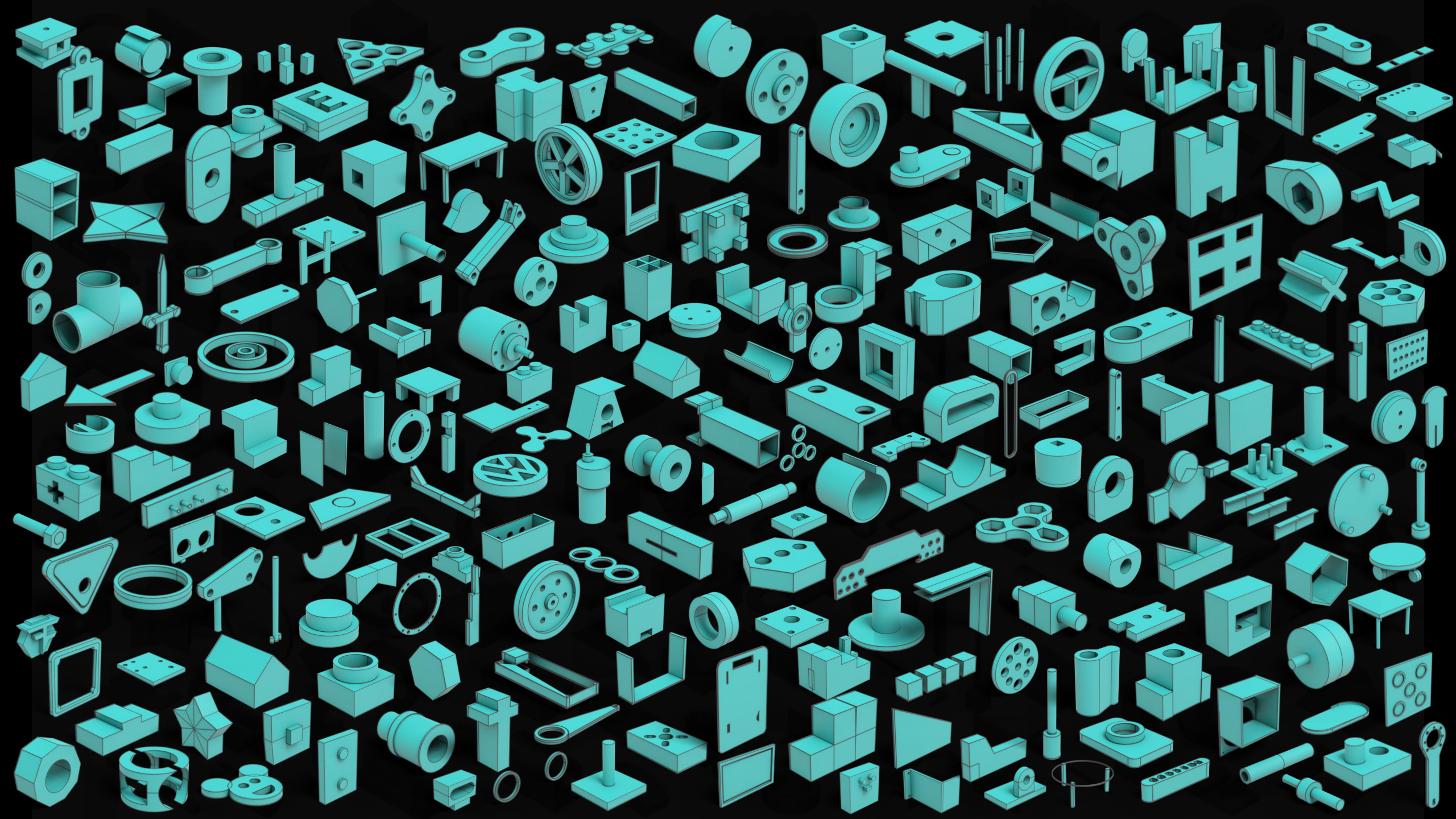
Three-Level Codebook Learning

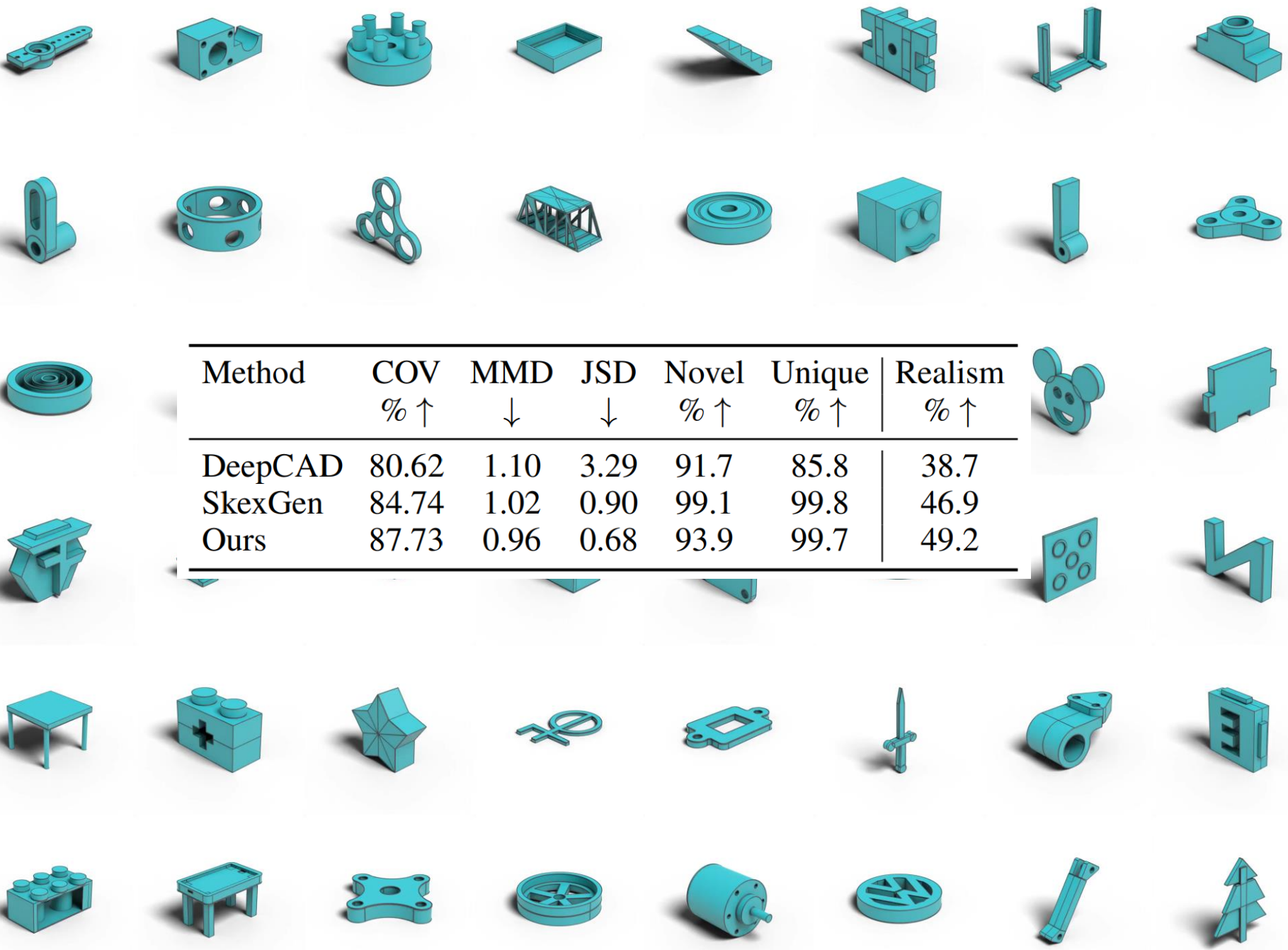
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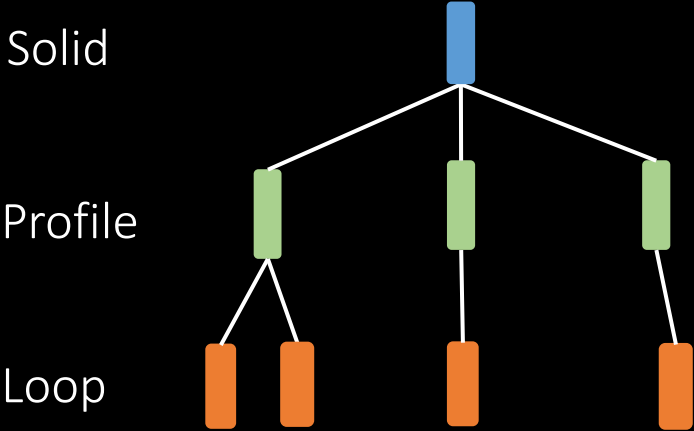




