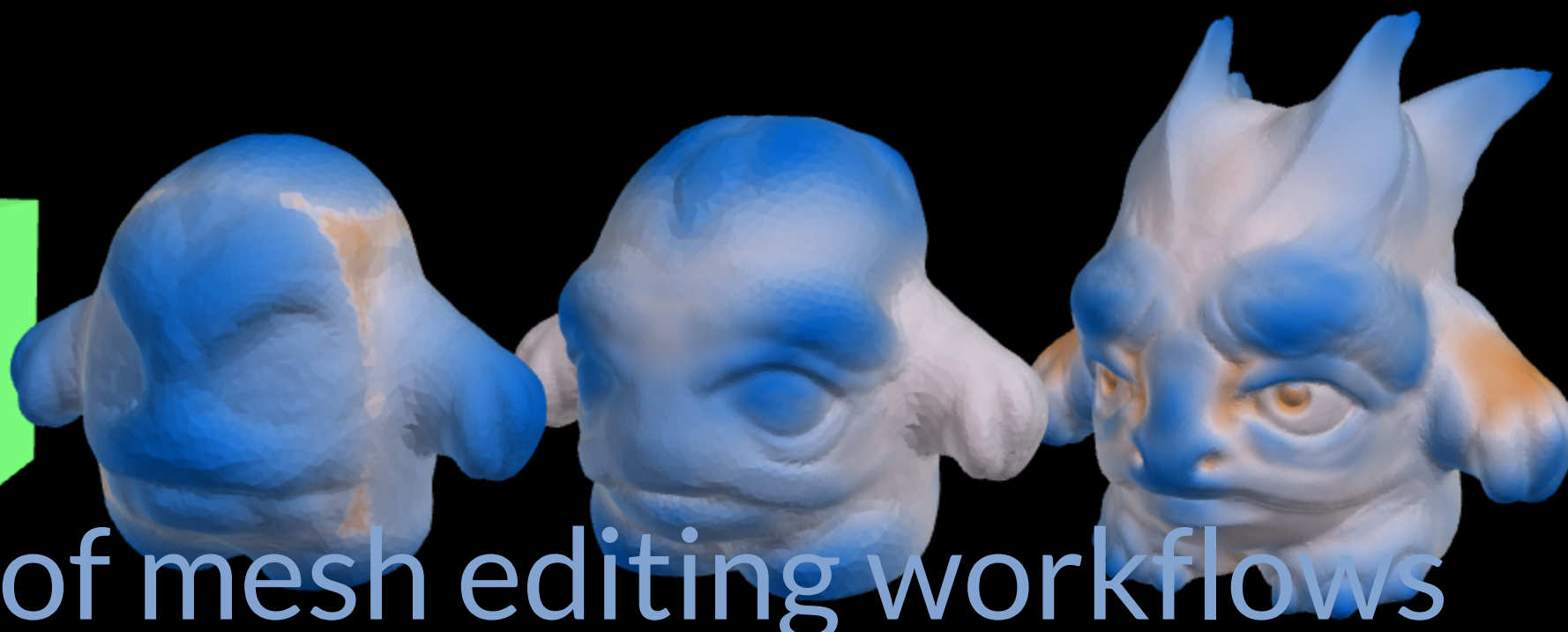
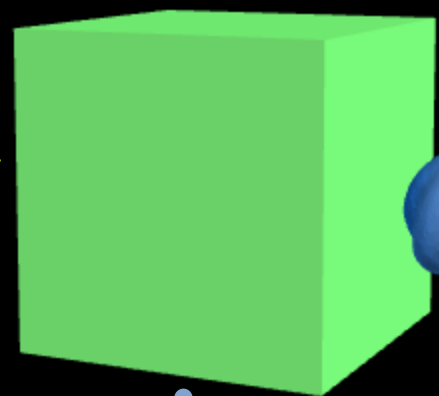


3dflow



continuous summarization of mesh editing workflows

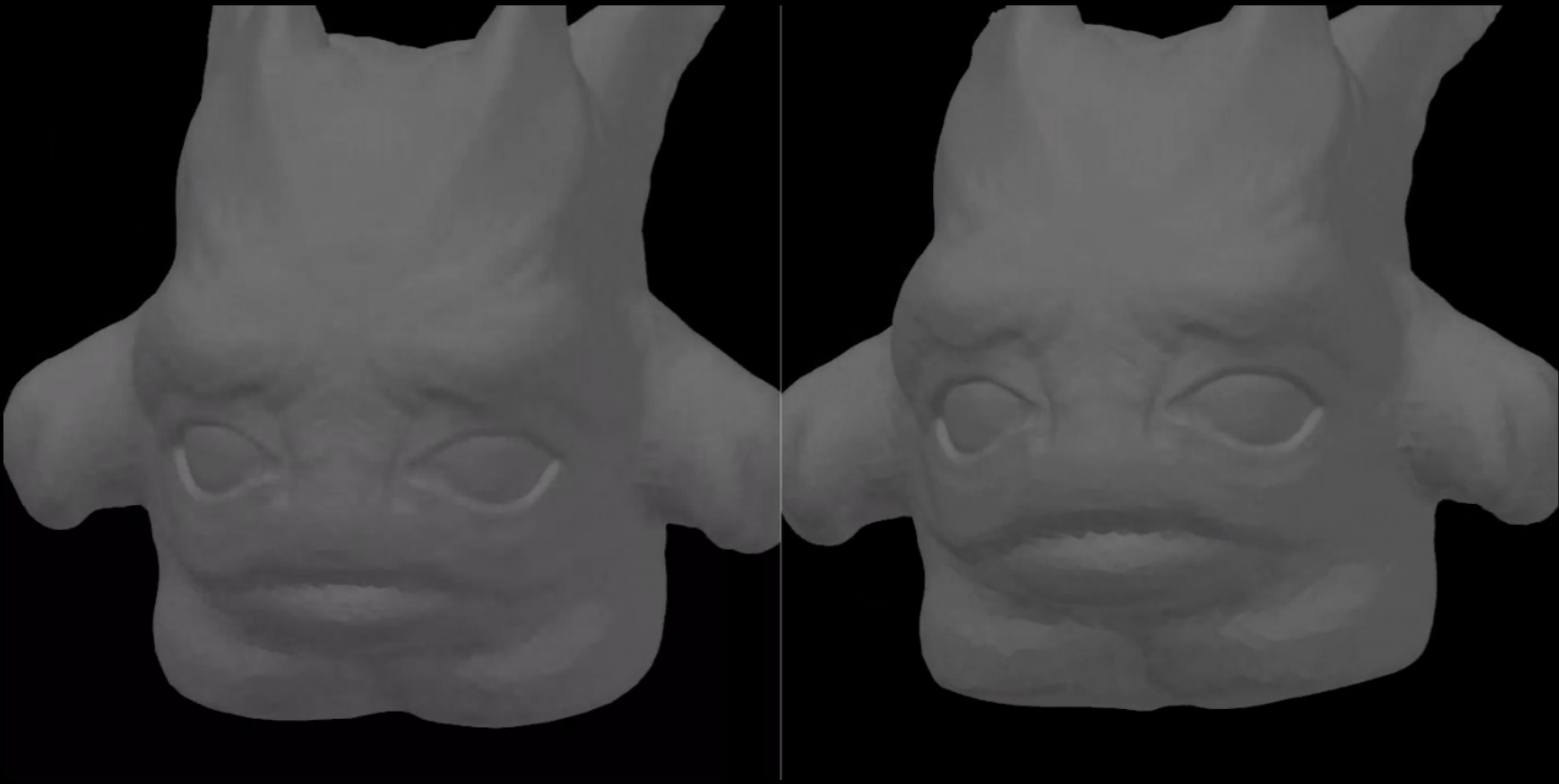
jon denning⁺ valentina tibaldo* fabio pellacini*
⁺taylor university *sapienza university of rome

