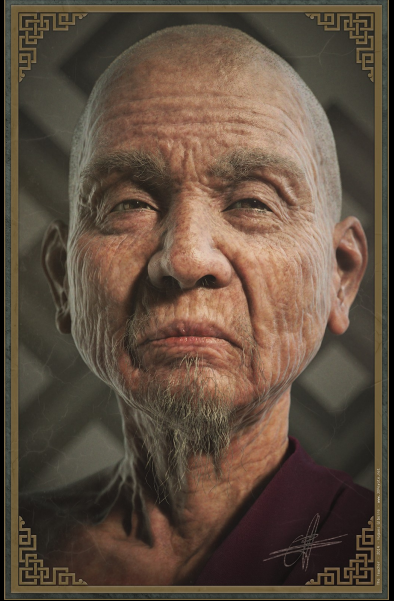
modflows

methods for studying and managing mesh editing workflows

jonathan d. denning
dartmouth college

ph.d. thesis defense, 2014 april 23


tyler bolyard, 2014



[hugues giboire, 2014]


[tamas gyerman, 2014]

[hossein diba, 2012]

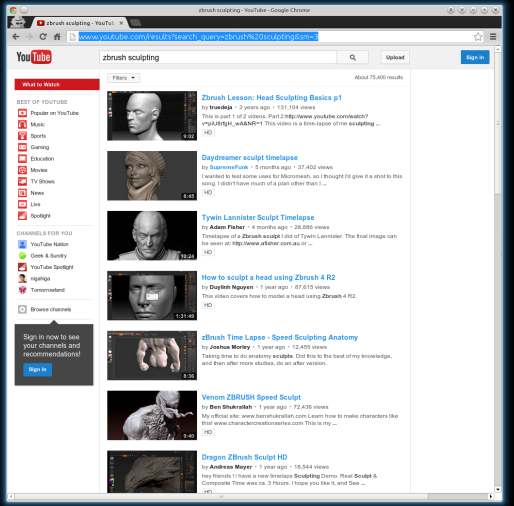

Kranks - ekho - zsolt, 2014

[orangegraphics, 2014]

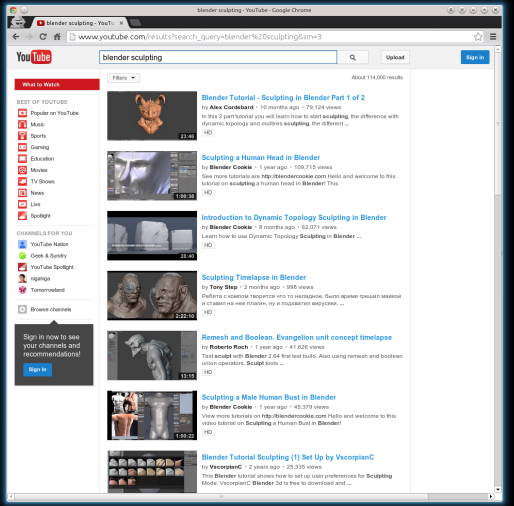

Blender* [/home/probusto2/projects12/sculpt/oldman01/snap000430.blend]
File Add Render Window Help
Default
Scene
Blender Render
v2.68 | Verts:98306 | Faces:98304 | Tris:196608 | Objects:1/3 | Lamps:0/1 | Mem:32
Brush
Grab 2 F
Radius: 77
Autosmo: 0.000
Normal Weig: 0.000
Area Plane
Front Faces Only
Overlay:
Alpha: 1%
Sculpt Mode
View
Lens: 35.000
Lock to Object:
Lock to Cursor
Lock Camera to View
Clip:
Start: 0.100
End: 1000.000
Local Camera:
Camera
Render Border
3D Cursor
Location:
X: -0.0215
Y: 0.1614
Z: -0.0874
Item
Icosphere
Display
Only Render
Outline Selected
All Object Origins
Relationship Lines
Grid Floor X Y Z
View Search All Sce
Scene
RenderLayer
World
metal putty
wax red
wax red F
Type Image or Movie
Preview
Texture Material Both
Show Alpha
Colors
Image
stone.jpg F
Source: Single Image
tcaps/wax_red.JPG
View Sculpt Brush Hide/Mask Sculpt Mode
-40 -20 0 20 40 60 80 100 120 140 160 180 200 220 240 260
View Marker Frame Playback
Start: 1 End: 250 1
No Sync

study creation and editing of polygonal meshes

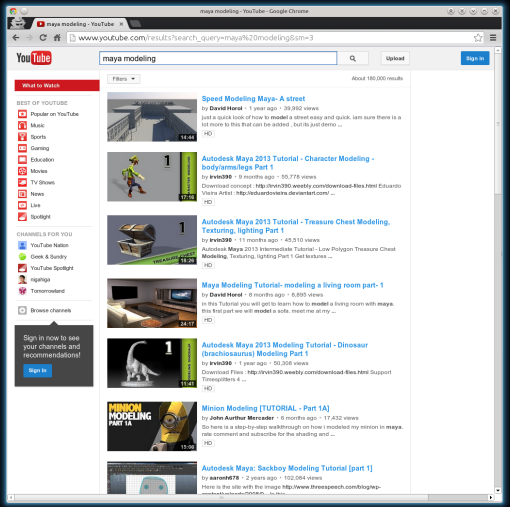
lots of workflows



"zbrush sculpting"
yields 75k results



"blender sculpting"
yields 114k results



"maya modeling"
yields 180k results

hundreds to thousands of
books teaching modeling

[amazon.com, williamson 2013]

websites dedicated to modeling and sculpting

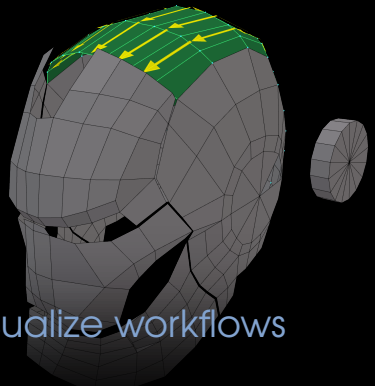
[cgcookie.com 2014]

medium is challenging

one-on-one	/	limited
tutorial	/	interrupt, practice
time-lapse	/	lost in details

outline

1. summarize workflows
2. workflows from meshes
3. compare workflows
4. other future work



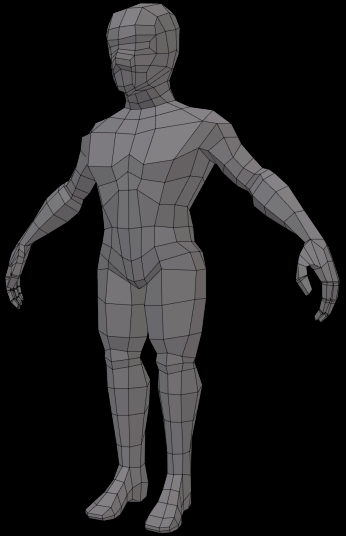
summarize

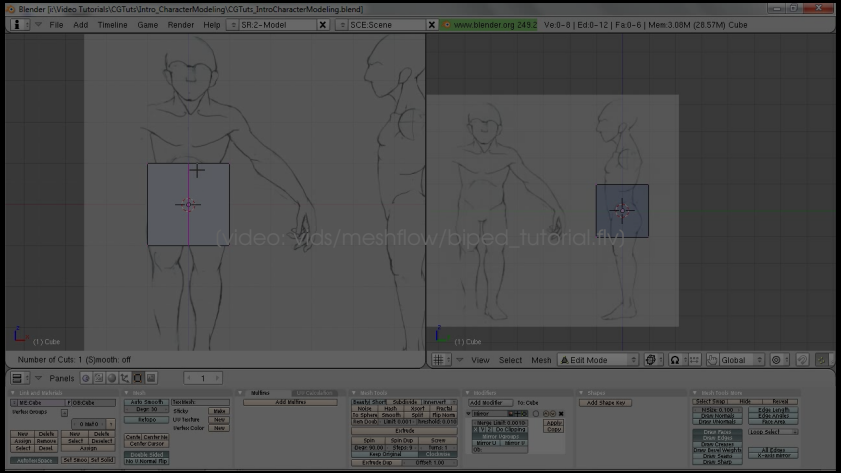
summarize and interactively visualize workflows

meshflow	3dflow*
siggraph11	sigasia14

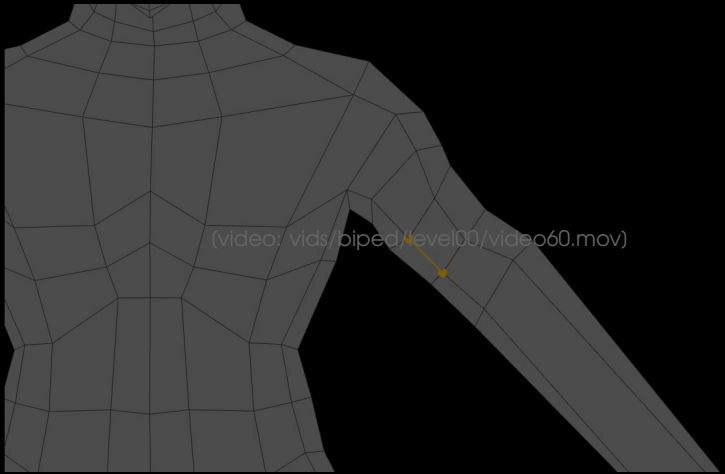
*to be submitted

biped
1012 faces
3:10 hrs
5759 ops
1267 edits

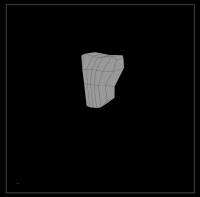
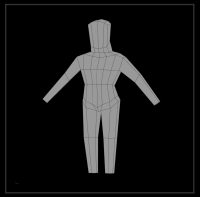
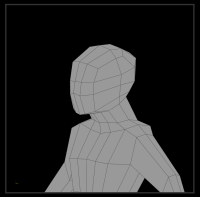
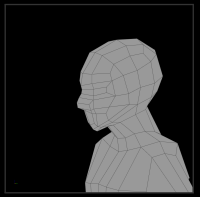


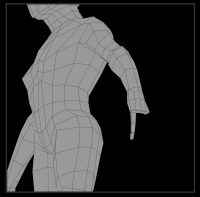
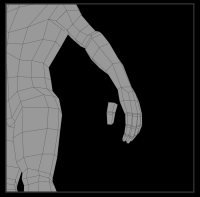
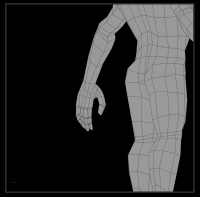


[cg tuts+, williamson 2011]

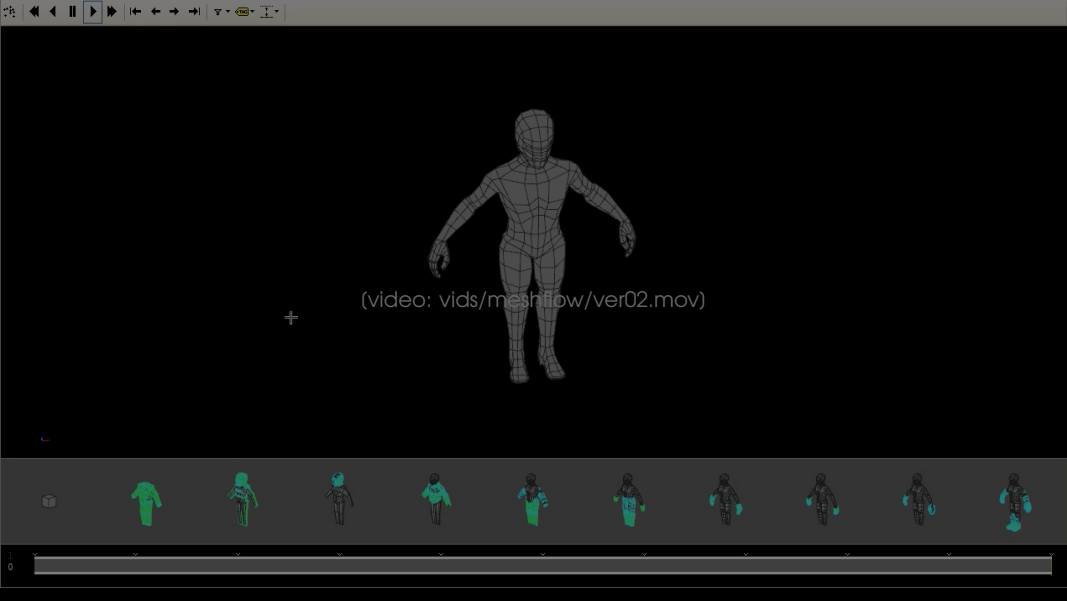


60x

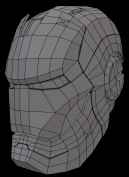





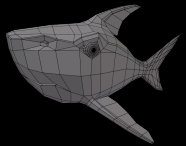
fully-automated approach to summarizing workflows