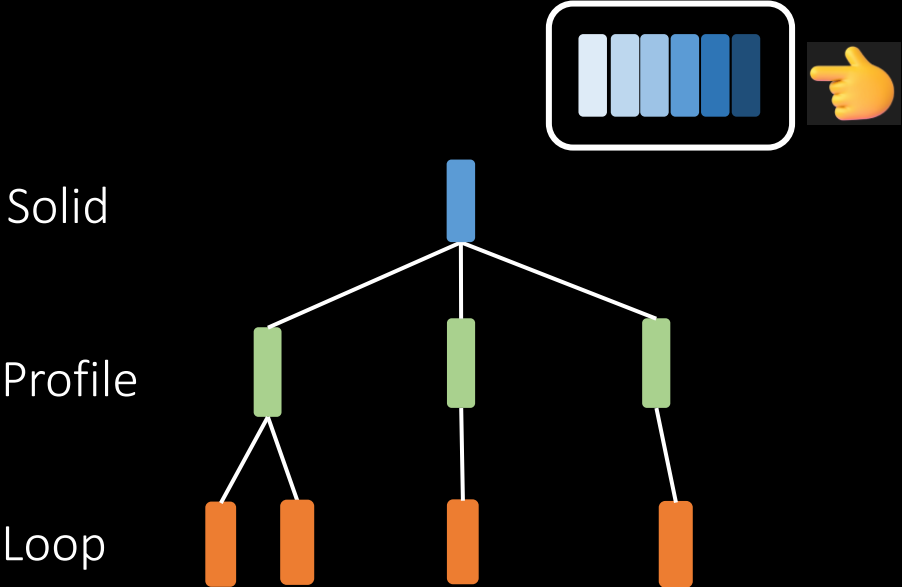


Method	COV % ↑	MMD ↓	JSD ↓	Novel % ↑	Unique % ↑	Realism % ↑
DeepCAD	80.62	1.10	3.29	91.7	85.8	38.7
SkexGen	84.74	1.02	0.90	99.1	99.8	46.9
Ours	87.73	0.96	0.68	93.9	99.7	49.2