“ We are always looking to share and showcase tutorials on the working process and workflows of our best users, and how they manage to get to beautiful results [...] So far, we have three ways to illustrate it: photos, 3D models with Sketchfab, and videos. A way to let them record and share the modeling process in 3D in real-time would be a killer feature. ”



monster

47 minutes, 797 sculpting edits



summarize with **meshflow**?

summarize with **meshflow**?
clustering rules based on modeling

summarize with **meshflow**?
clustering rules based on modeling
use **n-gram** analysis to build rules for sculpting

monster.bin, unique 1-gram count = 21

operation usage: "*" used, "." file, "|" subtask done

*****	314 (0.39)	sculpt.clay_strips
* ** **	120 (0.15)	sculpt.crease
* ** **	94 (0.12)	sculpt.smooth
* ** **	58 (0.07)	sculpt.clay_strips.invert
*****	45 (0.06)	sculpt.snake_hook
* ** **	31 (0.04)	sculpt.grab
* ** **	23 (0.03)	sculpt.polish
*****	23 (0.03)	sculpt.inflate_deflate
* ** **	20 (0.03)	sculpt.crease.invert
*****	19 (0.02)	sculpt.blob
* ** **	17 (0.02)	sculpt.scrape_peaks
* ** **	8 (0.01)	sculpt.clay
*****	6 (0.01)	sculpt.sculpt_draw
* ** **	5 (0.01)	undo.undo
*****	4 (0.01)	sculpt.inflate_deflate.invert
* ** **	3 (0.00)	sculpt.blob.invert
*****	2 (0.00)	sculpt.pinch_magnify
* ** **	2 (0.00)	sculpt.scrape_peaks.invert
*****	1 (0.00)	topo.convert.all_to_tris
* ** **	1 (0.00)	sculpt.clay.invert
*****	1 (0.00)	initial

biped.bin, unique 1-gram count = 16

*****	1063 (0.84)	transform.translate
* ** **	63 (0.05)	transform.resize
* ** **	36 (0.03)	transform.rotate
* ** **	32 (0.03)	topo.loopcut
*****	16 (0.01)	topo.add.edge_face
* ** **	14 (0.01)	topo.extrude
*****	11 (0.01)	topo.merge
* ** **	7 (0.01)	topo.subdivide
*****	7 (0.01)	undo.undo
* ** **	5 (0.00)	transform.scale_along_normals
*****	4 (0.00)	topo.duplicate
* ** **	3 (0.00)	transform.edge_slide
*****	3 (0.00)	topo.convert.tris_to_quads
* ** **	1 (0.00)	transform.set_x
*****	1 (0.00)	obj.mod.add_mirror
* ** **	1 (0.00)	interface

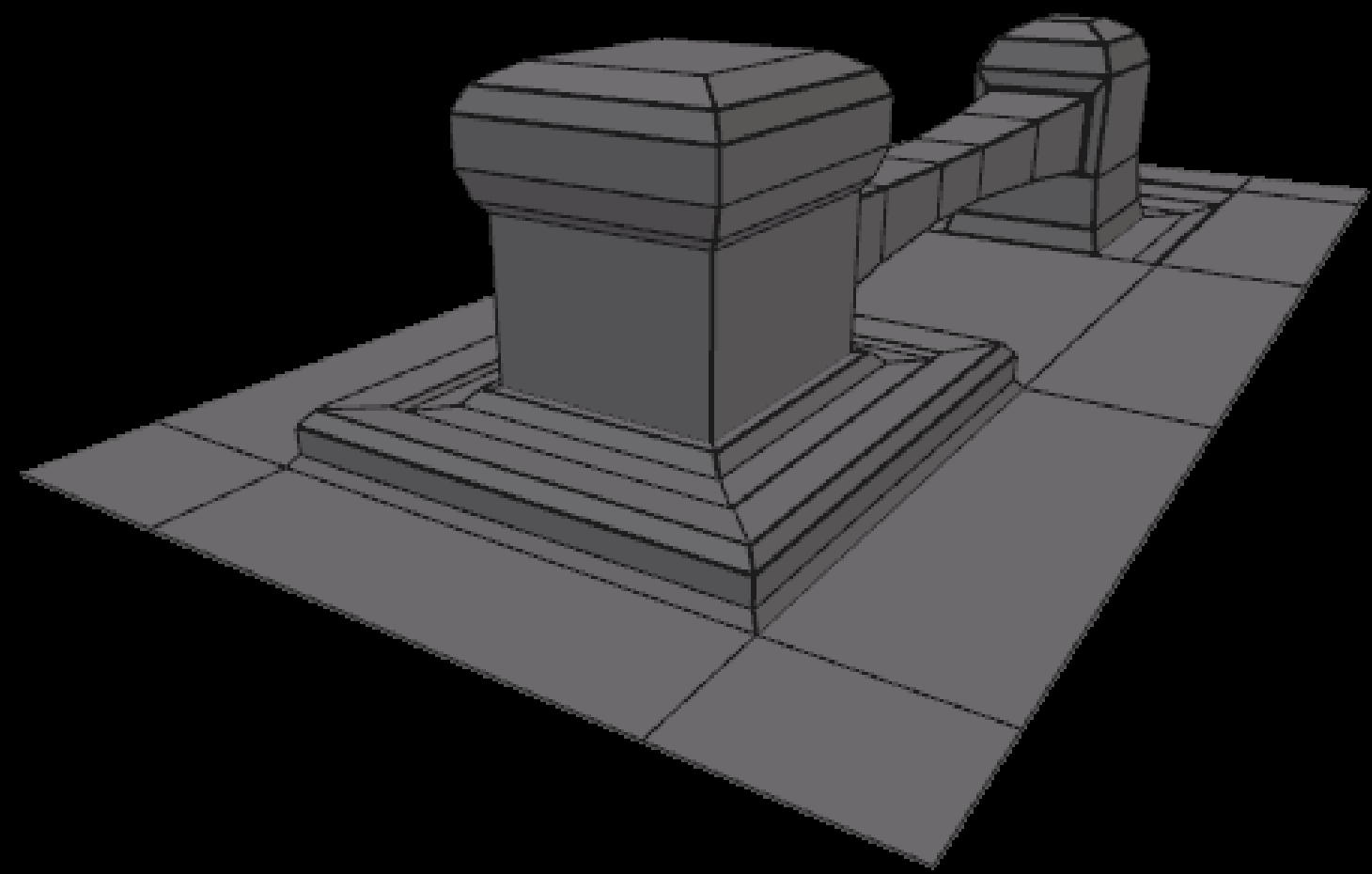
sculpting workflows are vastly different than modeling

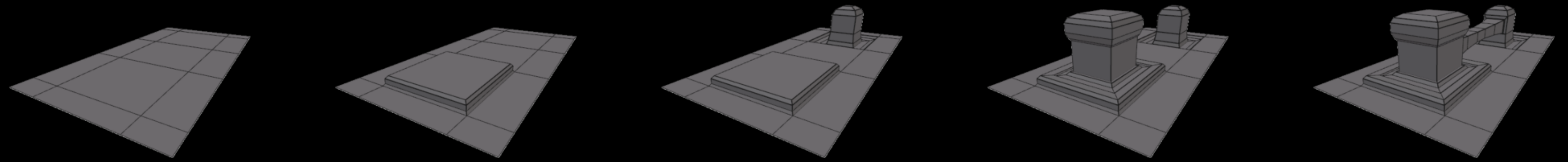
- :(no obvious editing pattern of tool usage
- :(single tool can produce different effects
- :(large sculpt brushes modify many faces

also, what if we do not have tight instrumentation,
or used different tool set, specialized plug-ins, or software?