(video: vids/meshflow/ver02.mov)


File Add Render Help
Modeling
Scene
Blender Render
Ve:1014 | Fa:1012 | Ob:0-1 | La:0 | Mem:6.74M (0.10M) | Model
Object Tools
Transform:
Translate
Rotate
Scale
Origin
Object:
Duplicate Objects
Delete
Join
Shading:
Smooth
Flat
Keyframes:
Insert
Remove
Motion Paths:
Calculate Paths
Clear Paths
Repeat:
Repeat Last
Operator
User Persp
(1) Model
Model
Modifiers
Add Modifier
Copy
Textures:
Merg
U
Clippi
V
Verte
mit: 0.001000
ct:
Instrumented
Blender 2.5
2.57.1
r36798M
www.img-nation.de
Interaction:
Preset
Links
Donations
Release Log
Manual
Blender Website
User Community
Python API Reference
Recent
step000330.blend
step004284.blend
step004272.blend
step004257.blend
step004243.blend
Recover Last Session
Cmd O
View Select Object
Object Mode
Global



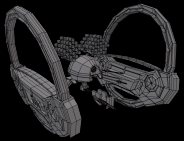
helmet
1867 faces
5:05 hrs
8510 ops



shark
1796 faces
3:30 hrs
8350 ops

hydrant
10808 faces
2:30 hrs
4609 ops

biped
1012 faces
3:10 hrs
5759 ops



robot
15580 faces
9:40 hrs
13478 ops


raw seq
summarized
:
select
select
view
view
view
view
topo
trans
trans
select
trans
trans
trans
:
:
select
view
topo
trans
select
trans
:

top 4 bigrams

5759		3781		3118		1843		225	
cam,cam	.33	select,trans	.22	select,trans	.27	trans,trans	.40	trans,cam	.20
select,trans	.15	trans,select	.16	trans,select	.20	trans,cam	.26	cam,$topo_a$	.17
trans,select	.11	cam,select	.13	trans,cam	.15	cam,trans	.25	cam,trans	.16
cam,select	.09	select,select	.13	cam,select	.14	cam,$topo_a$	.02	$topo_a$,trans	.12

summarizing by substitution regexs

2 $(\text{cam})+\ (\text{cam})^\diamond \mapsto (\text{cam})^\diamond$

3 $(\text{view})\ (\text{view})+ \mapsto (\text{view})$

4 $(\text{select})\ (\text{view} \mid \text{select})*\ (\text{select})^\diamond \mapsto (\text{select})^\diamond$

5 $(\text{select})\ (\text{view})*\ (\text{topo} \mid \text{trans})^\diamond \mapsto (\cdot)^\diamond$

6 $(\text{trans})\ (\text{view} \mid \text{trans})*\ (\text{trans})^\diamond \mapsto (\cdot)^\diamond$

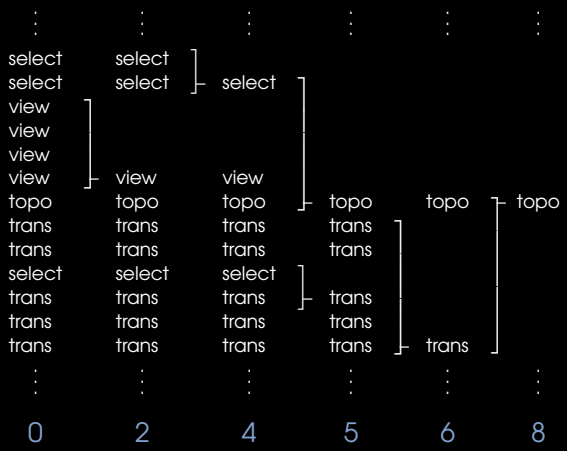
7 $(\cdot)^\diamond\ (\text{view} \mid (\cdot)^\diamond)*\ (\cdot)^\diamond \mapsto (\cdot)^\diamond$

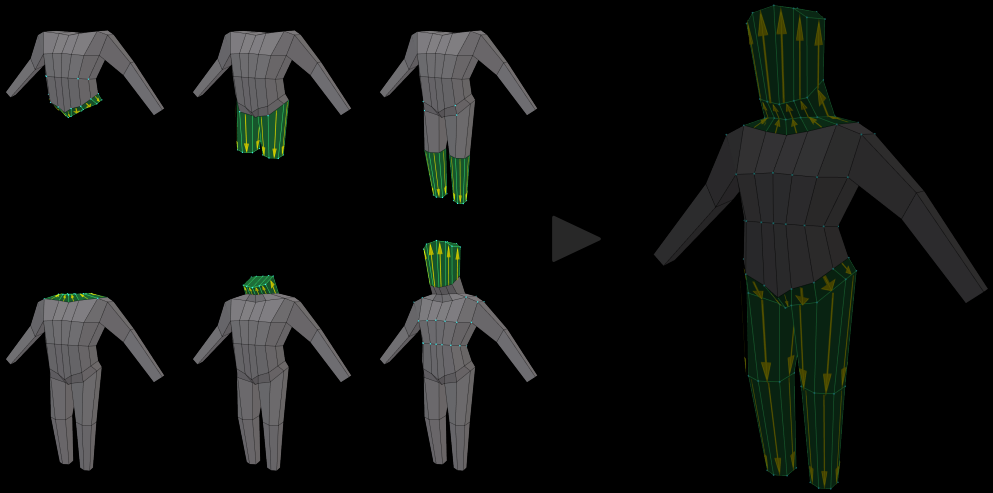
8 $(\text{topo})^\diamond\ (\text{view} \mid \text{trans})*\ (\text{trans}) \mapsto (\cdot)^\diamond$

9 $(\text{topo}_a)^\diamond\ (\text{view} \mid \text{topo}_b)*\ (\text{topo}_b) \mapsto (\cdot)^\diamond$

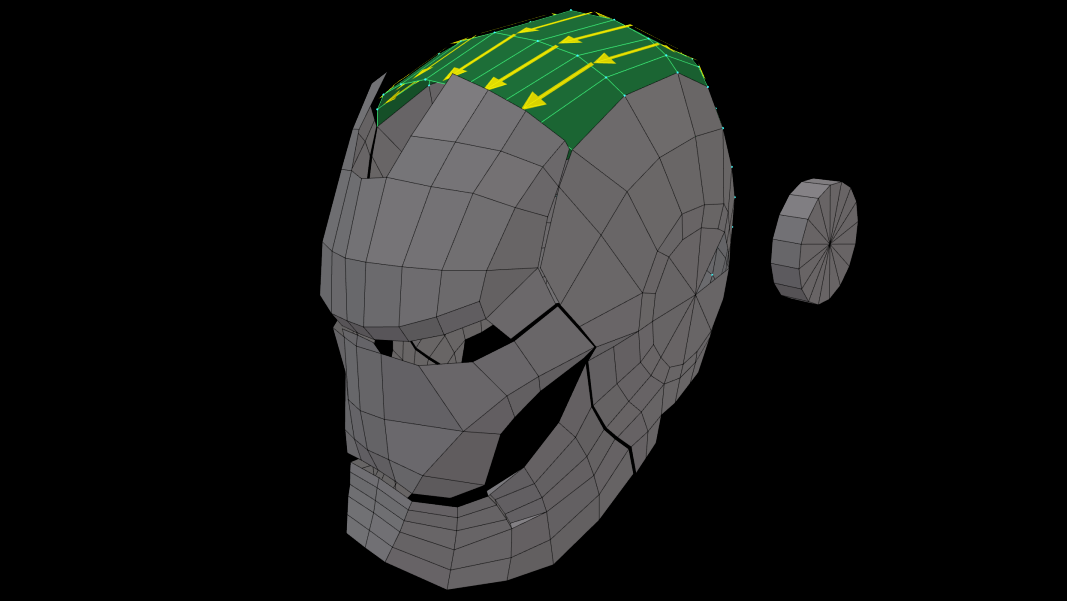
10 $(\cdot)^\diamond\ (\text{view} \mid (\cdot)^\diamond)*\ (\cdot)^\diamond \mapsto (\cdot)^\diamond$

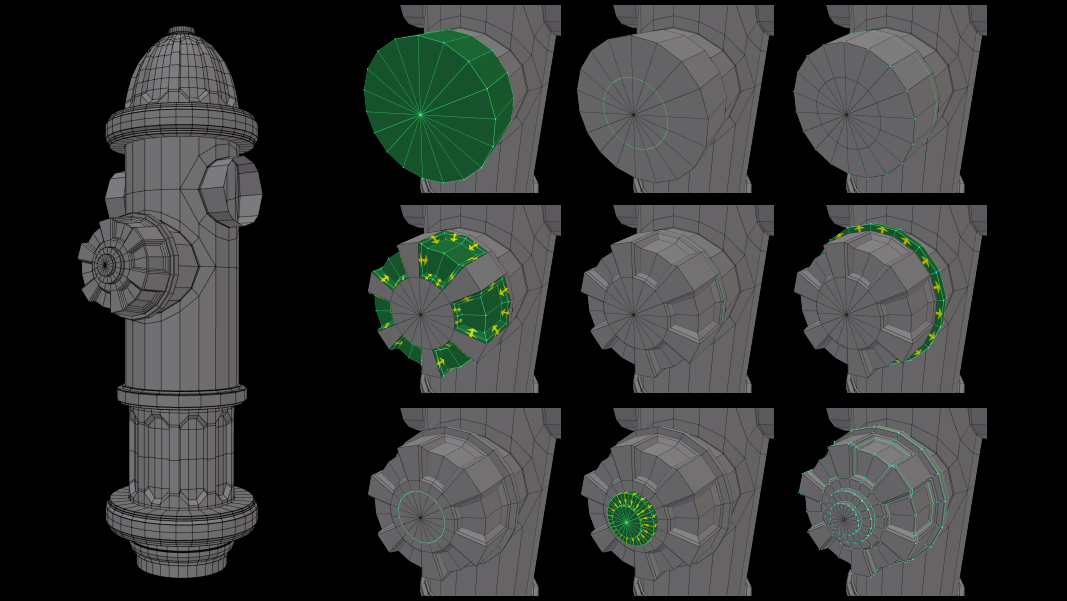
levels of detail





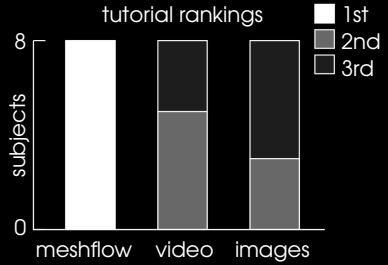
Level 9
Level 5
Level 7

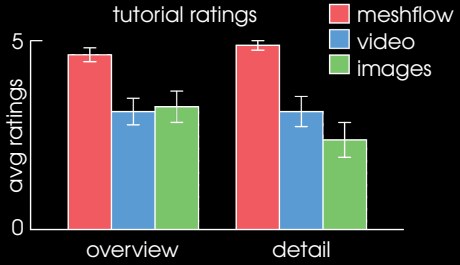




case study

8 college students
modeling class
followed tutorial


tutorial rankings
1st
2nd
3rd
8
0
subjects
meshflow
video
images


tutorial ratings
meshflow
video
images
5
0
avg ratings
overview
detail

I would have loved to ~~have~~ use this interactive vis tutorial in a digital arts modeling class. Though I suppose with it, the professor would not need to do much.