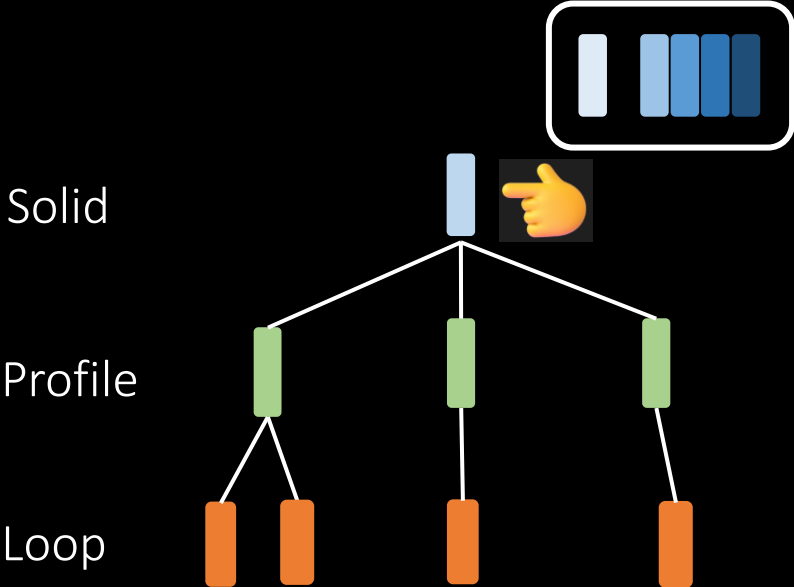
Code Tree Editing



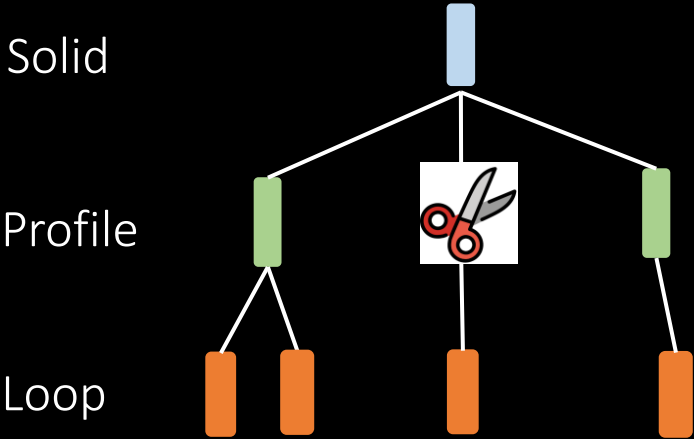
Code Tree Editing



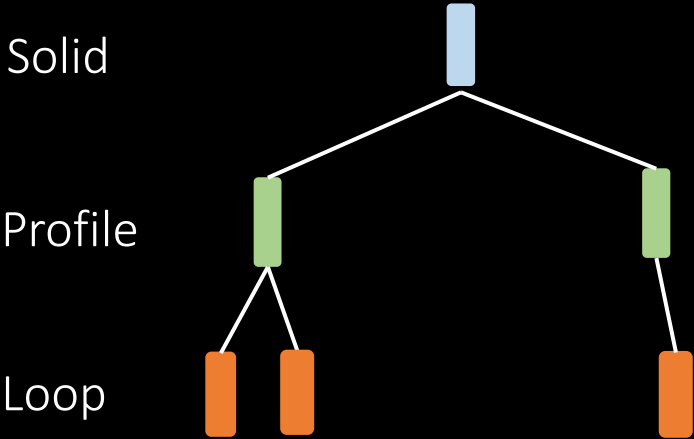
Code Tree Editing



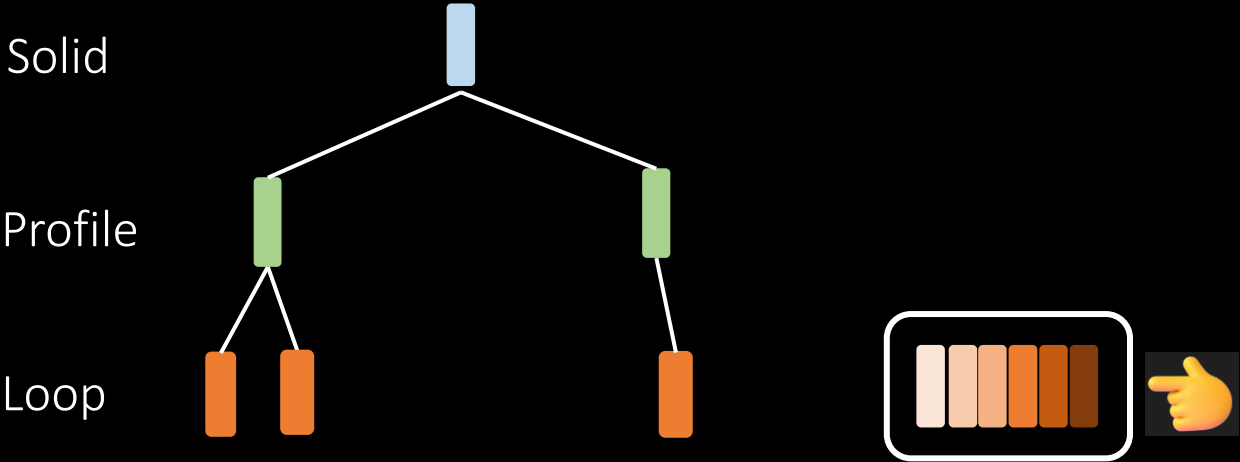
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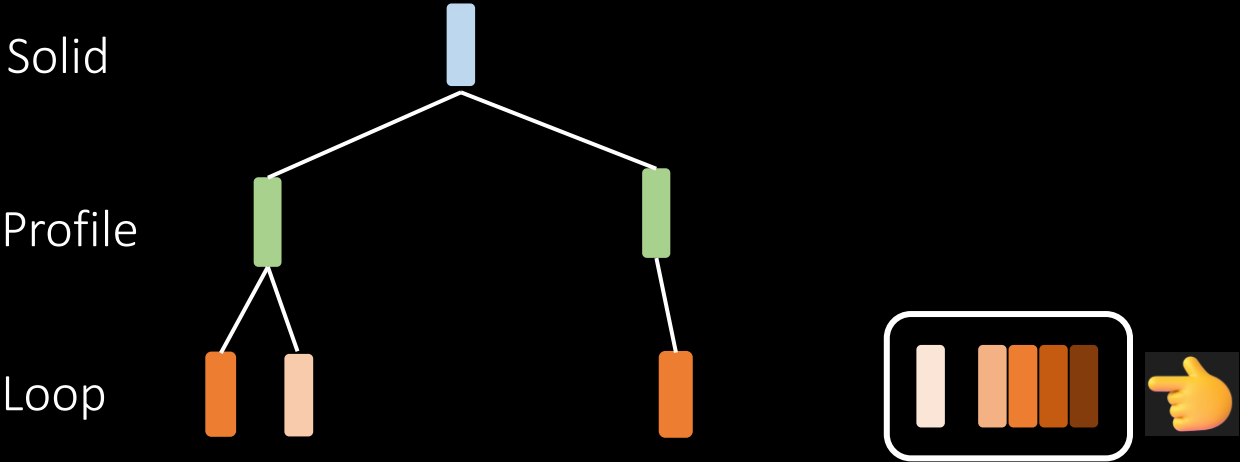
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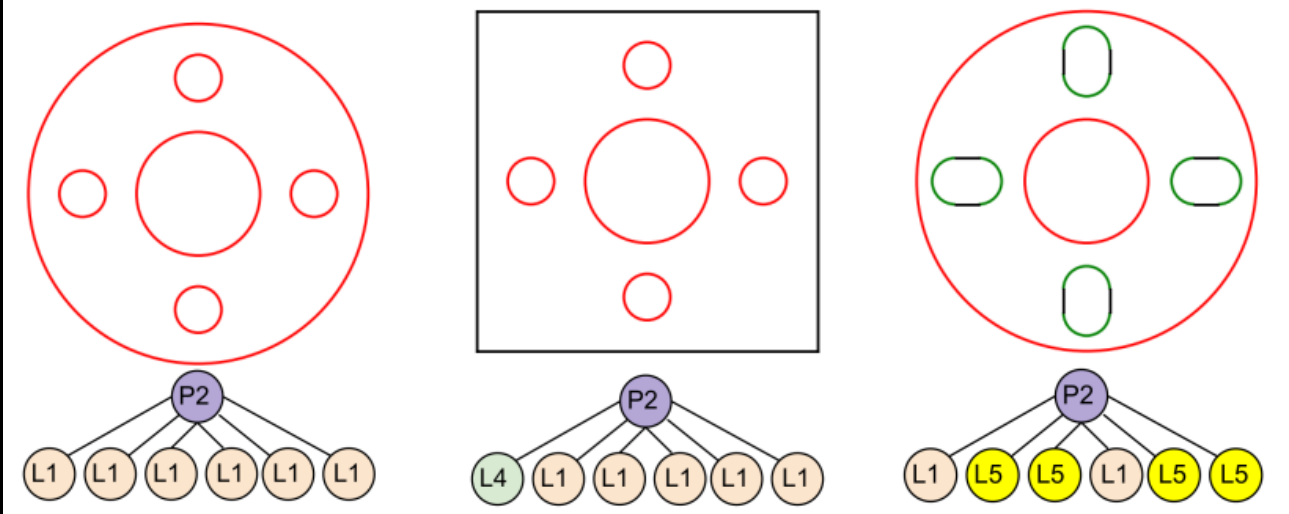
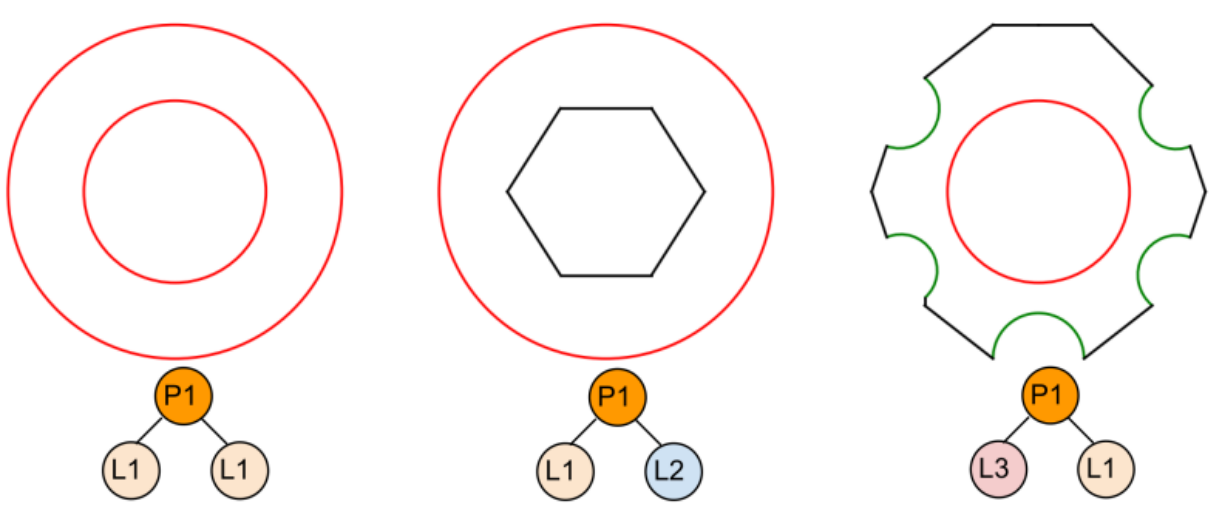
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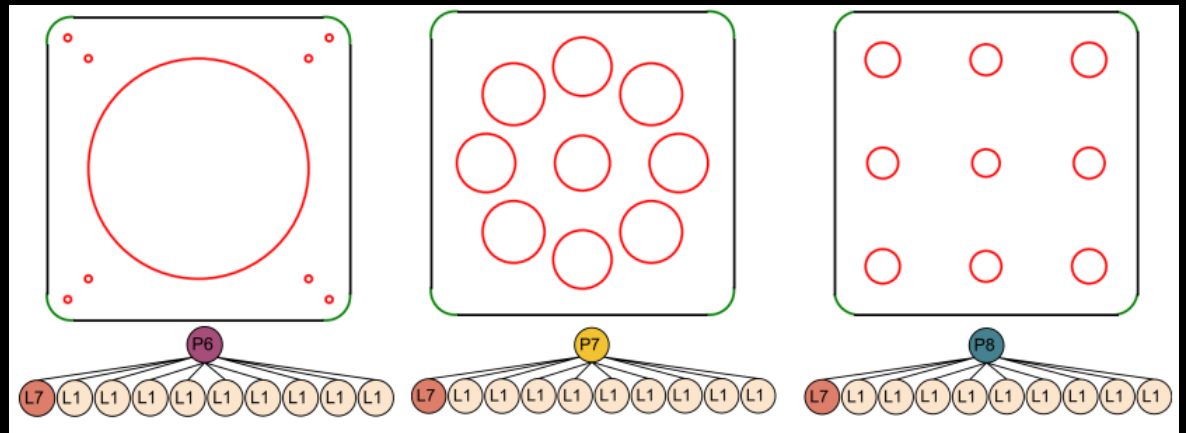
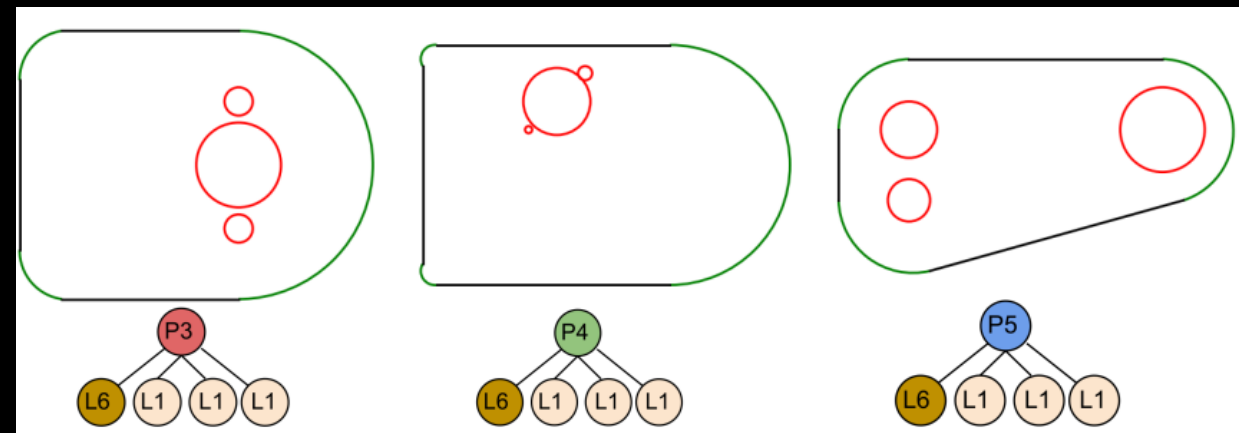
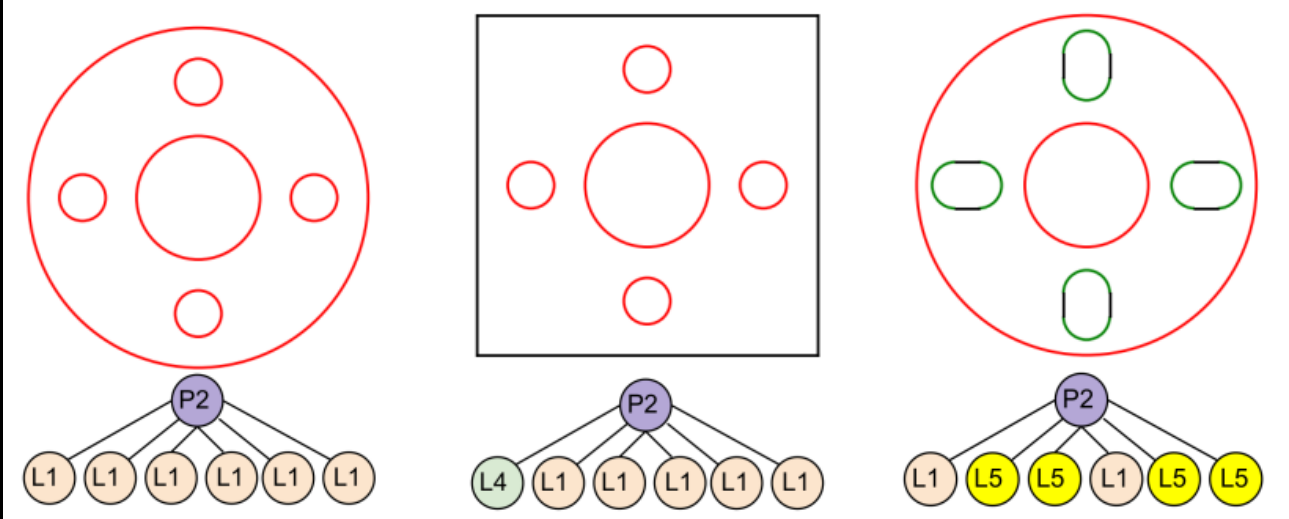
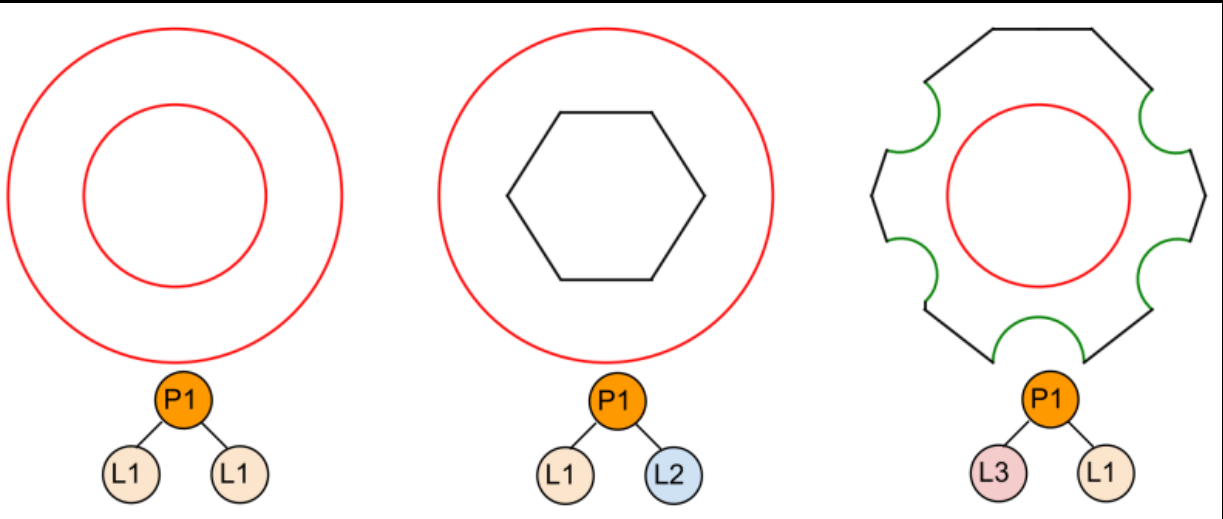
Code Tree Editing