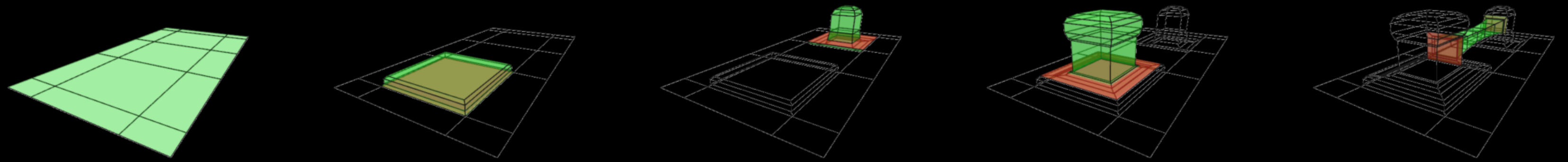
must use different clustering process

input
deltas
depgraph
collapse/split
edit metric

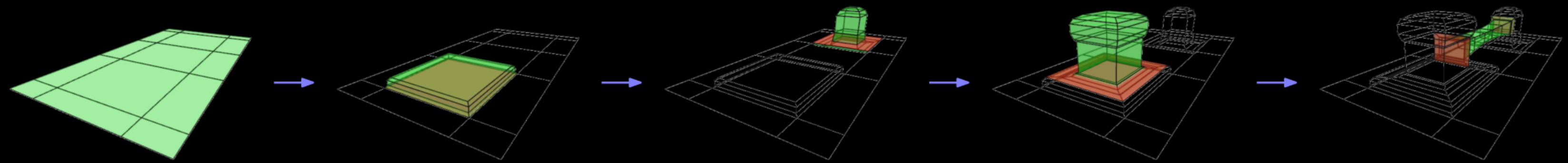




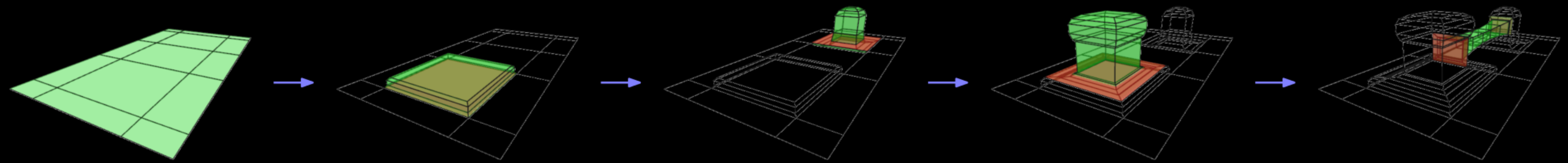
mesh snapshot sequence is input



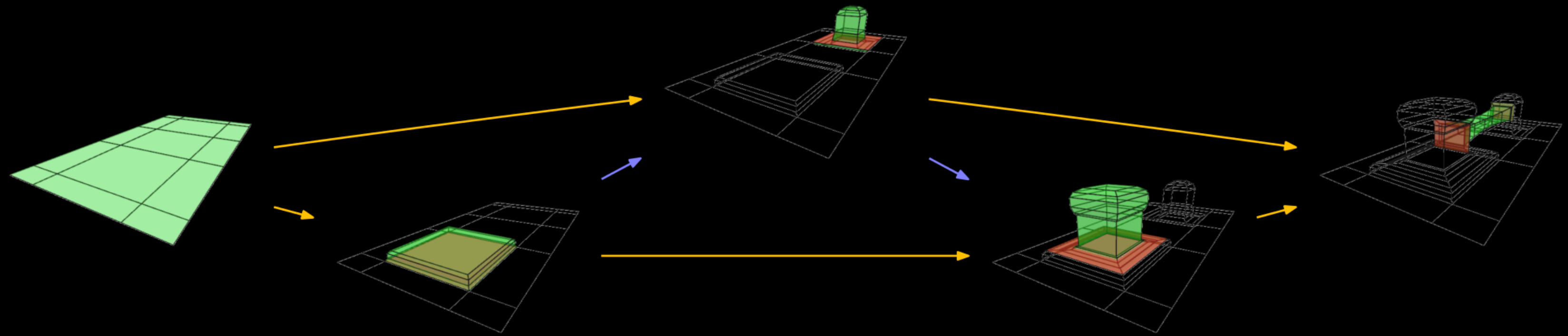