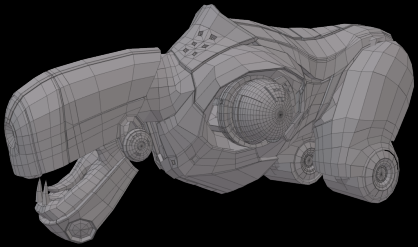
summarize

overview / details
automatic
highlights and annotations

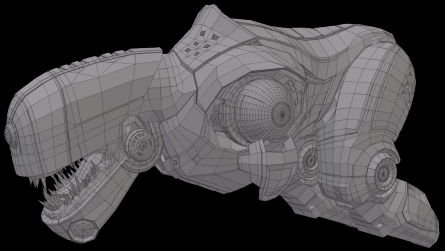
from meshes

generating workflows from a set of meshes

[meshgit
siggraph13]



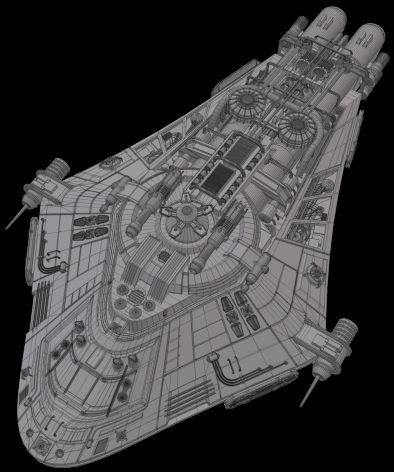
original



derivative

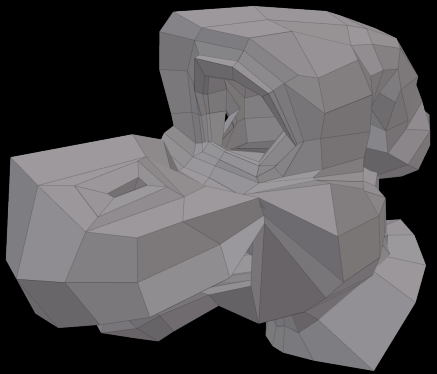
original

derivative



original

derivative



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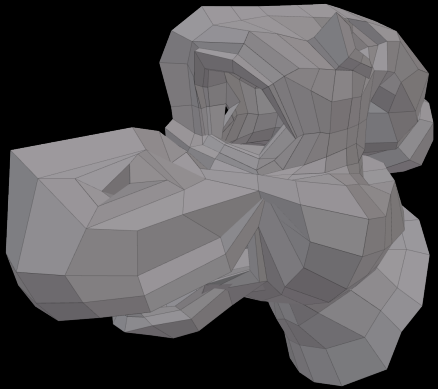
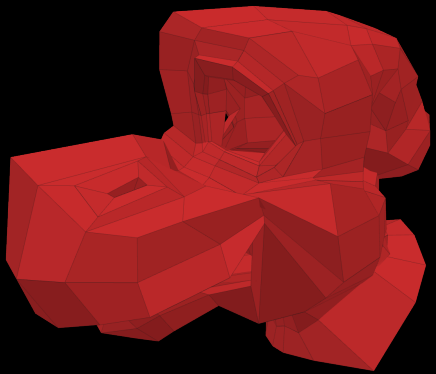


derivative

del, add



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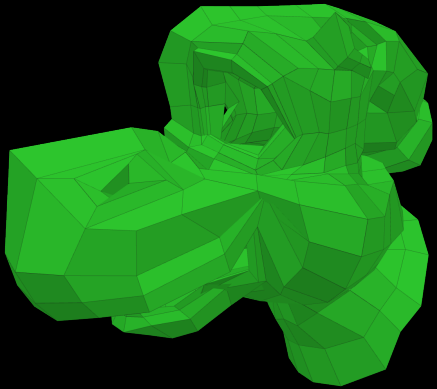
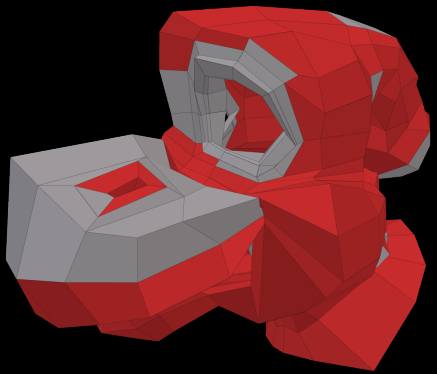
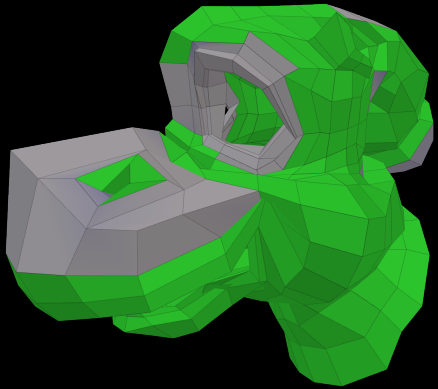


derivative

exact matching

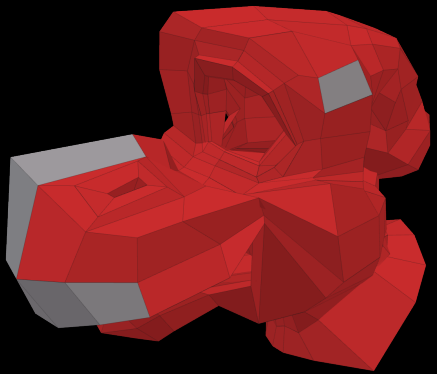


original



derivative

surface correspondence



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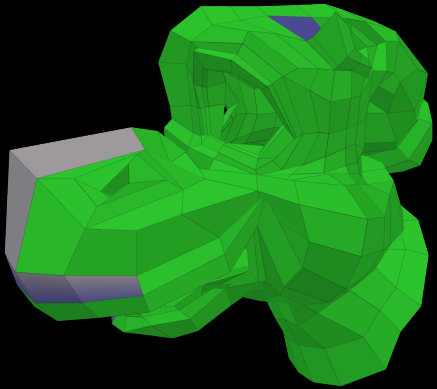
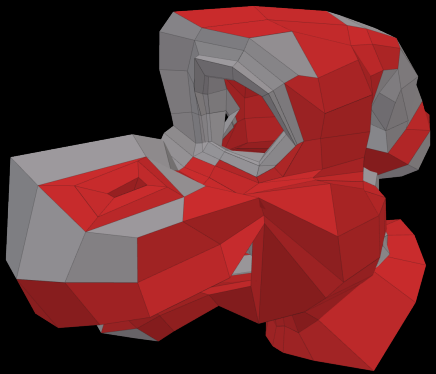
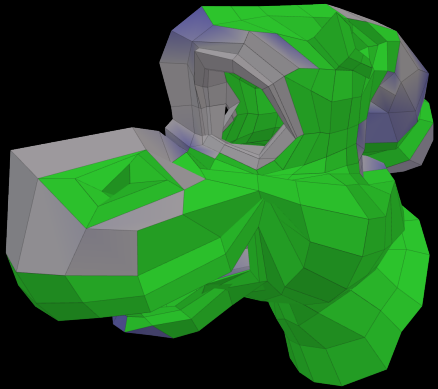


derivative

[kim et al. 2011]

graph match



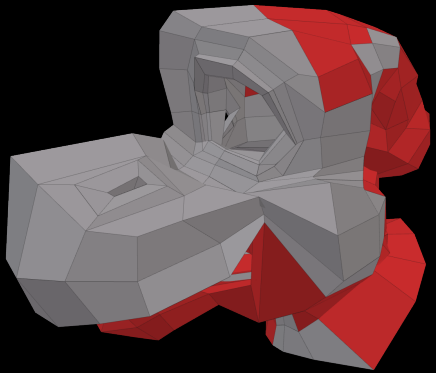


[cour et al. 2006]

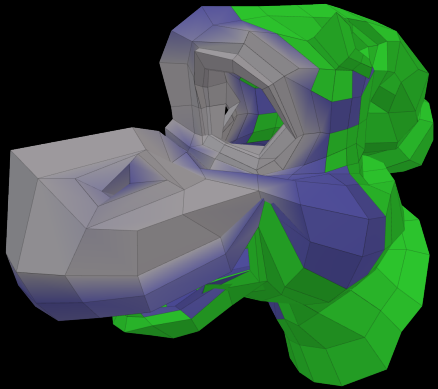
original

derivative

adjacency matching



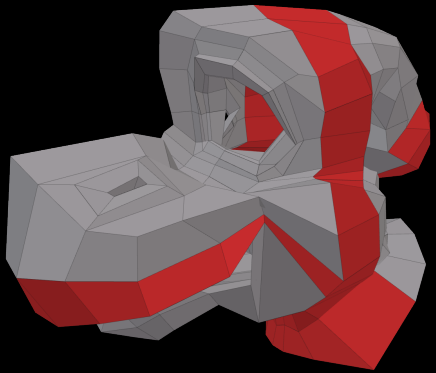
original



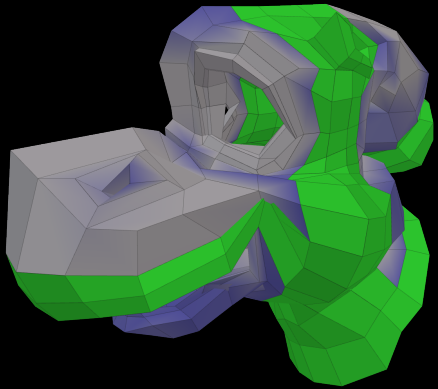
derivative

[eppstein et al. 2009]

meshgit



original



derivative

string edit distance / mesh edit distance

[levenshtein 1965]

mesh edit distance

min cost of partially matching meshes

$$C(O) = C_u(O) + C_g(O) + C_a(O)$$

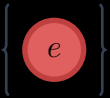
C_u : unmatched faces and verts

C_g : geometric changes

C_a : adjacency changes

O : partial matching of two meshes

$$C(O) = C_u(O) + C_g(O) + C_a(O)$$



original

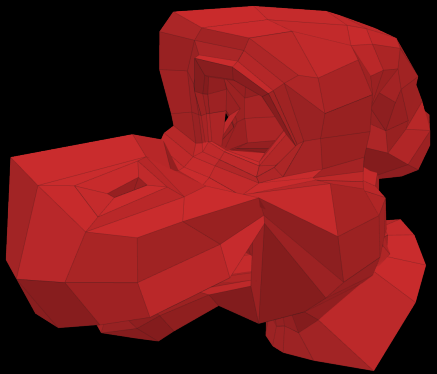
derivative

$$C(O) = C_u(O) + C_g(O) + C_a(O)$$

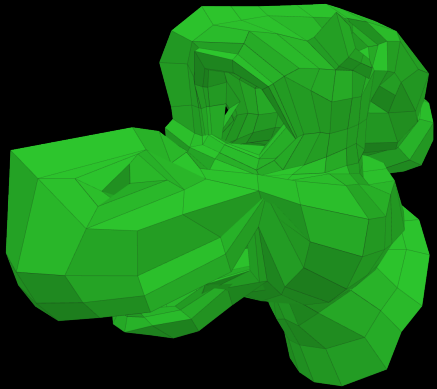
$$C_u(O) = N_u + N'_u$$

N : number of unmatched faces and verts

$$C(O) = C_u(O) + C_g(O) + C_a(O)$$

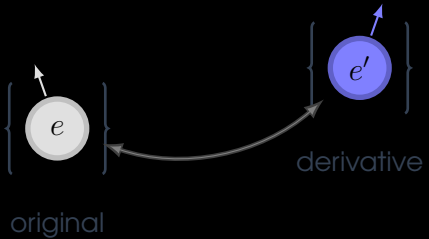


original



derivative

$$C(O) = C_u(O) + C_g(O) + C_a(O)$$



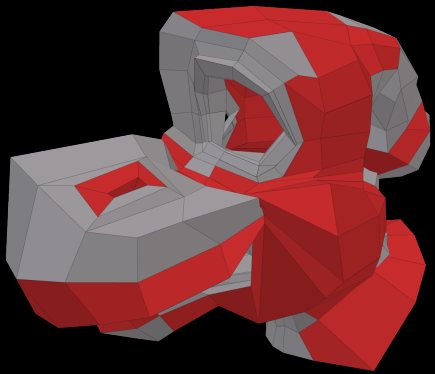
$$C(O) = C_u(O) + C_g(O) + C_a(O)$$

$$C_g(O) = \sum_{e \in E} \left[\frac{d(\mathbf{x}_e, \mathbf{x}_{e'})}{d(\mathbf{x}_e, \mathbf{x}_{e'}) + 1} + (1 - \mathbf{n}_e \cdot \mathbf{n}_{e'}) \right]$$