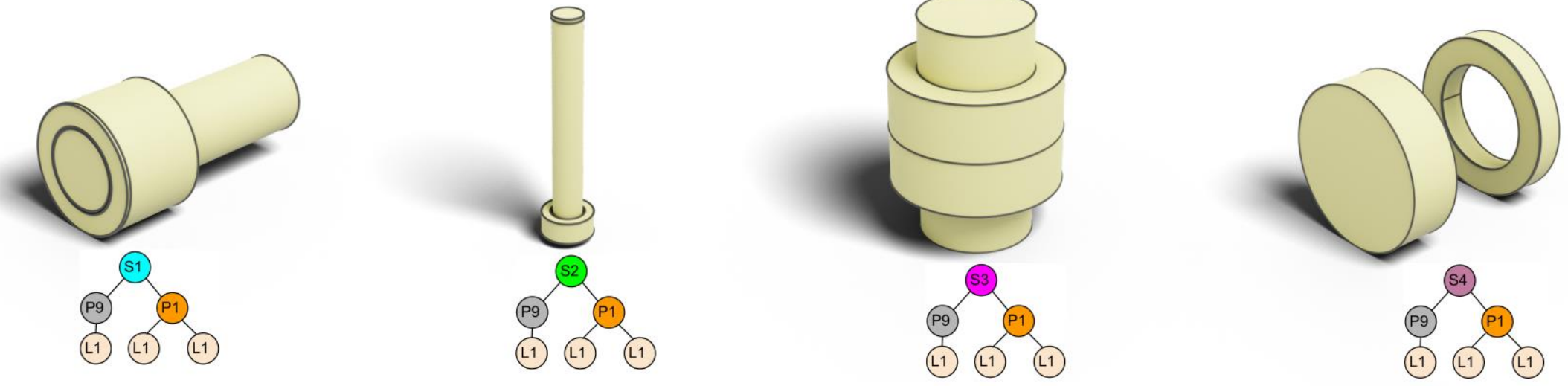
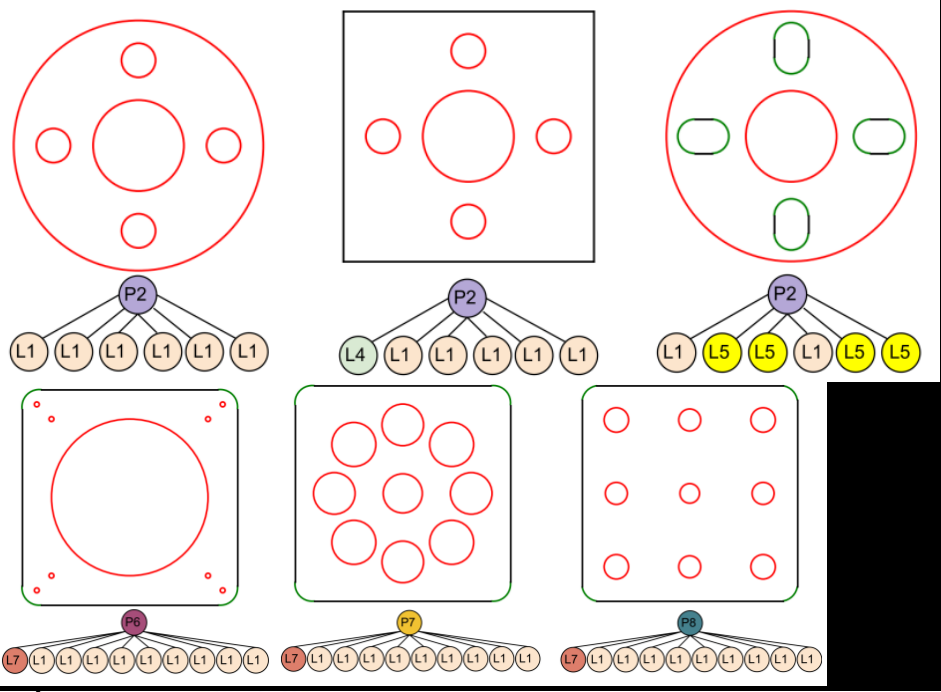
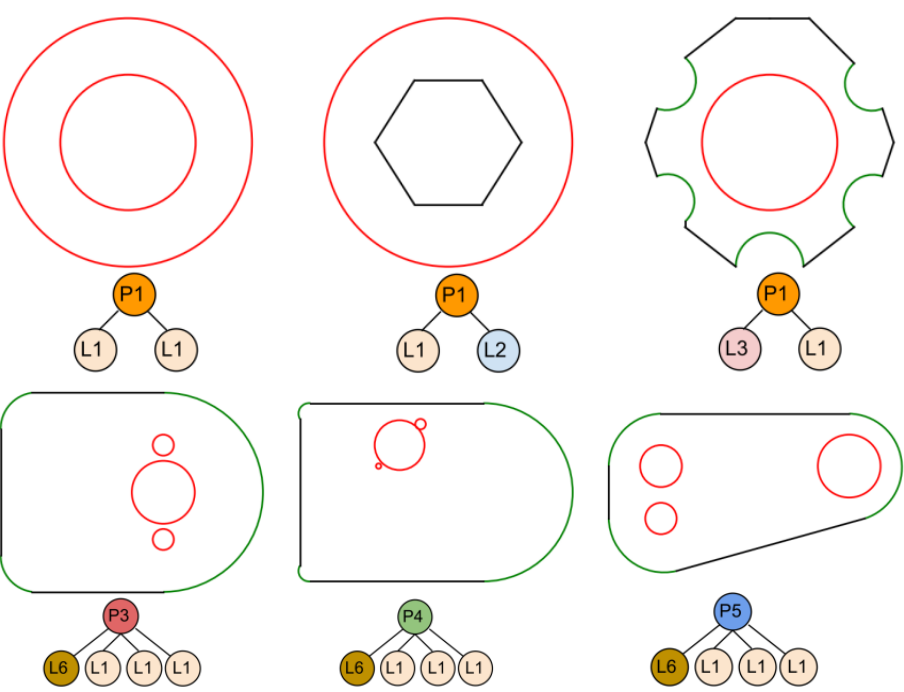
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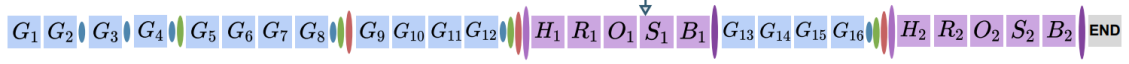
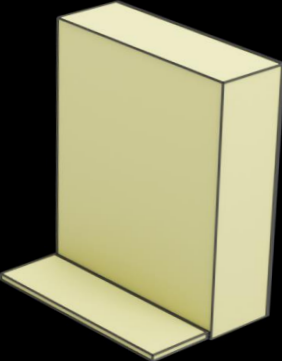
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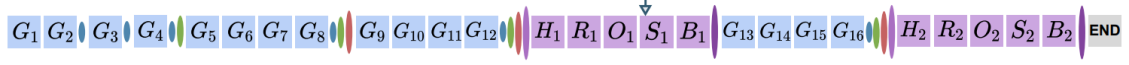
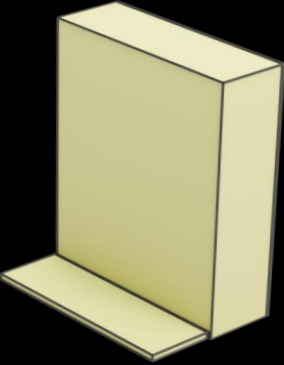
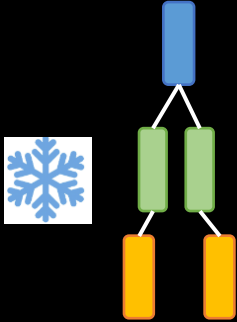
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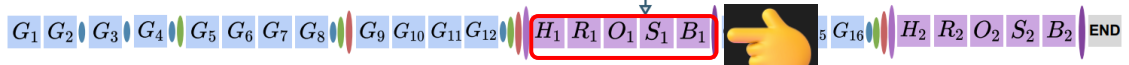
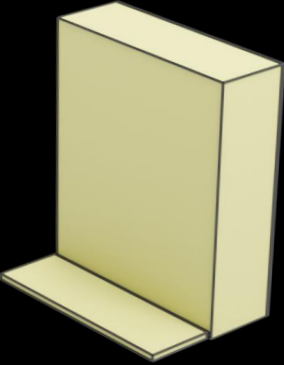
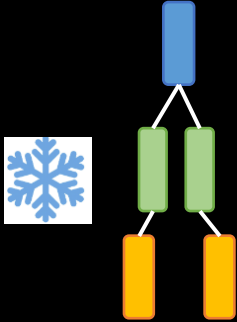
Design-Preserving Editing