compute mesh deltas



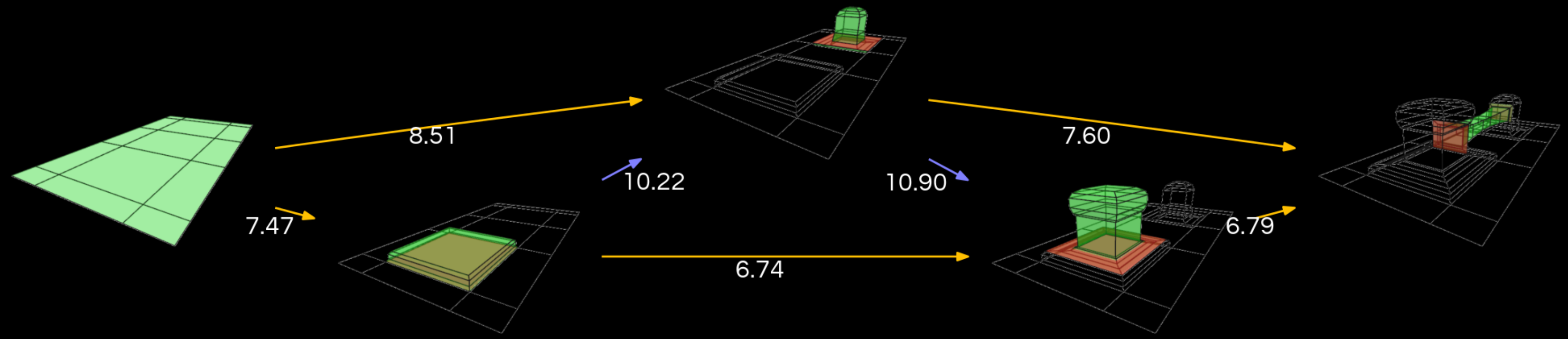
simple, temporally-linear depgraph



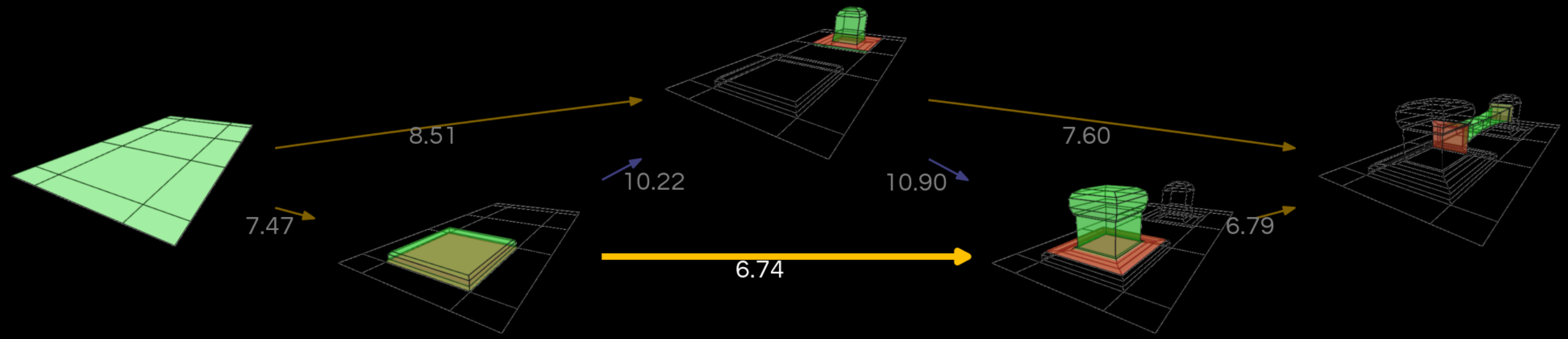
note: some edits do not spatially overlap



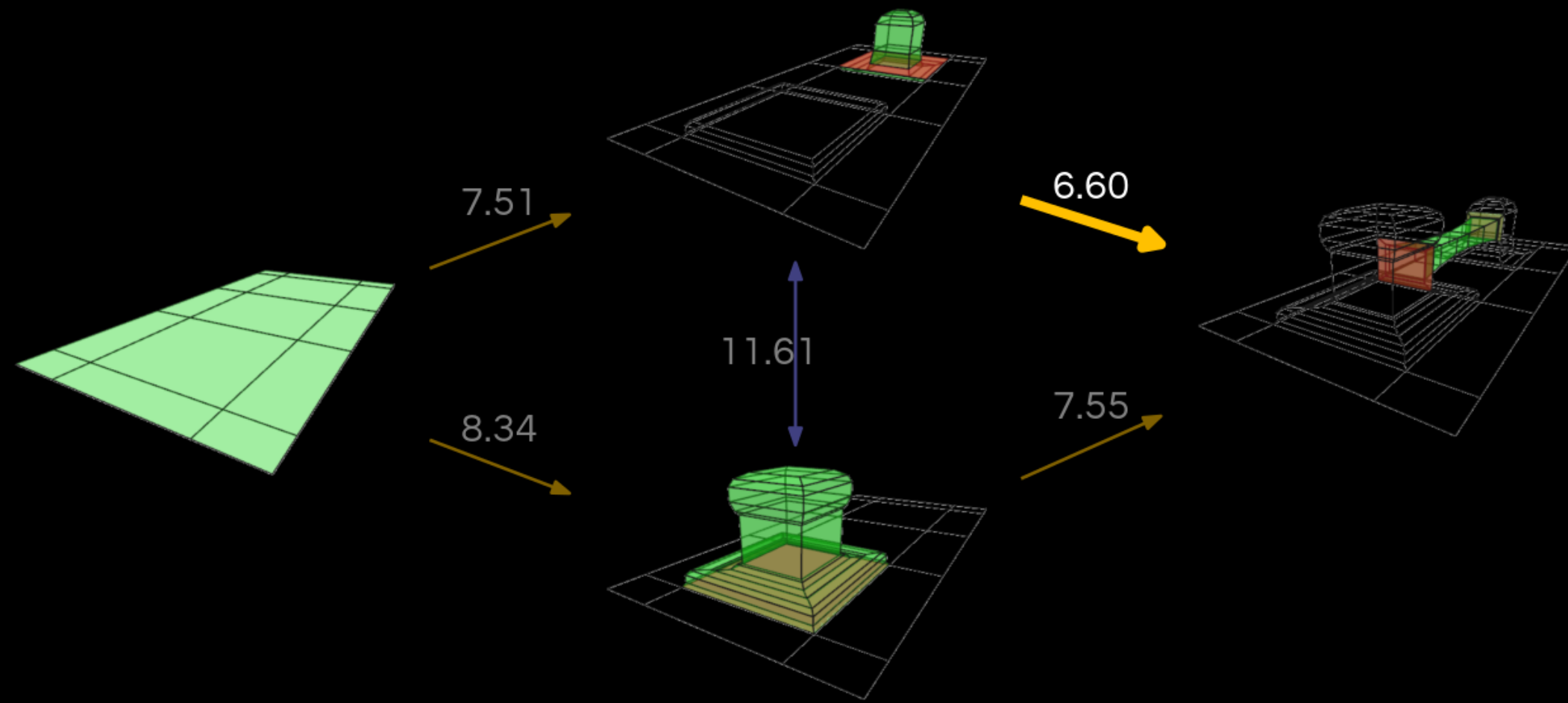
nonlinear depgraph (temporal, spatial)