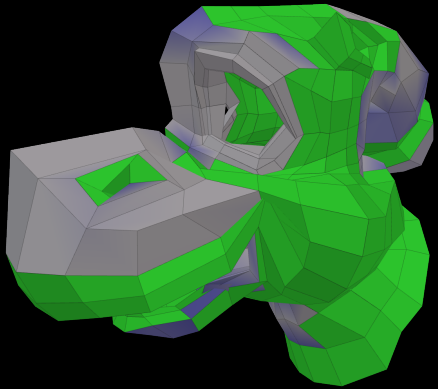
E : matched faces and verts

$\mathbf{x}$: position $\mathbf{n}$: normal $d(\mathbf{x}_e, \mathbf{x}_{e'}) = |\mathbf{x}_e - \mathbf{x}_{e'}|$

$$C(O) = C_u(O) + C_g(O) + C_a(O)$$

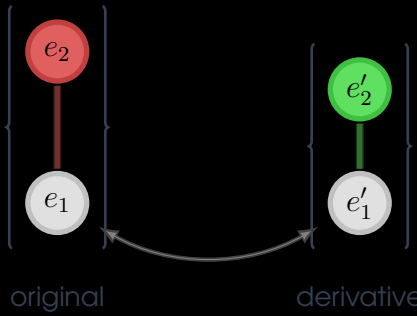


original

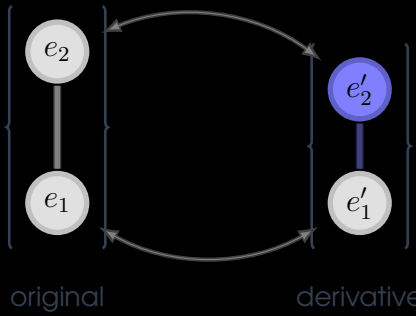


derivative

$$C(O) = C_u(O) + C_g(O) + C_a(O)$$



$$C(O) = C_u(O) + C_g(O) + C_a(O)$$



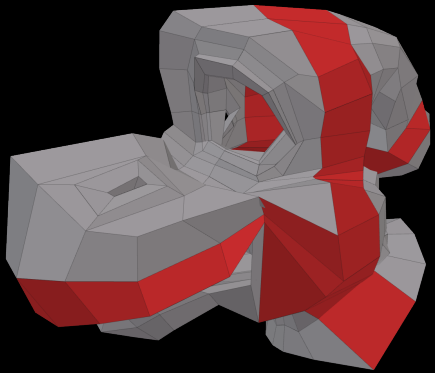
$$C(O) = C_u(O) + C_g(O) + C_a(O)$$

$$C_a(O) = \begin{cases} \displaystyle\sum_{(e_1,e_2)\in\{U,U'\}} \frac{1}{v(e_1)+v(e_2)} \quad + \\ + \displaystyle\sum_{(e_1,e_2)\in\{A,A'\}} \frac{w(e_1,e_2,e_1',e_2')}{v(e_1)+v(e_2)} \end{cases}$$

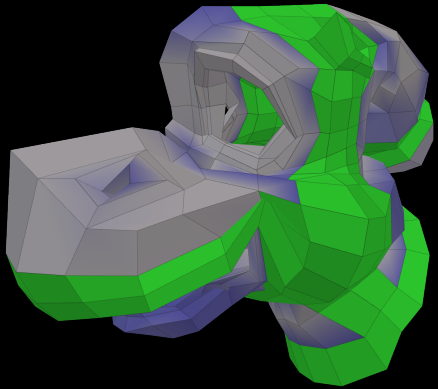
U, U' : unmatched adj pair $\qquad$ A, A' : matched adj pair

$v(\cdot)$: valence $\qquad$ $w(e_1,e_2,e_1',e_2') = \frac{|d(\mathbf{x}_{e_1},\mathbf{x}_{e_2}) - d(\mathbf{x}_{e_1'},\mathbf{x}_{e_2'})|}{d(\mathbf{x}_{e_1},\mathbf{x}_{e_2}) + d(\mathbf{x}_{e_1'},\mathbf{x}_{e_2'})}$

$$C(O) = C_u(O) + C_g(O) + C_a(O)$$



original



derivative

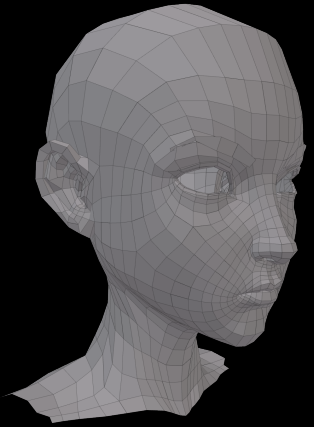
min $C(O)$ / max common subgraph isomorphism

NP-Hard

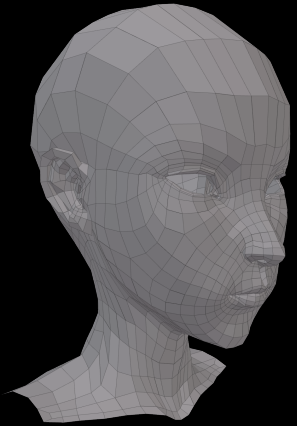
iterative greedy algorithm

feasibly approximate med

1. init 2. greedy 3. backtrack 4. repeat 2,3



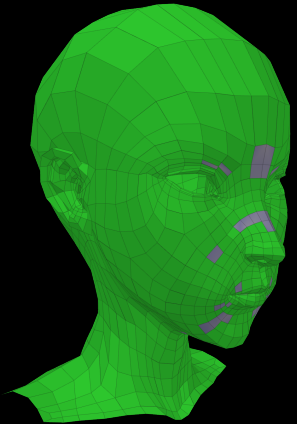
original



derivative

1. init 2. greedy 3. backtrack 4. repeat 2,3

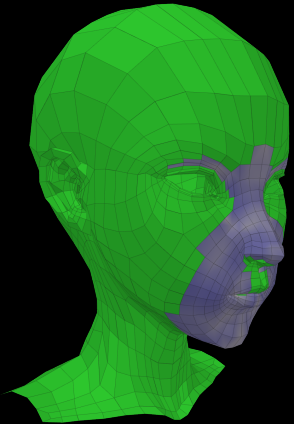
original



derivative

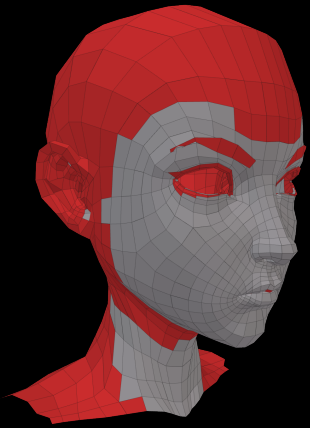
1. init 2. greedy 3. backtrack 4. repeat 2,3