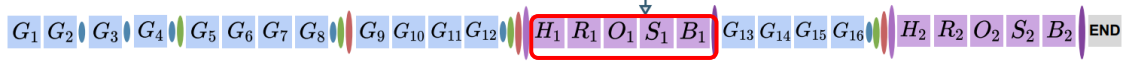
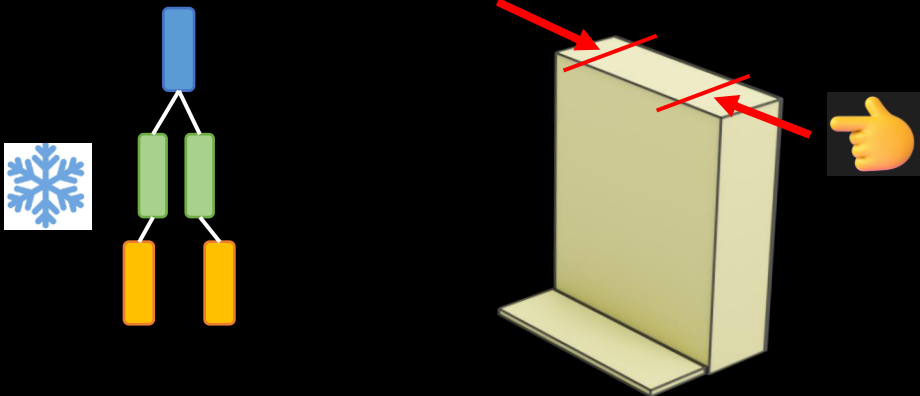
Design-Preserving Editing