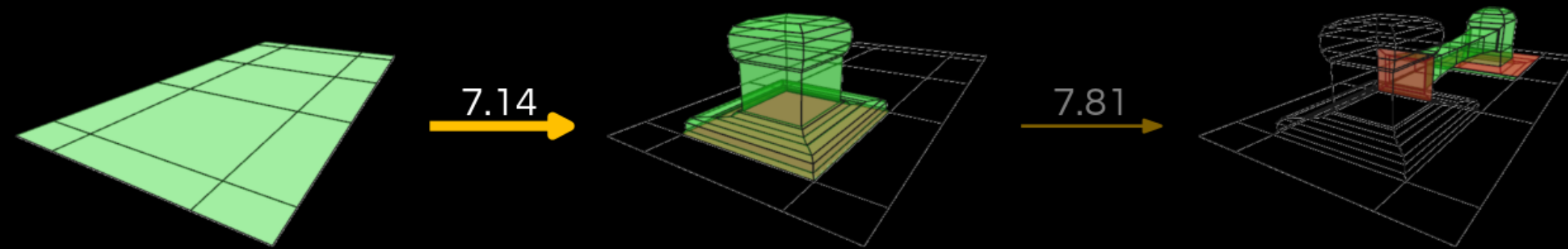
assign weights to each edge



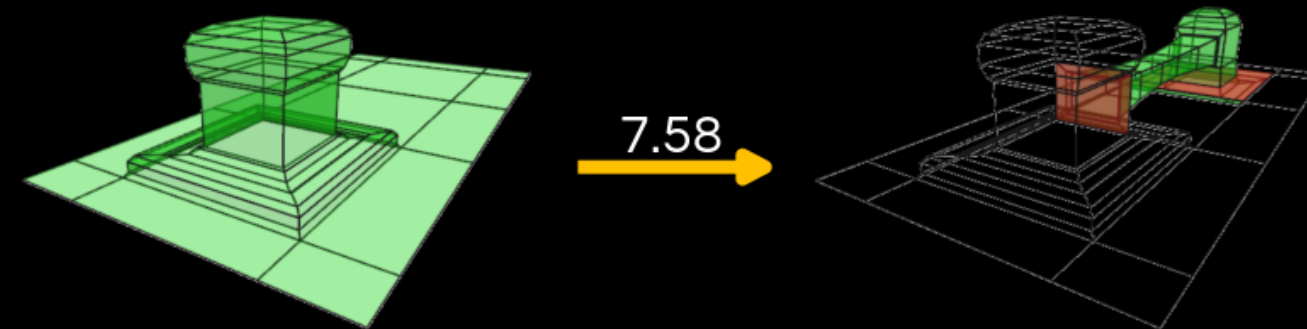
collapse min edge + merge delta; repeat



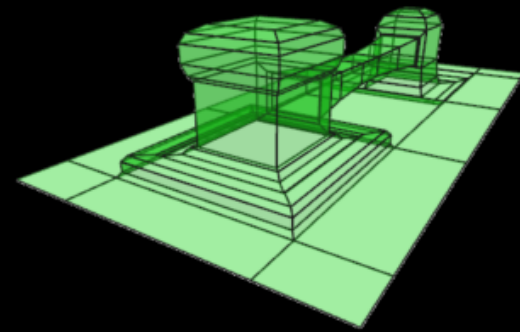
collapse min edge + merge delta; repeat



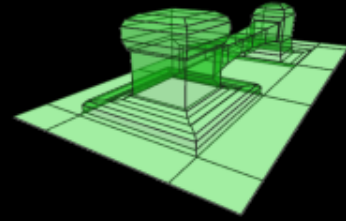
collapse min edge + merge delta; repeat



collapse min edge + merge delta; repeat