original

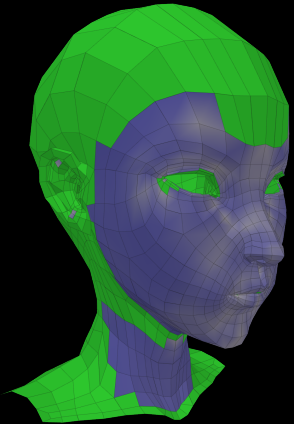


derivative

1. init 2. greedy 3. backtrack 4. repeat 2,3

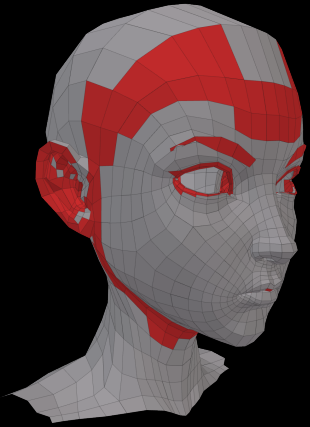


original

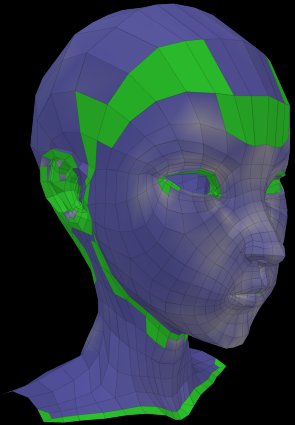


derivative

1. init 2. greedy 3. backtrack 4. repeat 2,3

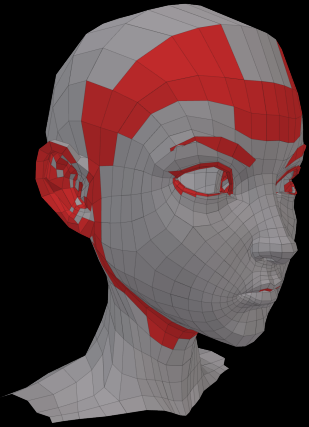


original

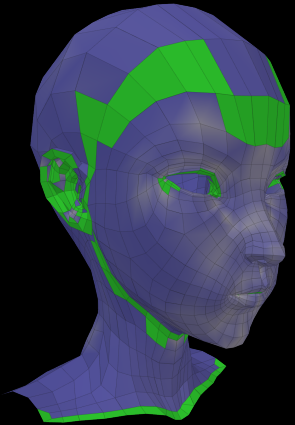


derivative

1. init 2. greedy 3. backtrack 4. repeat 2,3

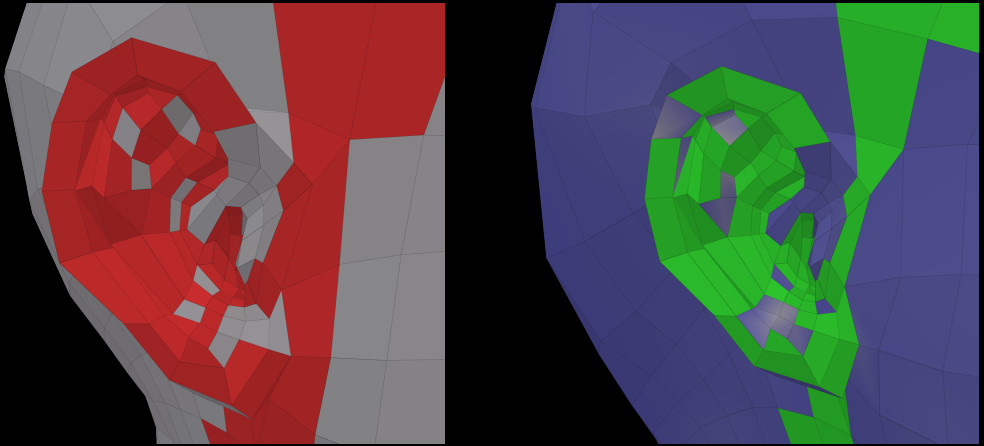


original



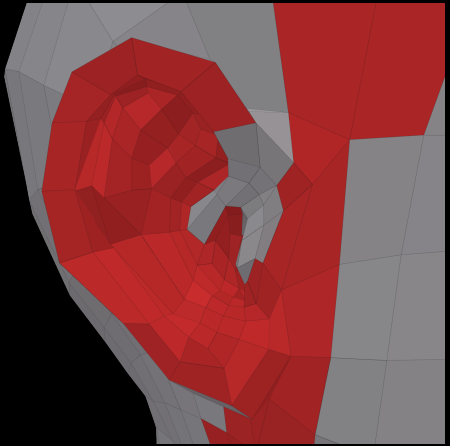
derivative

1. init 2. greedy 3. backtrack 4. repeat 2,3

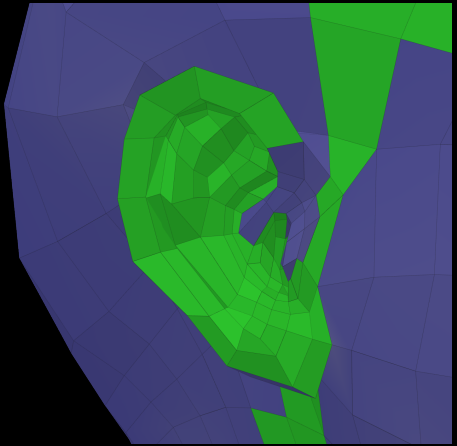


original derivative

1. init 2. greedy 3. backtrack 4. repeat 2,3

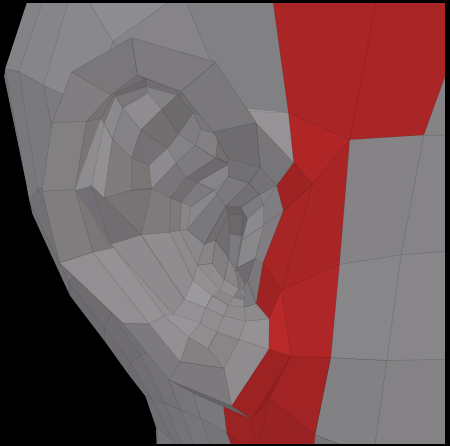


original

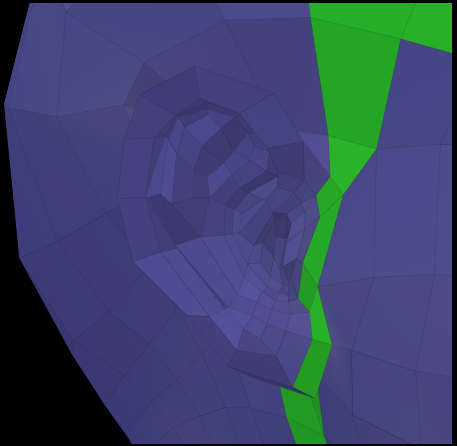


derivative

1. init 2. greedy 3. backtrack 4. repeat 2,3

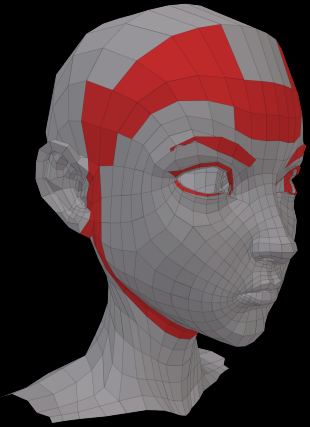


original

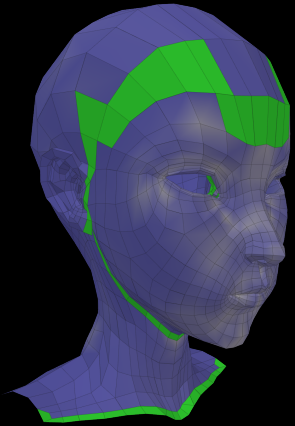


derivative

1. init 2. greedy 3. backtrack 4. repeat 2,3



original



derivative

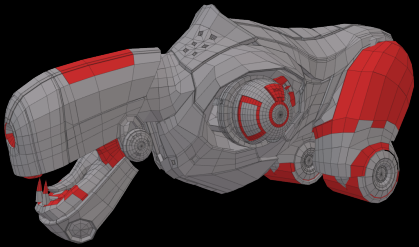
mesh edit operations

low-level workflow to turn one mesh into another

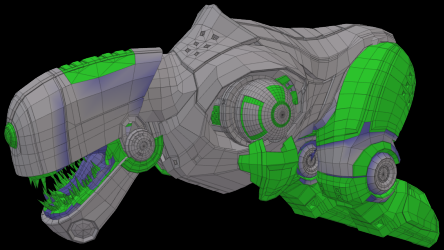
delete	:	unmatched geometry in original
add	:	unmatched geometry in derivative
transform	:	matched vertices with geometric cost

2-way diff

visualize edits from original to derivative

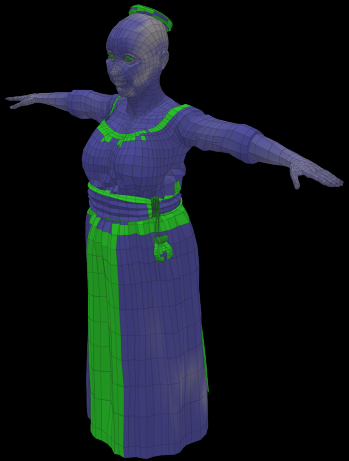


original

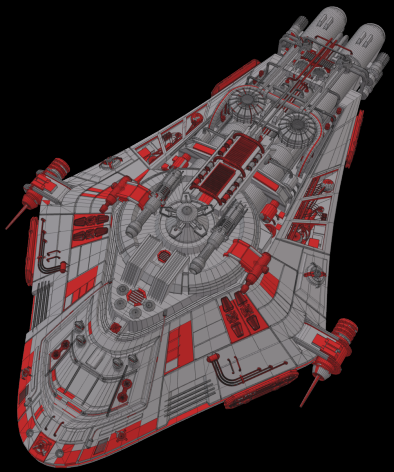


derivative

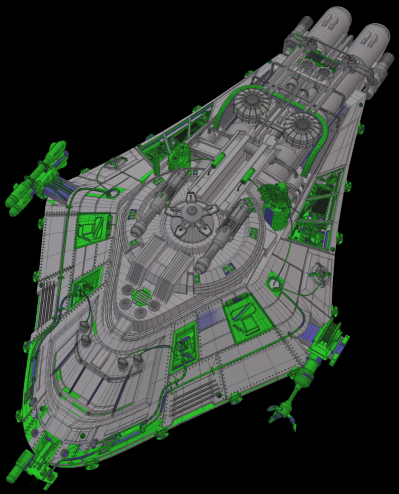
original



derivative



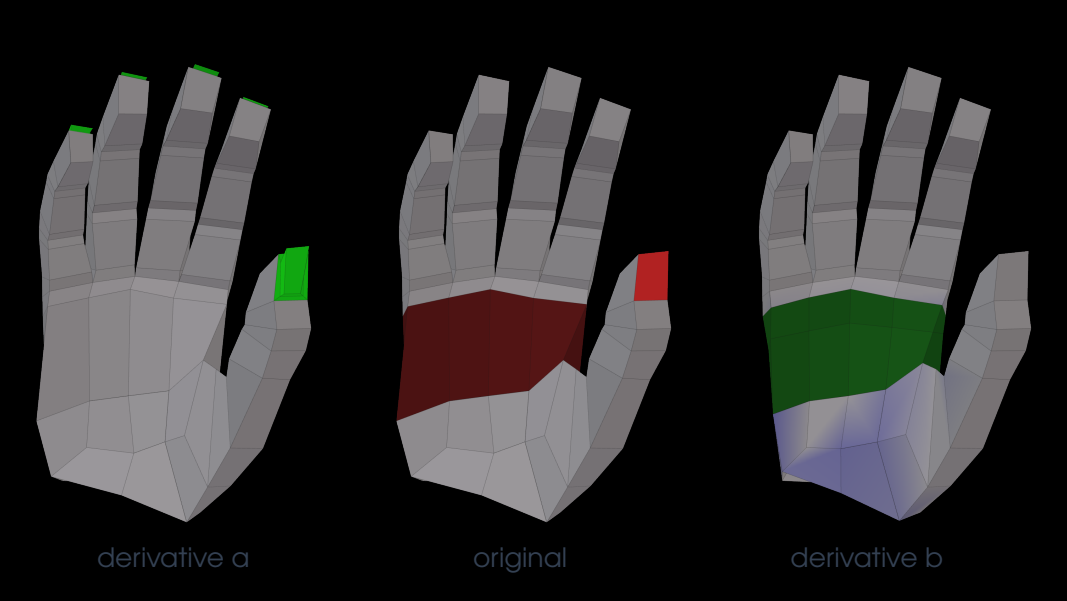
original



derivative

3-way diff

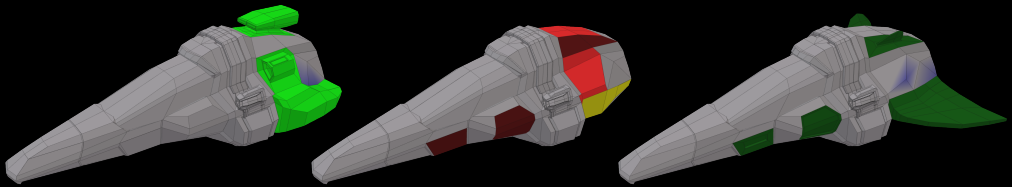
visualize edits from original to two independent derivatives


derivative a
original
derivative b

derivative a

original

derivative b



derivative a original derivative b

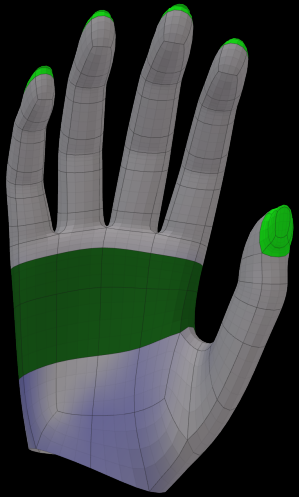
mesh edit merge

combining independent edits

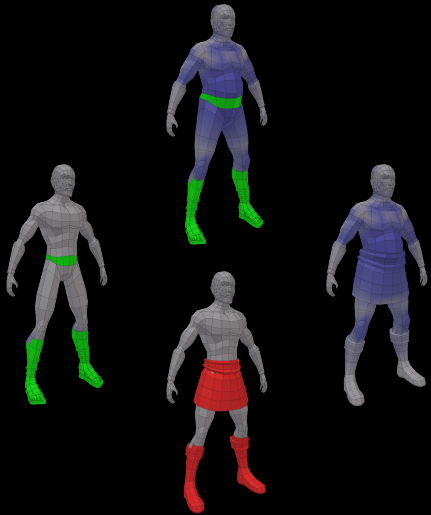
merge is automatic if edits do not overlap on original