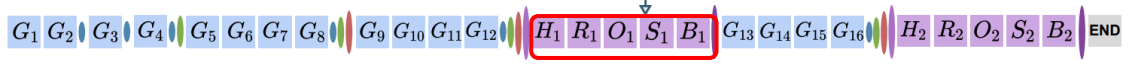
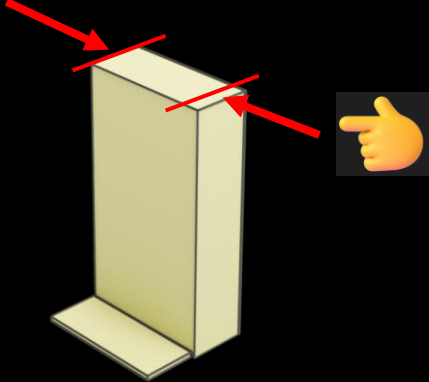
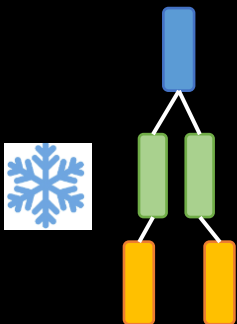
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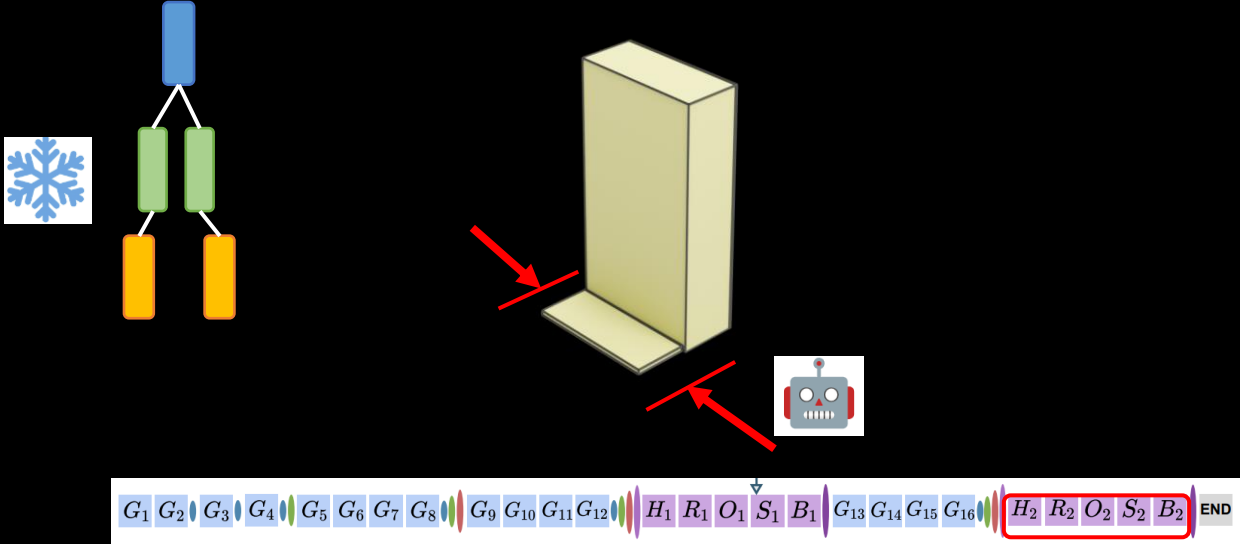
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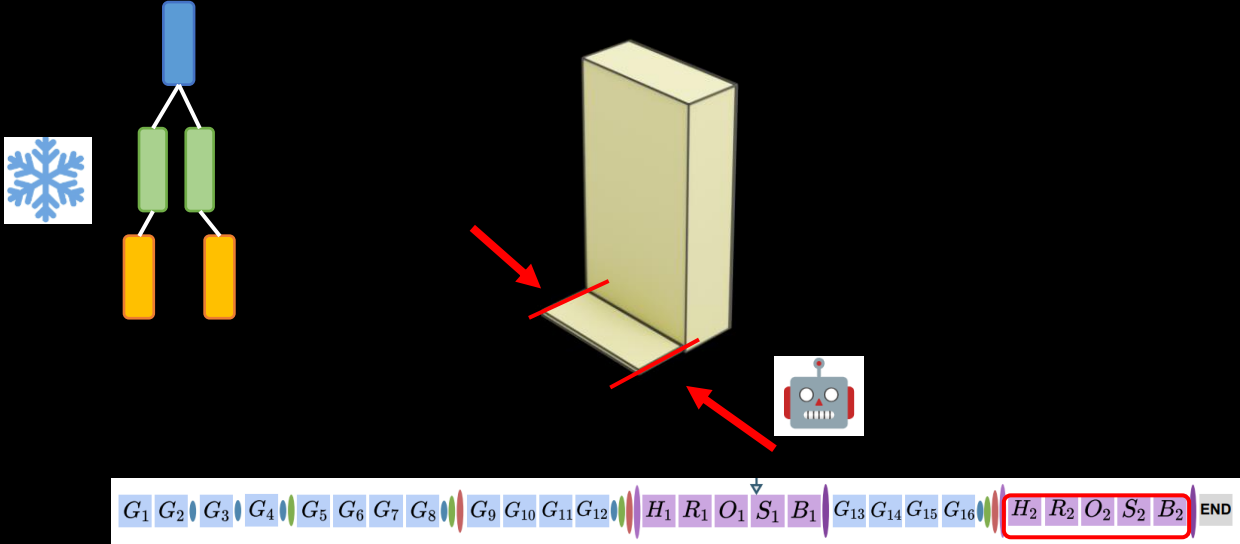
Design-Preserving Editing