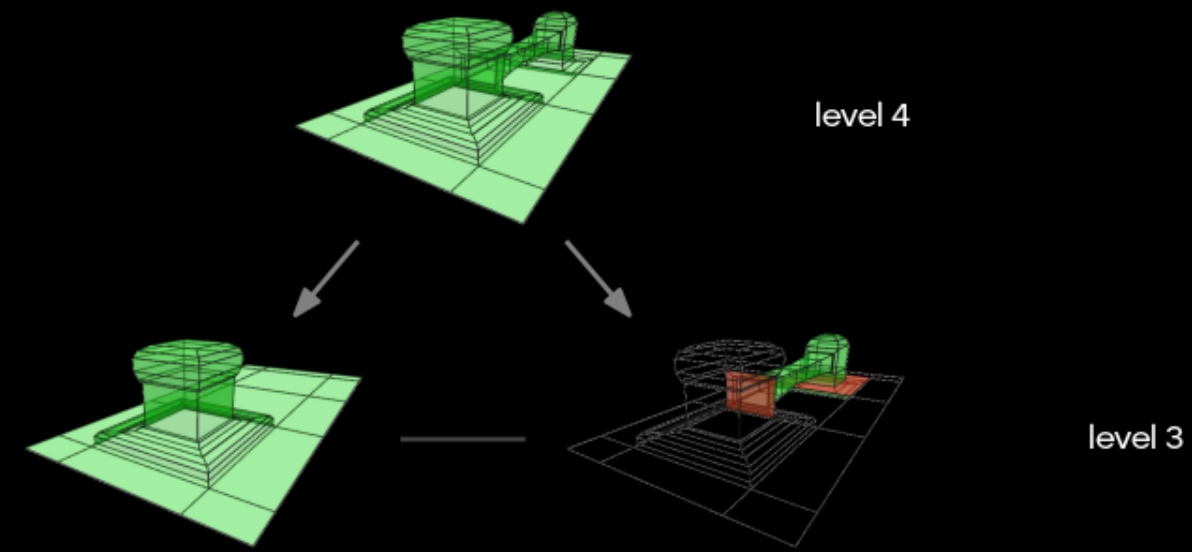


single delta containing all edits

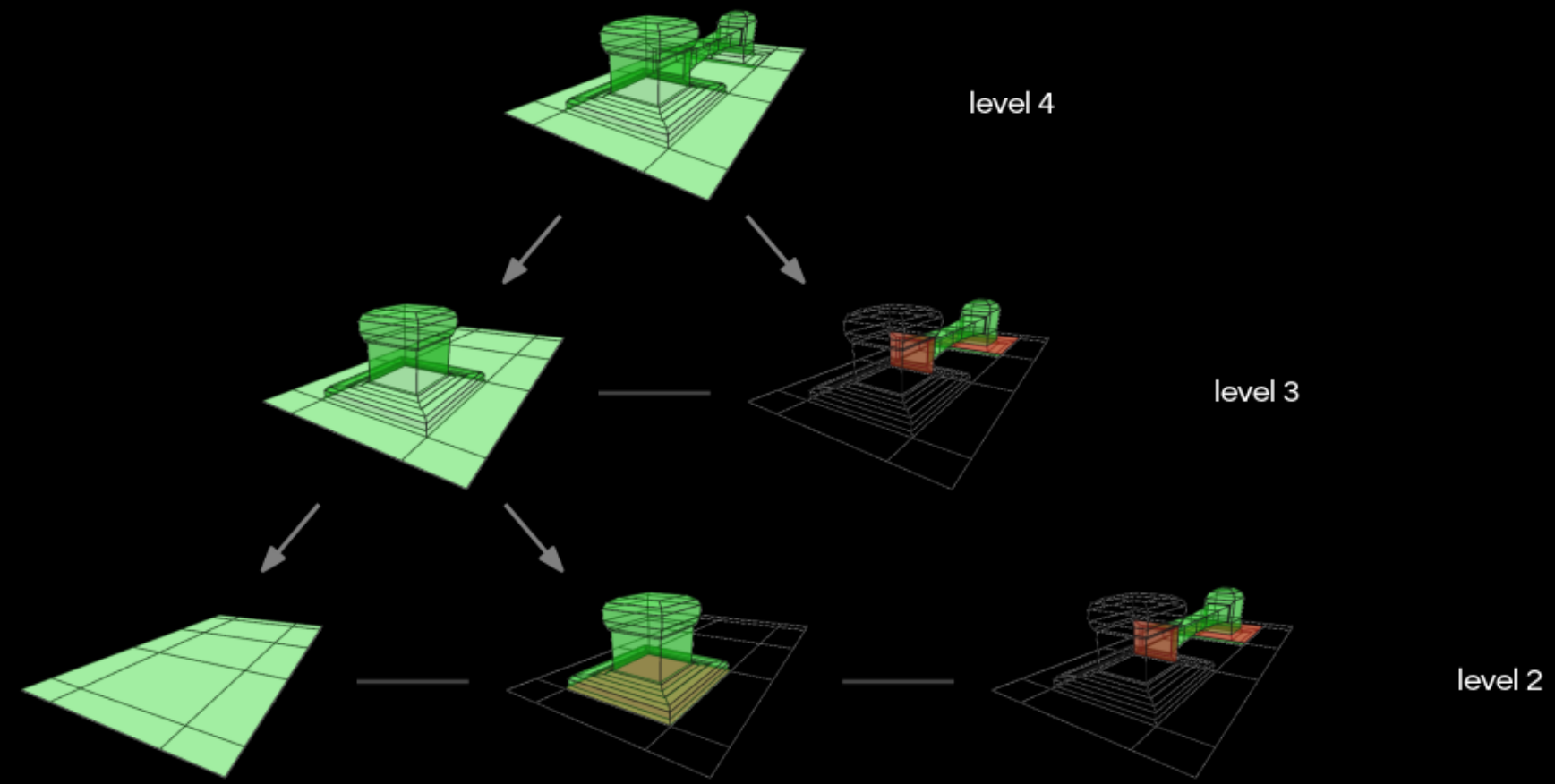


level 4

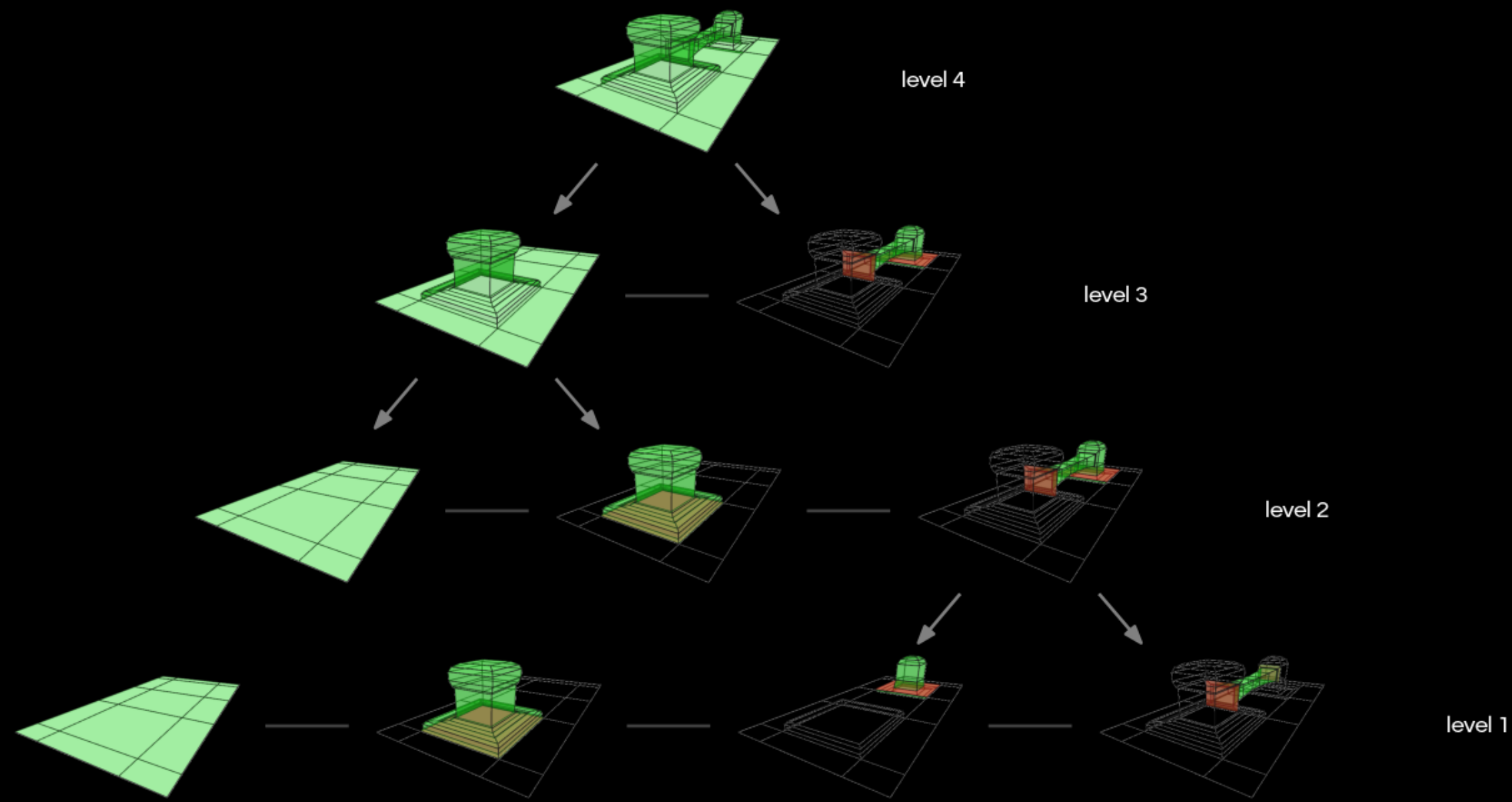
create **levels** by repeatedly **splitting** in reverse order



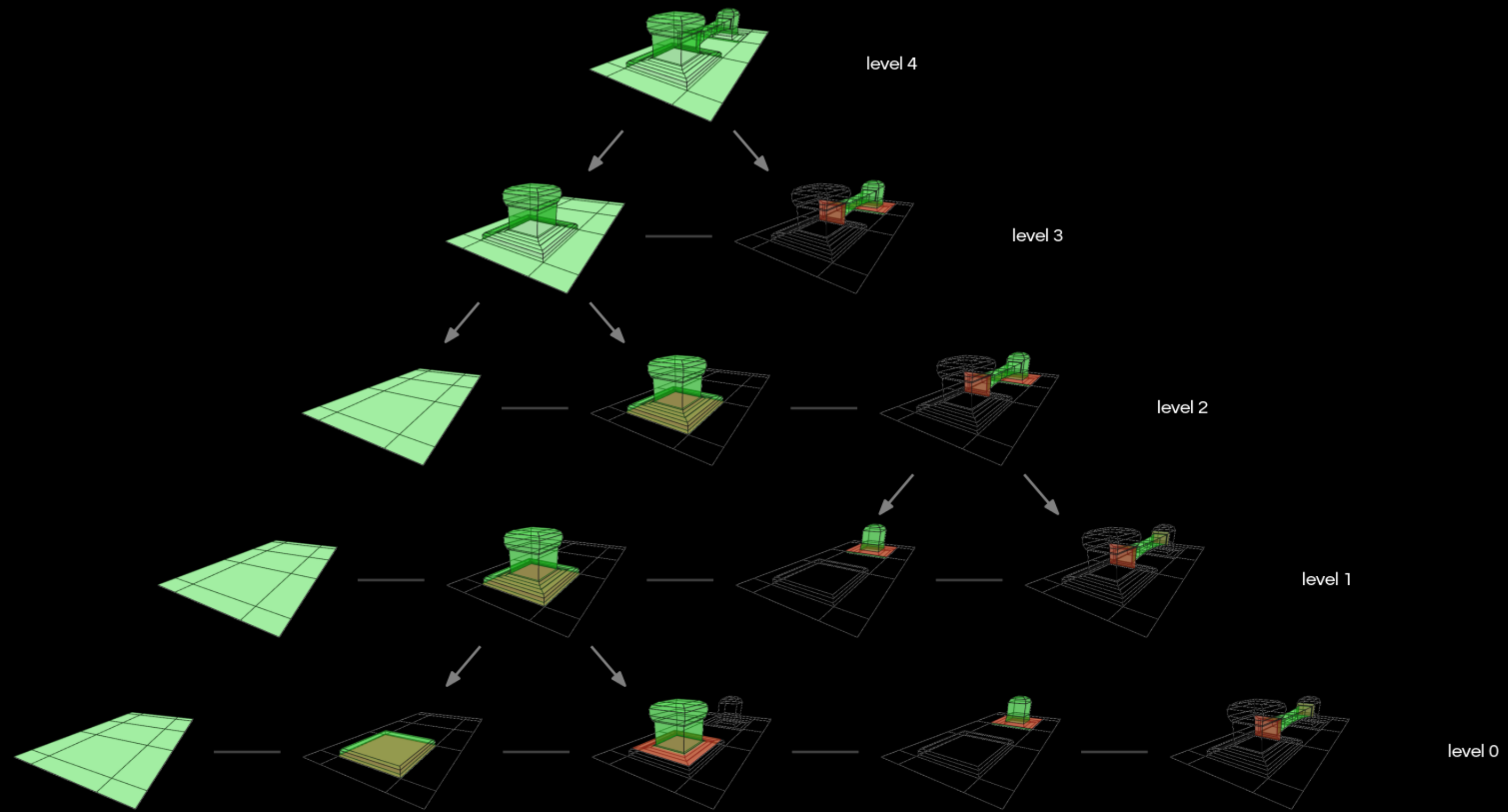
create levels by repeatedly splitting in reverse order