adjacency is maintained; subdivision surfaces

3-way + merge

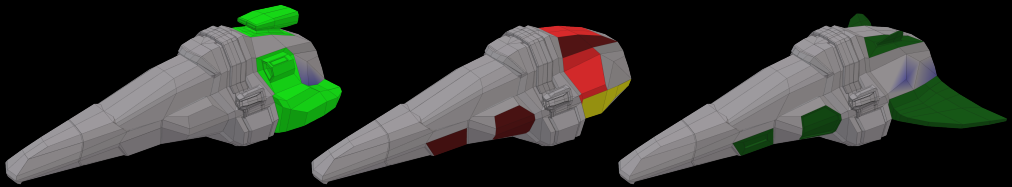


merge subd

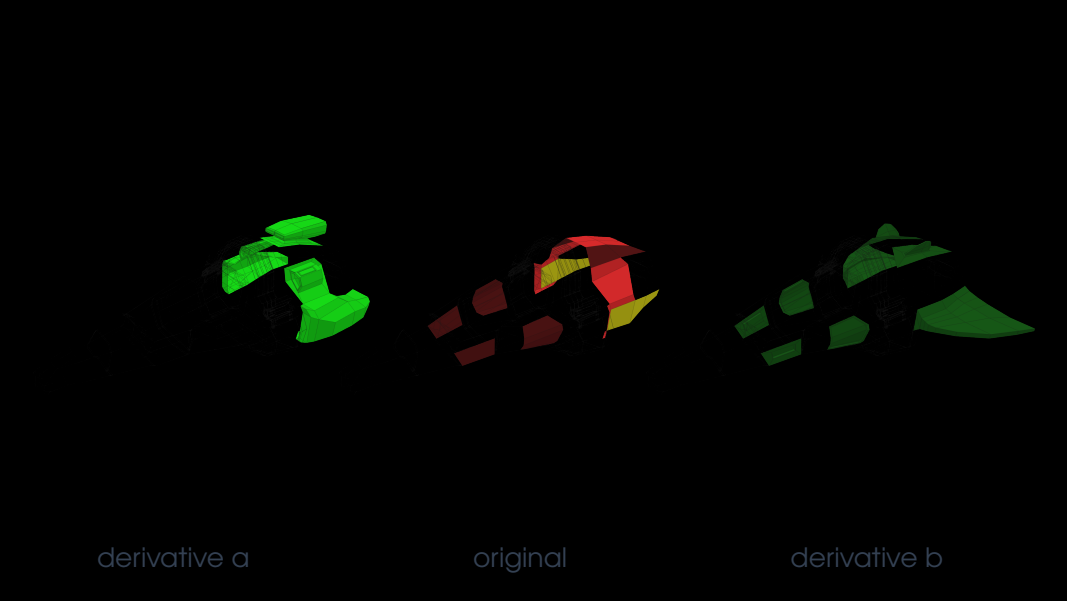


3-way + merge

merge subd

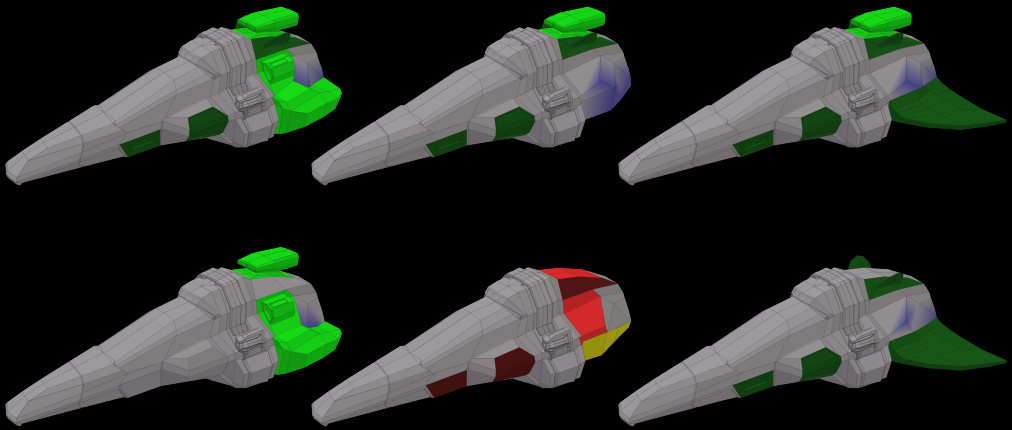


derivative a original derivative b


derivative a
original
derivative b

edit partitioning

reduce granularity of conflicts


choose a
neither
choose b
derivative a
original
derivative b

from meshes

partial matching meshes
low-level workflows
diff and merge

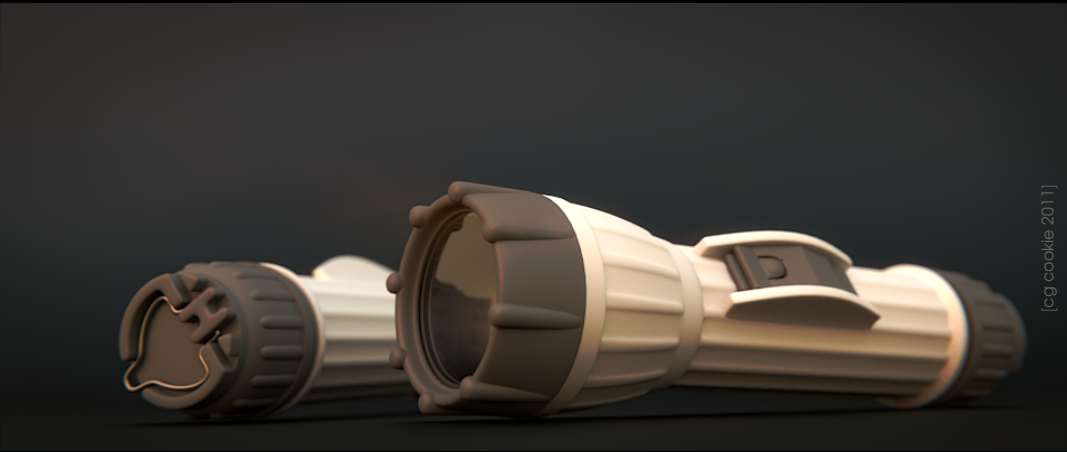
compare

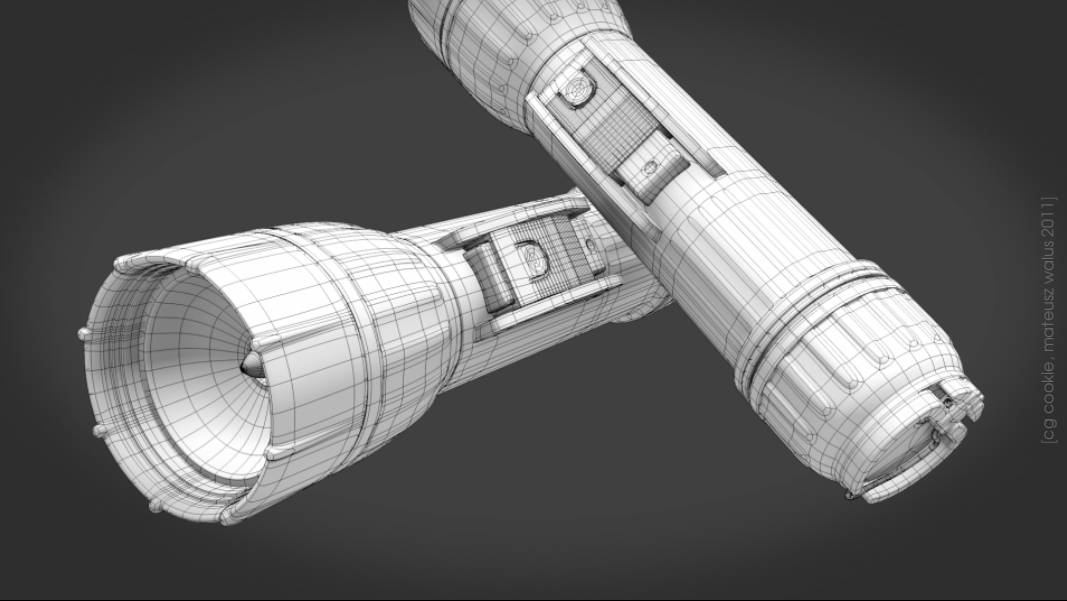
comparing multiple artists performing similar tasks

[crosscomp*
sigchi14/siggraph15]

*to be submitted

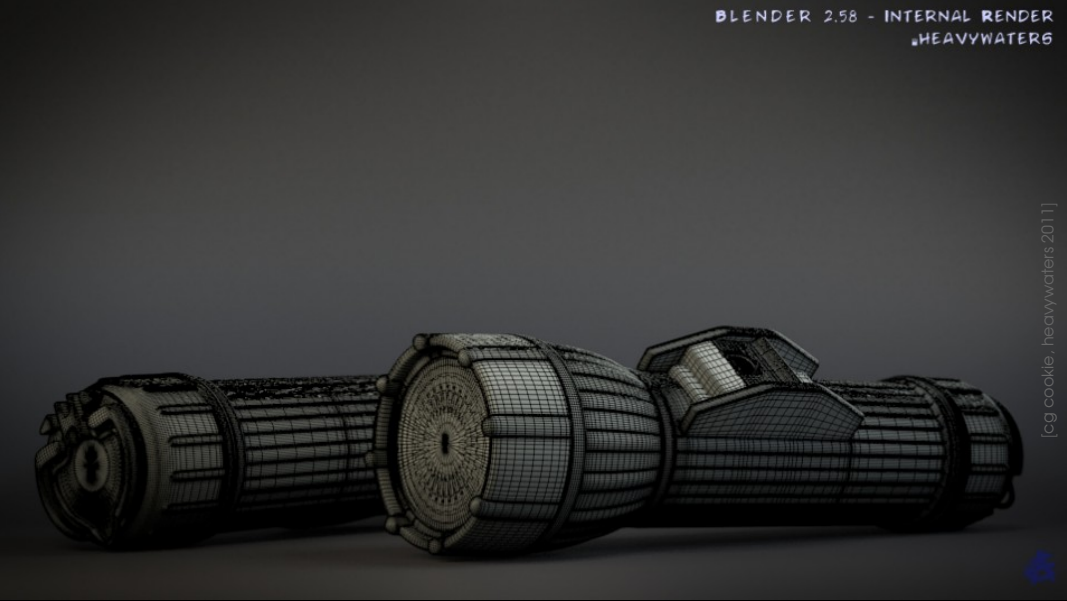
digital arts instructor assigns exercise


[cg cookie 2011]

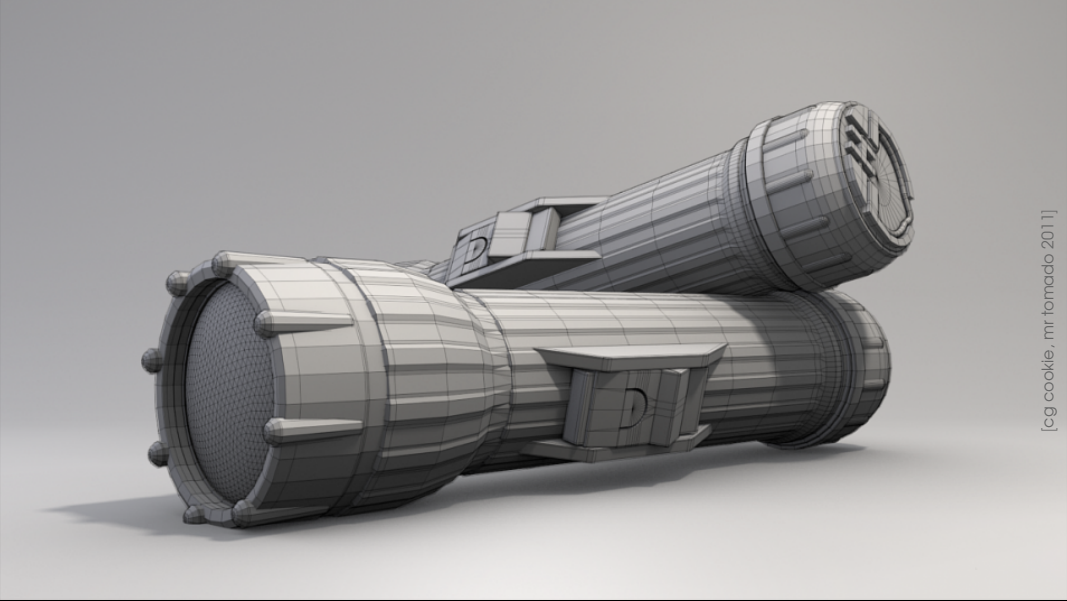


[cg cookie, mateusz wallus 2011]

BLENDER 2.58 - INTERNAL RENDER
.HEAVYWATER6



[cg cookie, heavywaters 2011]

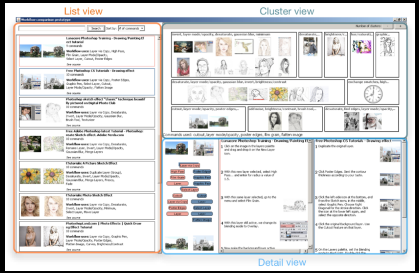


[cg cookie, mr tomado 2011]

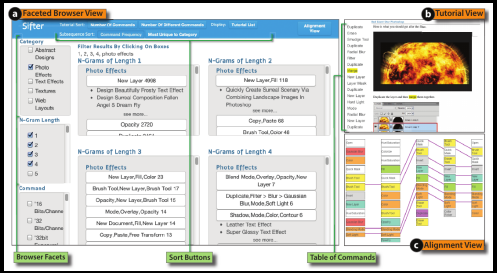
instructor makes video tutorial by reviewing student work

instructor makes video tutorial by reviewing student work

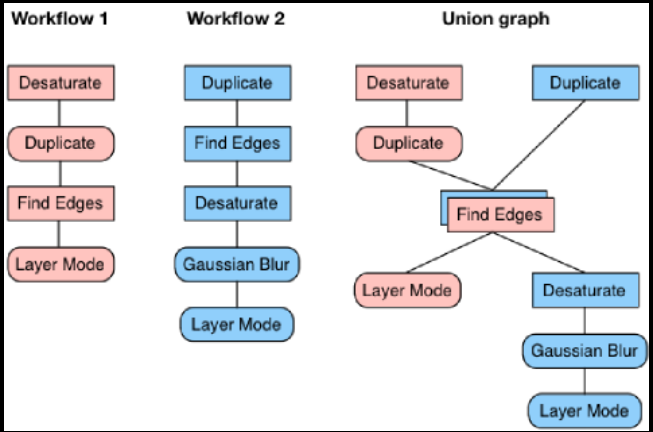
how to help with review process?



delta (kong et al. 2012)

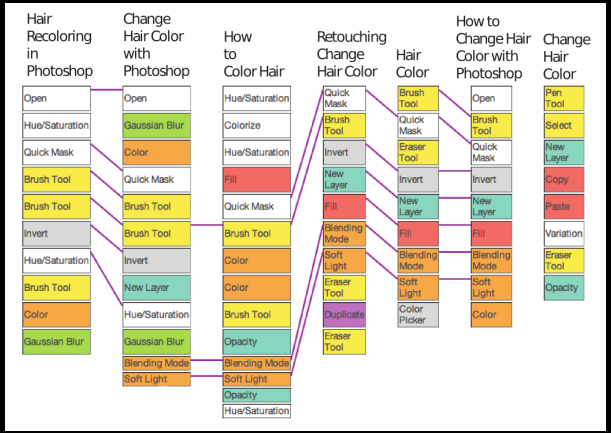


sifter (pavel et al. 2013)



[kong et al. 2012]

delta: union graph

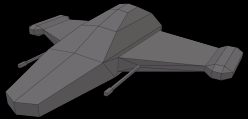
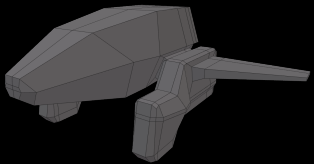
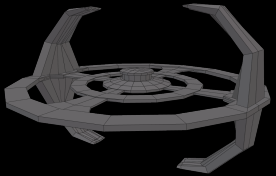
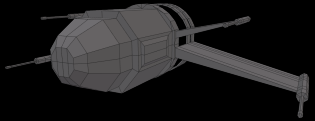