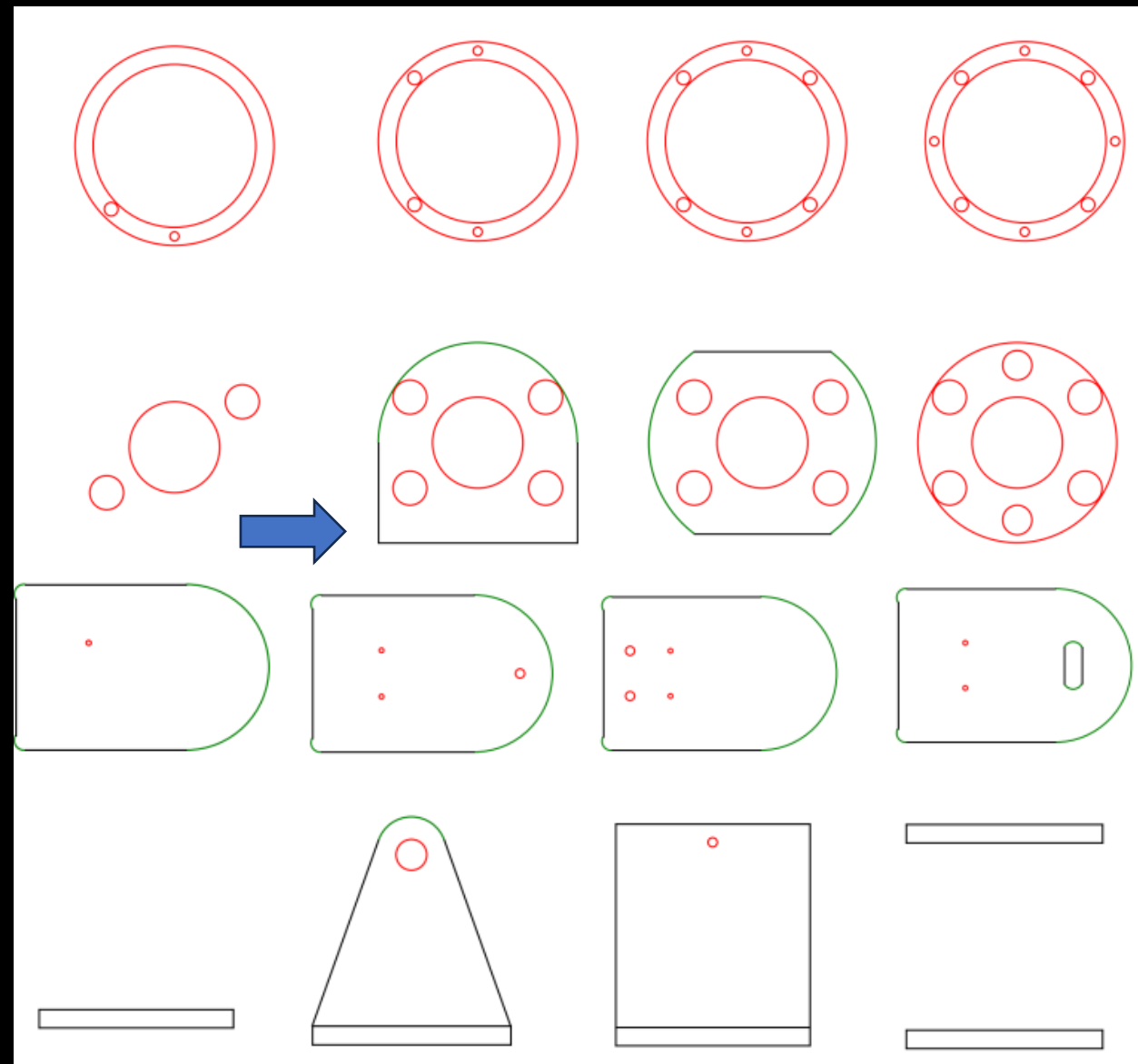
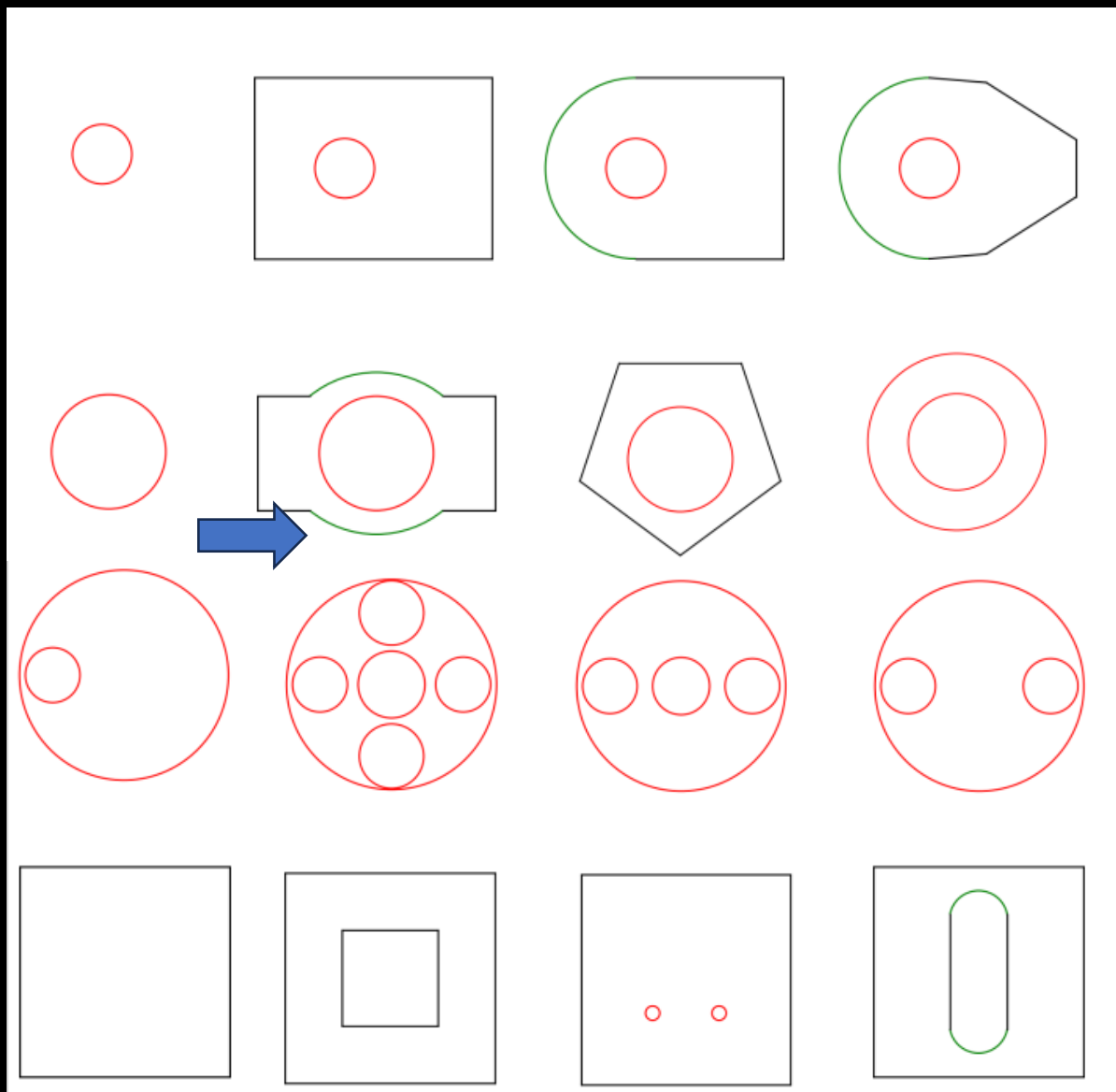
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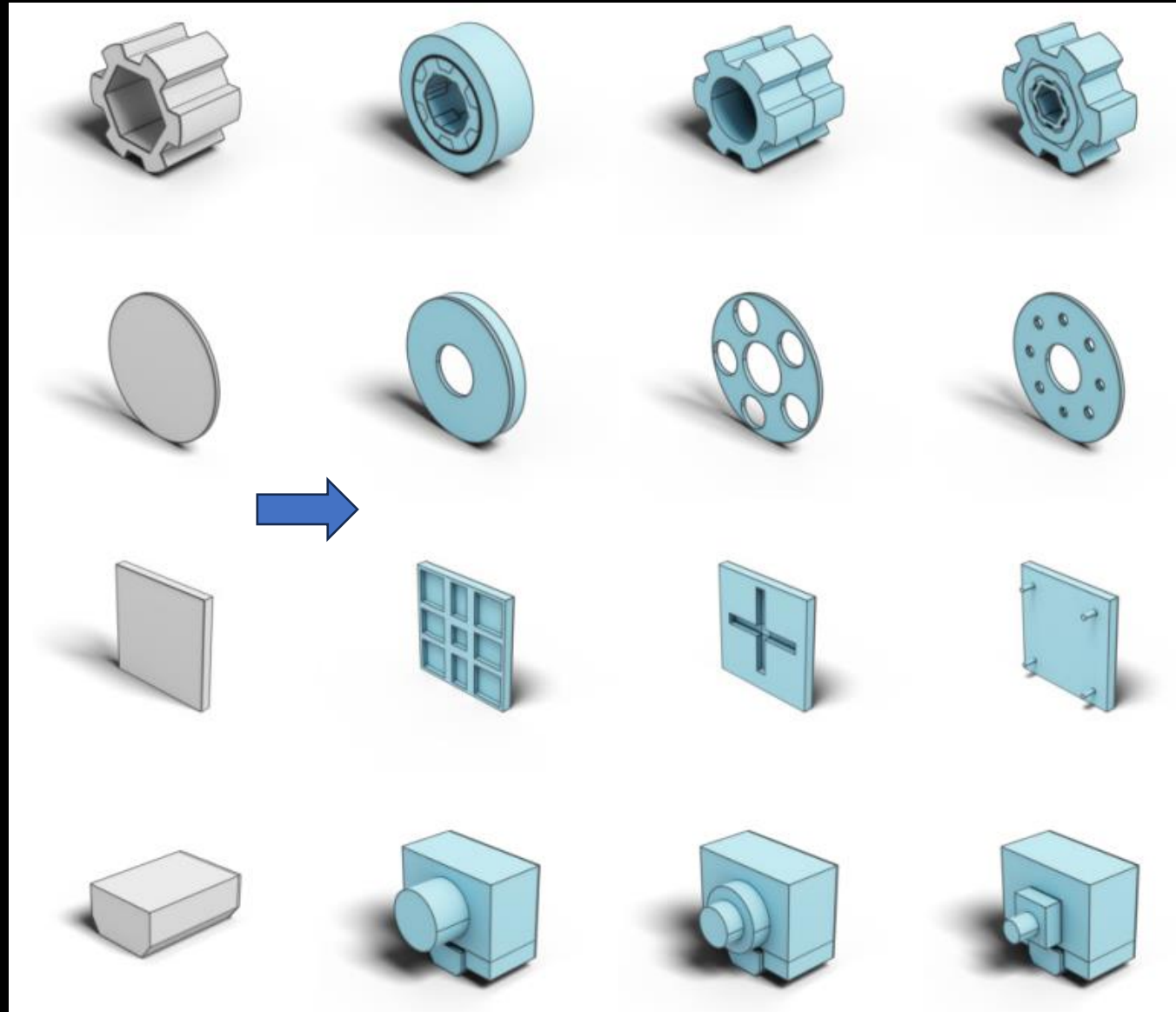
Design-Preserving Editing