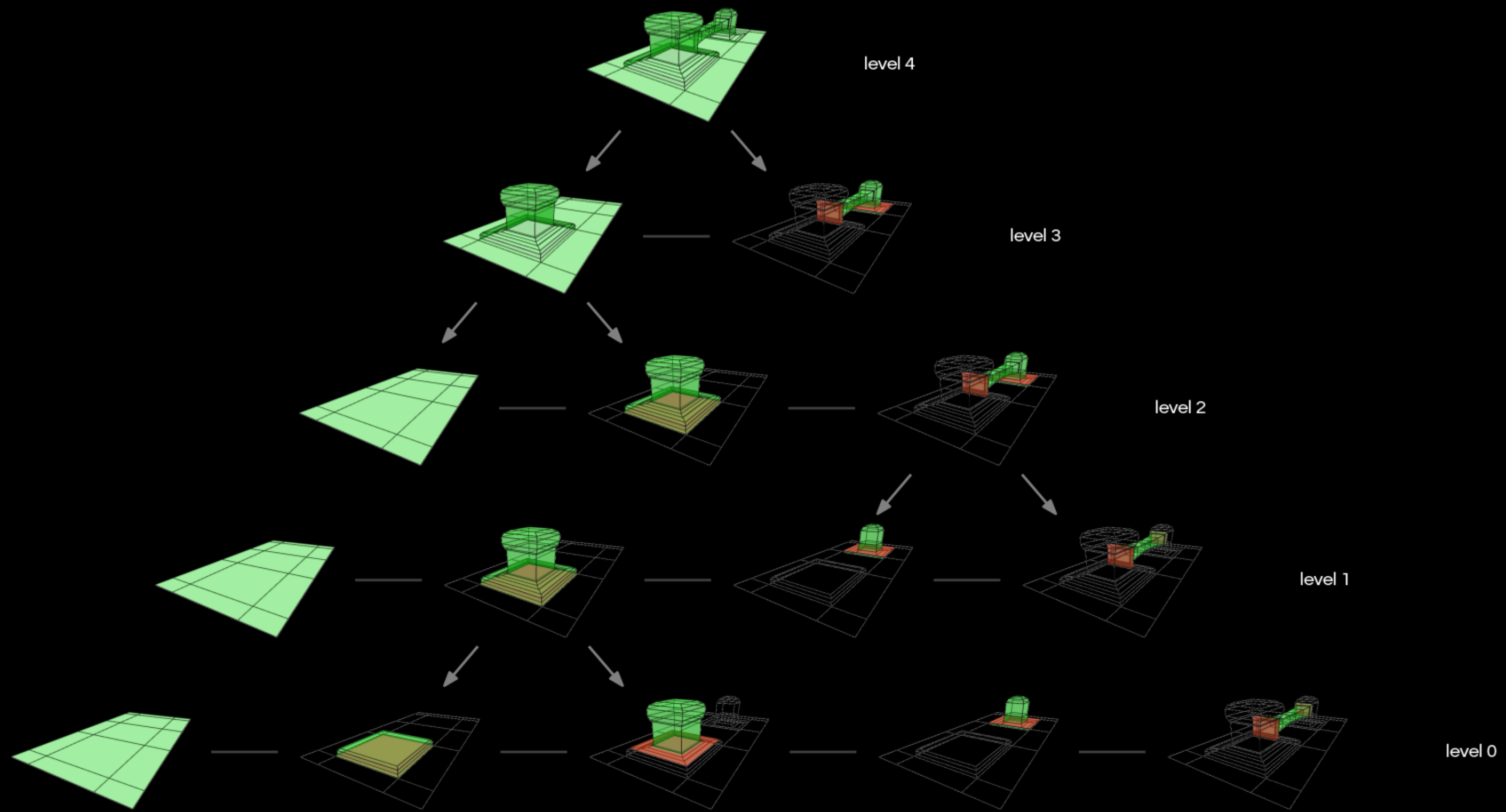
create levels by repeatedly splitting in reverse order



create levels by repeatedly splitting in reverse order



create levels by repeatedly splitting in reverse order



note: level 0 is temporally out-of-order from original sequence

edges of depgraph weighted by edit metric
computes cost of merging two deltas

idea

do not merge edits that are far apart or too strong
in either dimension, temporal or spatial

$$C(A, B) = \underbrace{w_0 S_t + w_1 D_t}_{\text{temporal}} + \underbrace{w_2 S_x + w_3 D_x}_{\text{spatial}}$$