[pavel et al. 2013]

sifter: alignment view

short sequences	/	long sequences
global change	/	local change
polished workflows	/	contain errors
op + params	/	edit effect

tasks	:	3 vid tutorials, 1 target mesh
subjects	:	4 student modelers

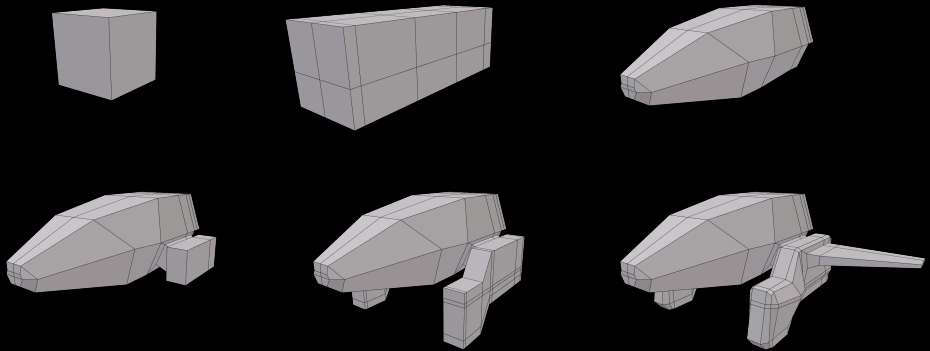
correspondences

know how regions correspond to compare workflows

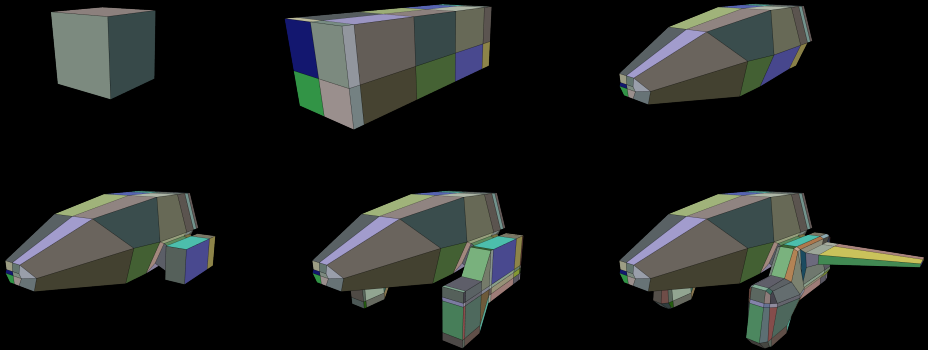
intra-correspondences : matching faces within workflow

inter-correspondences : matching faces between workflows

intra-correspondence

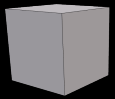
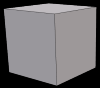
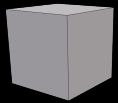
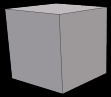
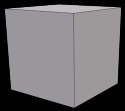


intra-correspondence



inter-correspondences?

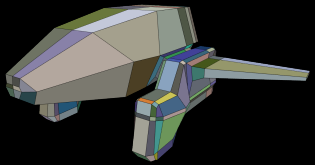
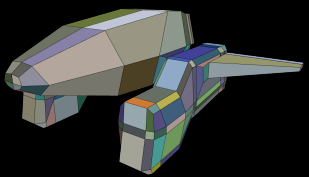
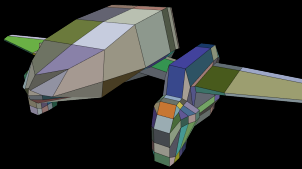
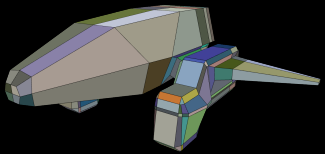
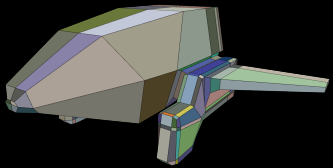
inter-correspondence

use meshgit to build inter-correspondences for final states

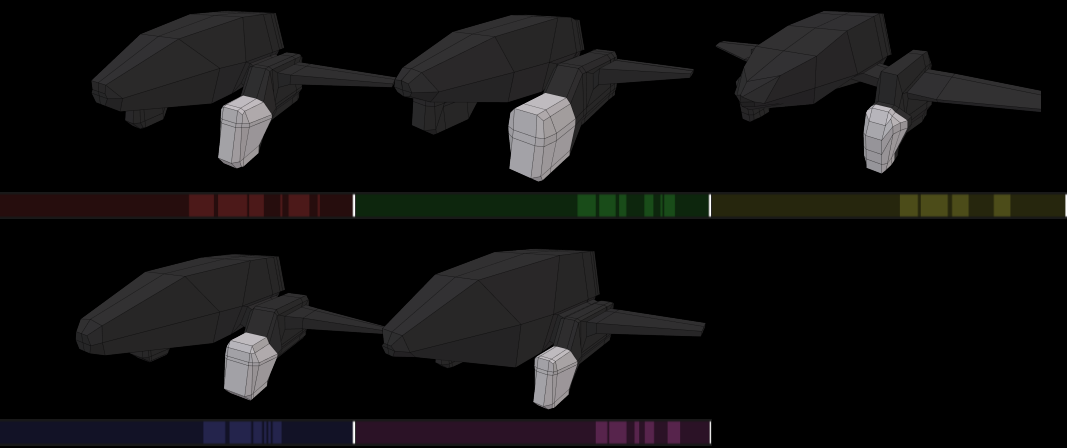
back-propagate using intra-correspondences

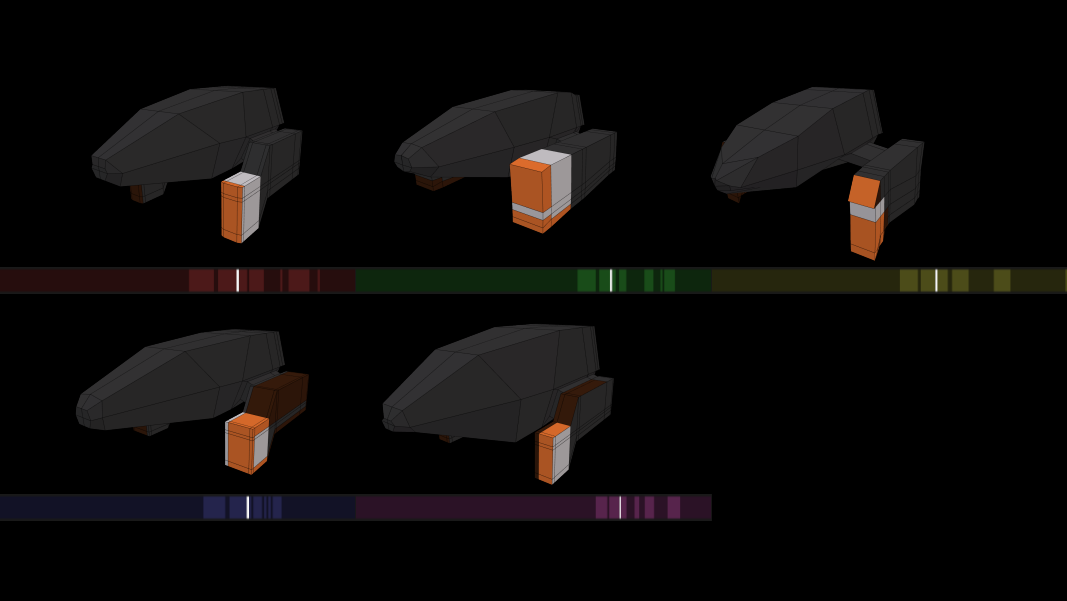
inter-correspondence

spatial filtering

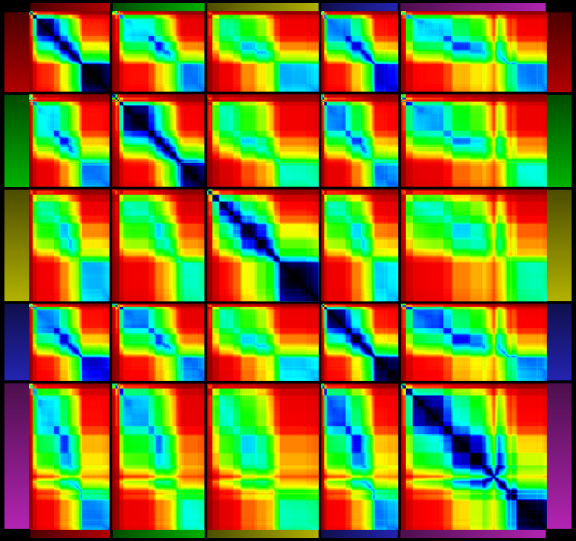
filtering timeline to edits on regions of interest

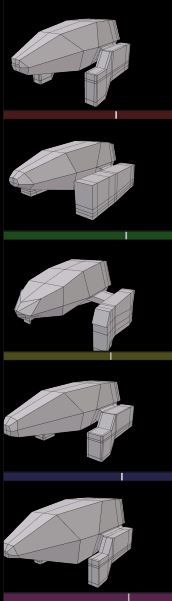




workflow heat map

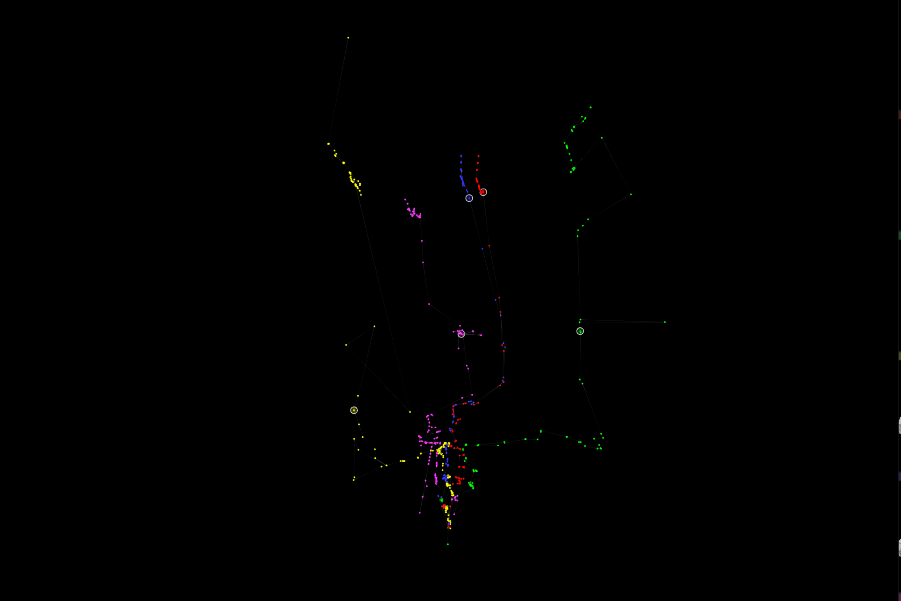
visualize pairwise normalized mesh edit distance
using built inter-correspondences





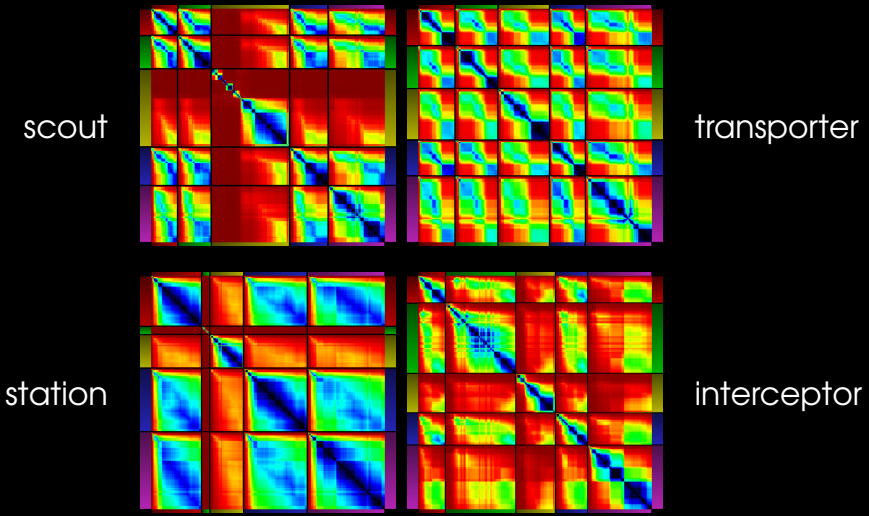
workspace

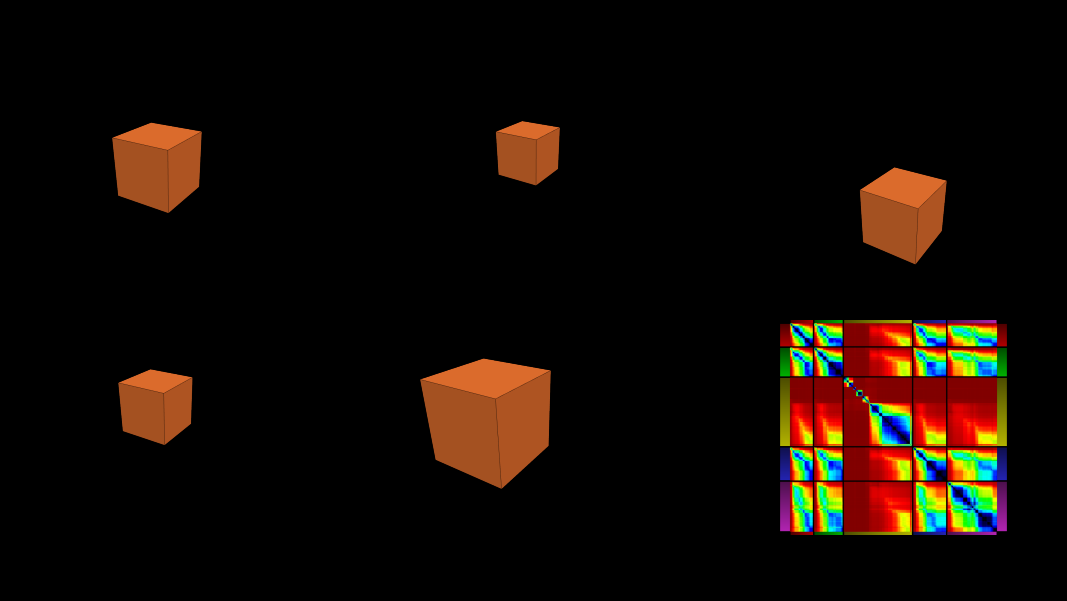
visualize workflows in 3d using isomap on med
with neighborhood shaping