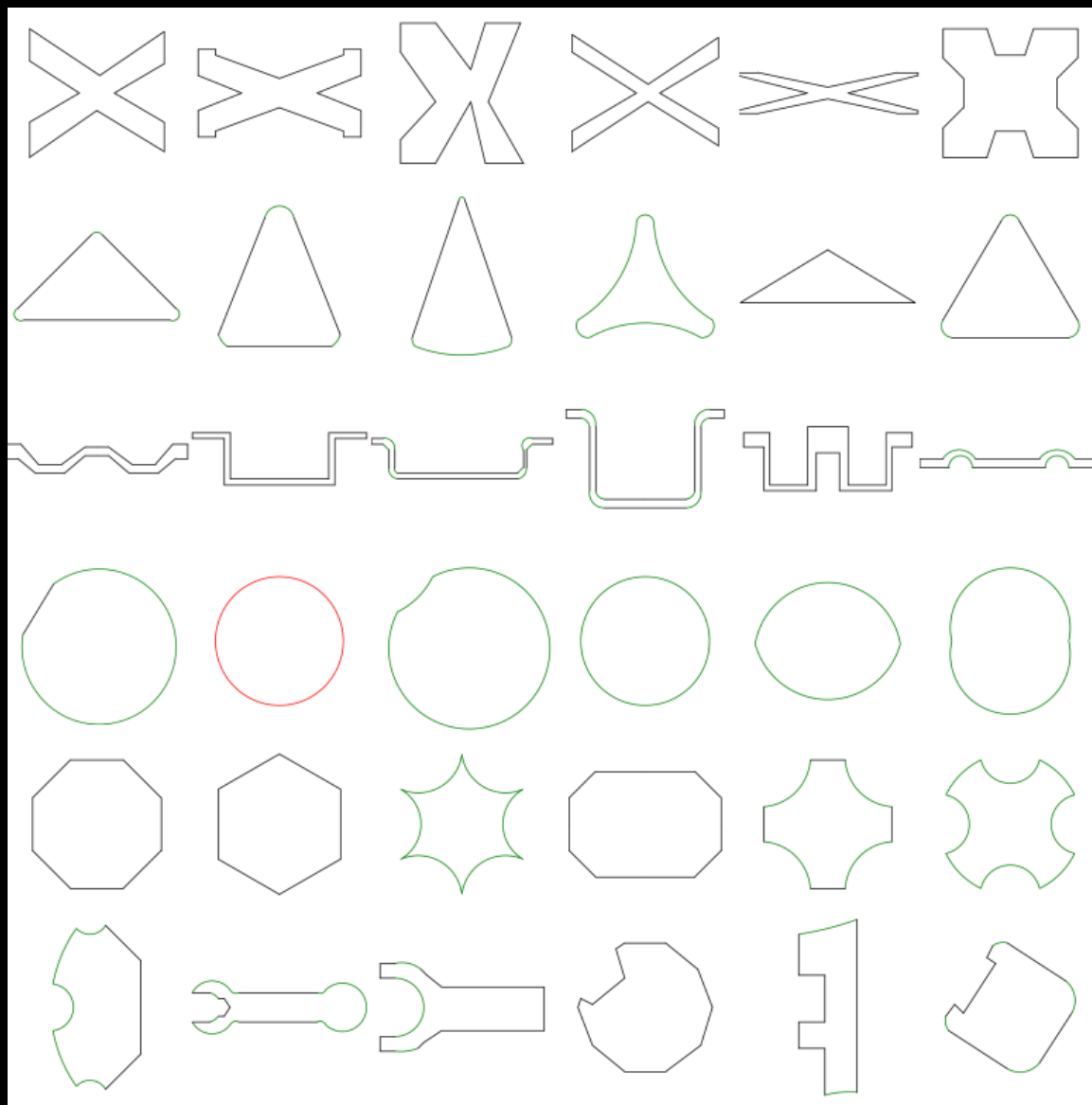
Autocomplete from Partial 2D Loops



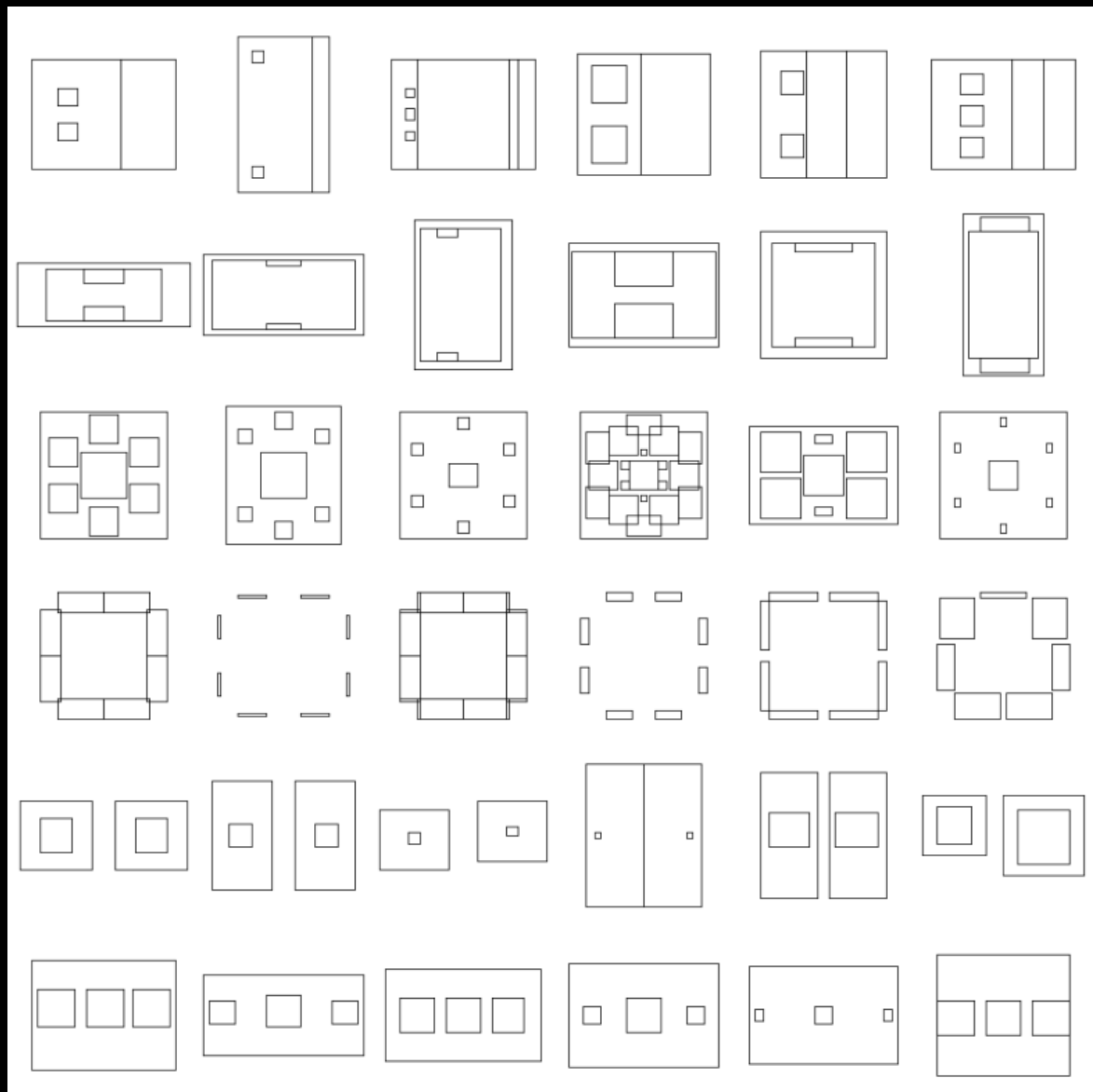
Autocomplete from Partial Extruded Profiles



Instance-Agnostic Design Pattern



Loop Codebook: each row mapped to the same code



Profile Codebook: each row mapped to the same code

Hierarchical Neural Coding for Controllable CAD Model Generation



Project Website: <https://hnc-cad.github.io/>



This research is partially supported by NSERC Discovery Grants with Accelerator Supplements and DND/NSERC Discovery Grant Supplement, NSERC Alliance Grants, and John R. Evans Leaders Fund (JELF)