# **Intelligent Tools for Creative Graphics**

SIGGRAPH 2020 Course



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# **Intelligent Tools for Creative Graphics**

- Geometric Reasoning
- Physical Constraints
- Data-Driven Techniques and Machine Learning
- Crowdsourcing



### **Geometry: Ideation, Design, Fabrication**







Estimated Creation Cost: \$200,000

Image from: The Next Leap: How A.I. will change the 3D industry, Andrew Price

### creating *high-quality content* is challenging and very expensive!!!

geometry semantics uv coordinates mesh quality motion material assignment illumination functionality







• Physics-guided geometric reasoning

Proxy-guided geometric reasoning

• Structure-guided geometric reasoning





Physics-guided geometric reasoning

Proxy-guided geometric reasoning

• Structure-guided geometric reasoning



"World's largest Rube Goldberg machine lights up Christmas tree"
https://www.youtube.com/watch?v=RBOqfLVCDv8

### **Learning Robustness from Simulations**







SIGGRAPH [Designing Chain Reaction Contraptions from Causal Graphs, Roussel et al., Siggraph, 2019] 🤋

### **Modeling High-dimensional Design Spaces**





### **Online Modeling**





### Simple Example







# **Design Options**



1. sketching

= interaction(sewing pattern, material, body shape)



### **Different Domain Representations**





SIGGRAPH [Learning a Shared Shape Space for Multimodal Garment Design, Wang et al., 2018]

# **Multimodal Design**





### Learning a Shared Latent Space





### **Loss Function Terms**





# **Supported Edits**



3

 $\sim$ 

### **Real Images**



### Sketch editing:

x4



# **Problem formulation**

#### **Character Motion**



[Learning an intrinsic garment space for interactive authoring of garment animation, Wang et al., Siggraph Asia, 2019]

SA2019.SIGGRAPH.ORG



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• Physics-guided geometric reasoning

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• Structure-guided geometric reasoning



### **Image Manipulation**





[Interactive Images: Cuboid Proxies for Smart Image Manipulation, Zheng et al., Siggraph, 2012]

### **Proxies: Arrangement of Cuboids**



### repetitions

co-planarity



# **Edit Examples**





### **Proxies: Generalized Cylinders**





[3-Sweep: Extracting Editable Objects from a Single Photo, Chen et al., Siggraph Asia, 2013]



10541.png



10772.png



12345.png



12855.png



14110.png



world: -48.4829, 47.248 FPSG:27700: 528681.9034.18

### **FrankenGAN Architecture**





[FrankenGAN: Guided Detail Synthesis for Building Mass Models Using Style-Synchonized GANs, Kelly et al., 2018]

# FrankenGAN: 'Procedural' Steps





Input: Madrid

# Output: Madrid







• Physics-guided geometric reasoning

• Proxy-guided geometric reasoning

Structure-guided geometric reasoning











[StructureNet: Hierarchical Graph Networks for 3D Shape Generation, Mo et al., Siggraph Asia, 2019]





#### structure: elements (parts) + relationships





# **Examples of Domains with Structure**

3d shapes



#### 2D layouts



#### Patterns



Scene Compositions & Scene Graphs





Li et al., GRAINS: Generative Recursive Autoencoders for INdoor Scenes, TOG 2018



# Why Structure?

#### **Unstructured representation**

- Regular sample grids and point clouds
- Have received more research

point clouds for man-made 3d objects



#### images for patterns



#### **Structured representation**

Provides additional information for down-stream tasks

Change type of backrest? Transform sub-graph?



Changes the data flow • and inductive bias of a network GT. w/o struc. with struc.

w/o edges with edges



# Goal: A Smooth, Explorable Shape Space







... of both geometry and structure









### With vs. Without Structure

source

target



### **Object Representation: Part Geometry**





### **Object Representation: Part Structure**





### **Object Representation: Part Structure**





### **Object Representation: Sibling Relationships**

Reflectional Symmetry  $\tau_{\rm r}$ Rotational Symmetry  $\tau_{\rm o}$ Translational Symmetry  $\tau_{\rm t}$ Adjacency  $\tau_{\rm a}$ 





### **Object Representation: Part Structure**





# **Architecture: Variational Autoencoder**





# A Hierarchy of Graphs

VAE with hierarchical graph encoder and decoder





# **Applications**

#### free generation

#### interpolation







generated

#### closest training samples





# **Comparison to GRASS**





# **Applications**

#### reconstruction



#### editing



### **Structuring Shape Distributions**





### **Shape Deltas**







[StructEdit: Learning Structural Shape Variation, Mo et al., CVPR, 2020]

# Shape Neighborhoods



Learn conditional distributions  $p(\Delta S_{ij}|S_i)$  of deltas in all neighborhoods with a VAE





### **Infer Main Edit Modes**





### **Transfer Analogous Edits**



58



### **Latent Space of Programs**











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xpression:	•	

All

Lighting Left->Right:	. <u> </u>
Right->Left:	·
Down->Up:	·
Up->Down:	+
No light:	
Front light:	



# **Further details**

Physics-guided geometric reasoning

Proxy-guided geometric reasoning

Structure-guided geometric reasoning

http://geometry.cs.ucl.ac.uk/publications.php

Special thanks to all our collaborators and group members.