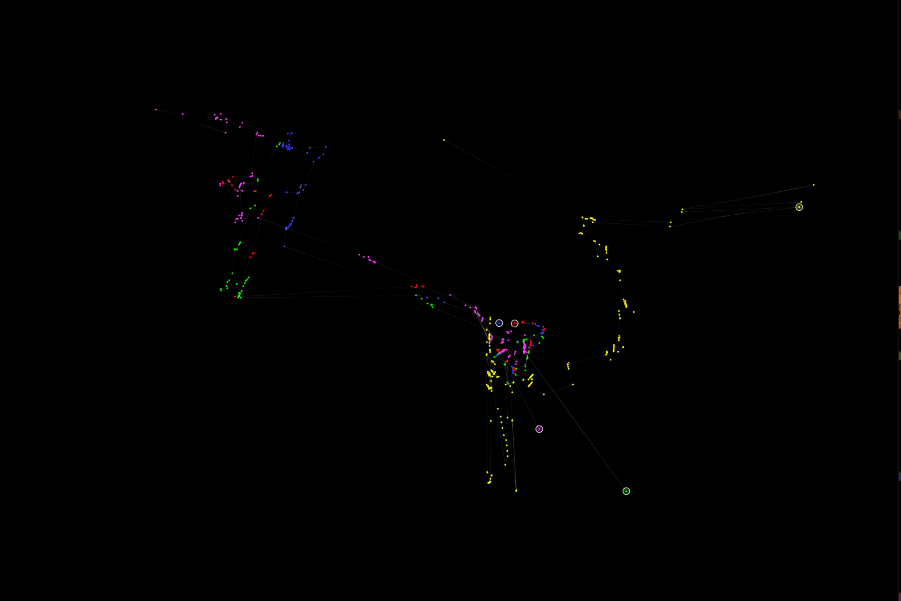


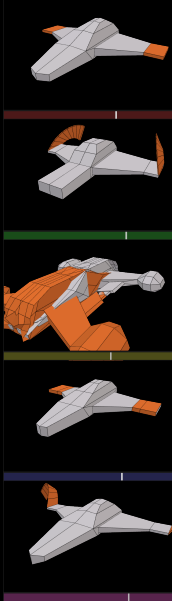
observations

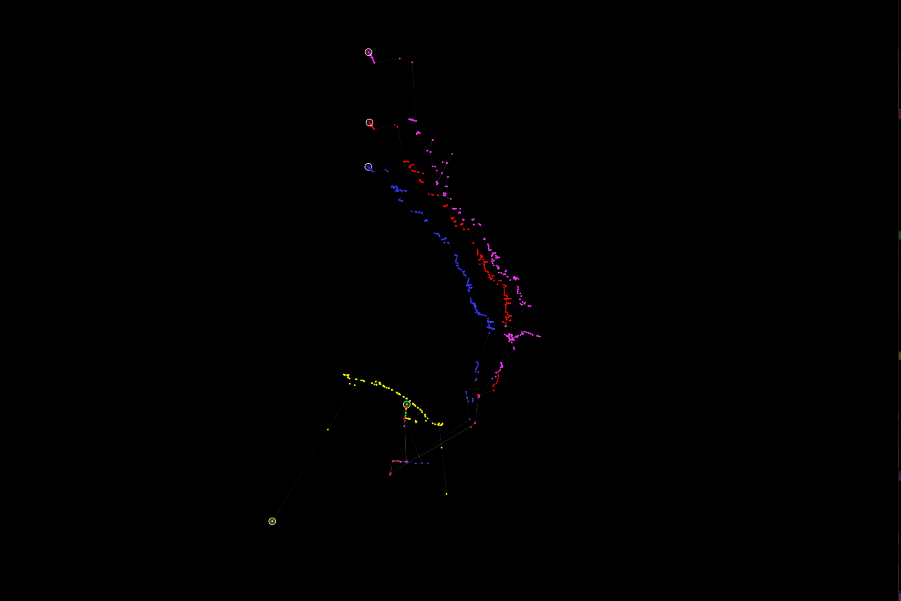
review student input using
heat map and workspace

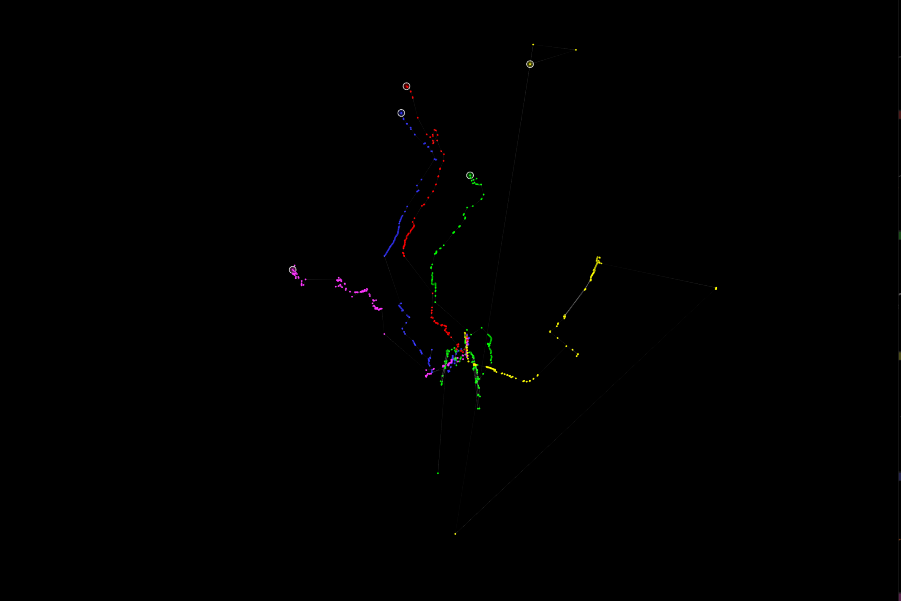

scout
transporter
station
interceptor











feedback

professional artist and instructor
created flashlight motivation exercise

"Based on the response we got I think the exercises have been incredibly helpful for the students. We get constant requests to do more of them. I believe they were helpful because it helps give the students some direct guidance but without hand holding. They're given a challenge but still have to find their own ways to complete that challenge. This is much more valuable than following along with a tutorial step by step. It allows them to apply the skills they learn from the tutorials."

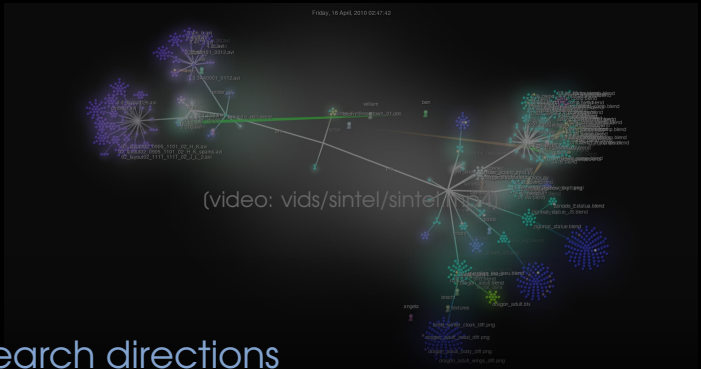
"We'd like to do more but just haven't been able to yet. Time is the issue; too much to do. Feedback is the most difficult part. More specifically, direct and constructive feedback that helps the student know what to improve upon. One thing that would be really helpful, I think, is an automated way of reviewing all the models. For example, dumping a batch into CrossComp and then receiving an interactive playback."

embedded view made artist's mistakes clear
curves hinted at the similarities of the workflows

subjects on interceptor took similar approach despite not having step-by-step instructions, which was unexpected

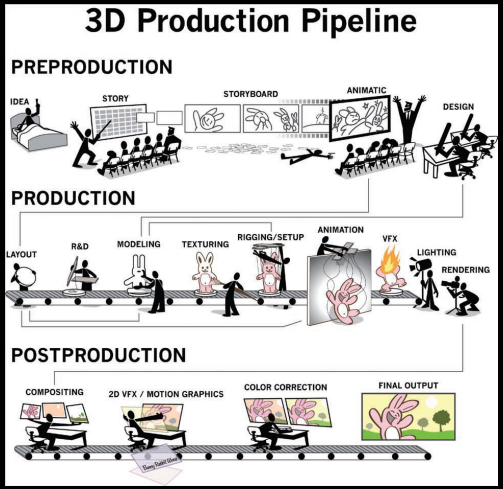
compare

intra- and inter-correspondences
pair-wise edit distance
non-linear dimensionality reduction

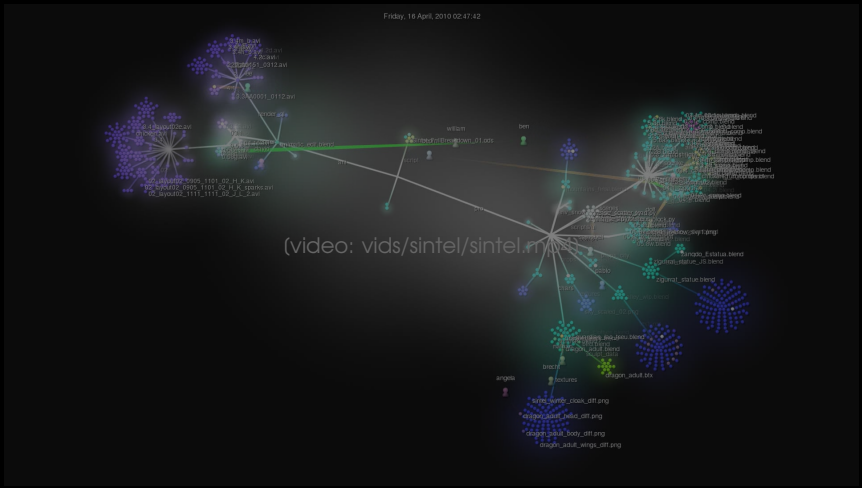


future

possible future research directions



[3d animation essentials, andy beane, 2012]



[blender foundation 2011, gource]

GOOSEBERRY STUDIO LINE-UP

28/01/2014 Production

When Gooseberry was announced, the shortlist of possible studio partners quickly grew to over 30… it's really great to see so many companies using Blender and be ready for film. We would love to work with all of them, but that's just not practical for a feature film. The original idea to involve "8-10" studios now already became 12.

Sponsor Prospectus

We are working on a well balanced offer to reward partners and sponsors. Contact institute@blender.org to learn more about this.

Twitter feed

Follow Gooseberry project: @gooseberry_film

extend to other evolving datasets (code repo)

most unusual (levenshtein dictionary)

modflows

summarize
from meshes
compare

all data and source code available

collaborators and support

fabio pellacini
brandon kerr
jiawei ou
jonathan williamson
roberto roch
many other artists

nsf, intel, sloan foundation

thank you!