A, B : deltas

S_t, S_x : strength

D_t, D_x : distance

w_0, \dots, w_3 : constants

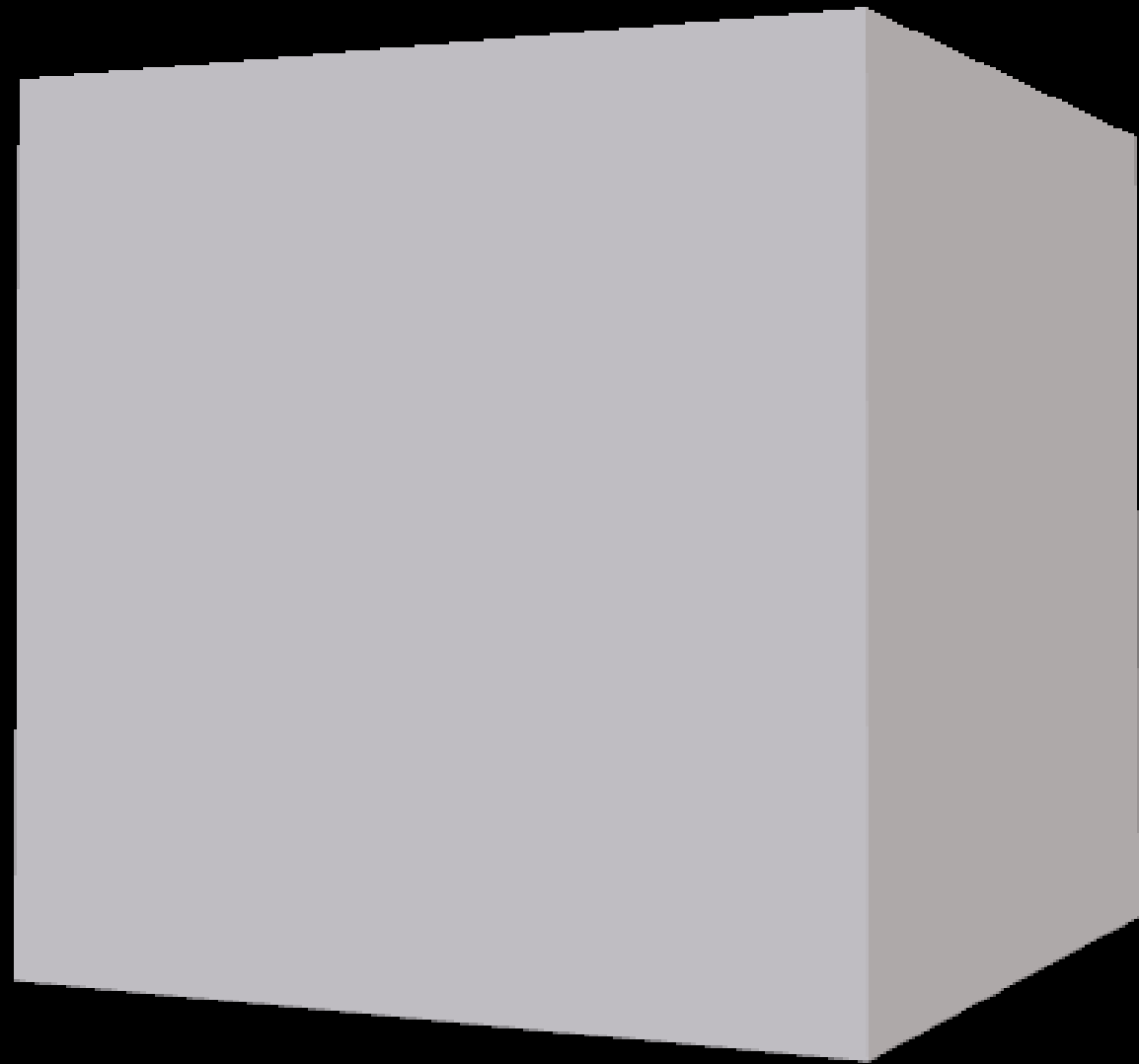
- S_t : total number of original snapshots covered by deltas
 D_t : minimum temporal distance between deltas
- S_x : absolute net change in surface area after merging
 D_x : minimum Euclidean distance between faces of deltas

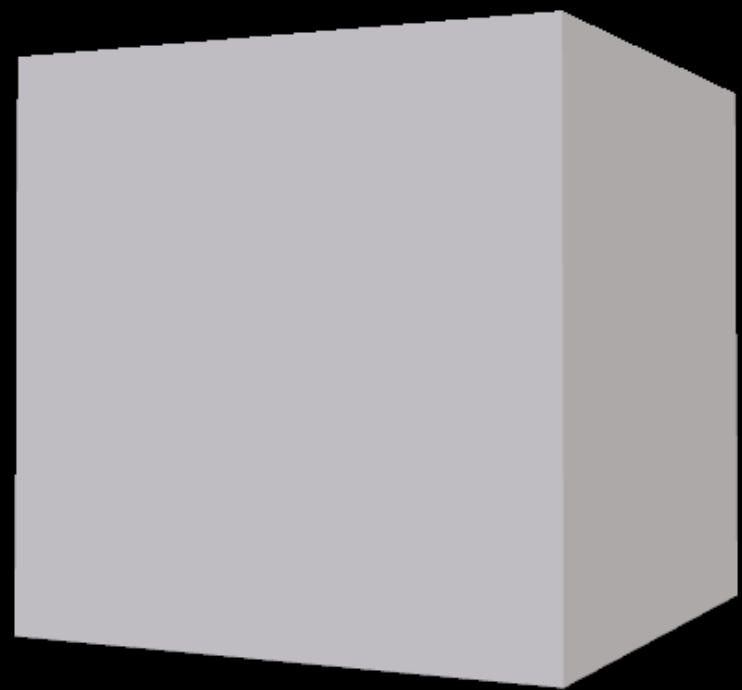
artist can edit weights to control summarization process

- :) prevent initial shape from merging
- :) prevent temporal reorder
- :) zero weight for edits not modifying areas of interest

see paper for details
gfx.cse.taylor.edu



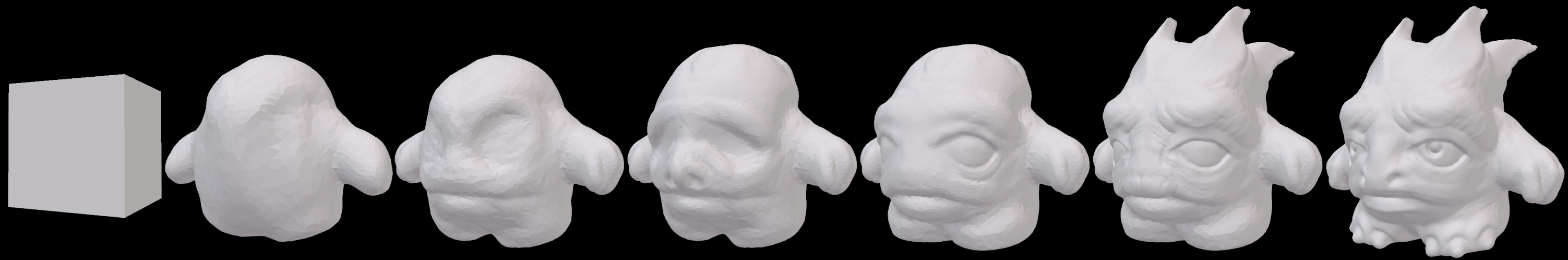


















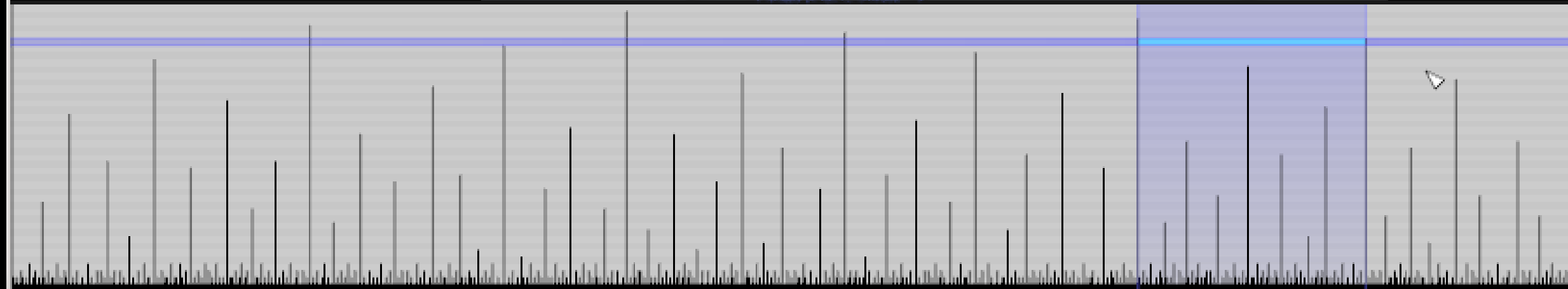
results



```
tab 3D View
view 5
max 6
level 36
multi.page 0

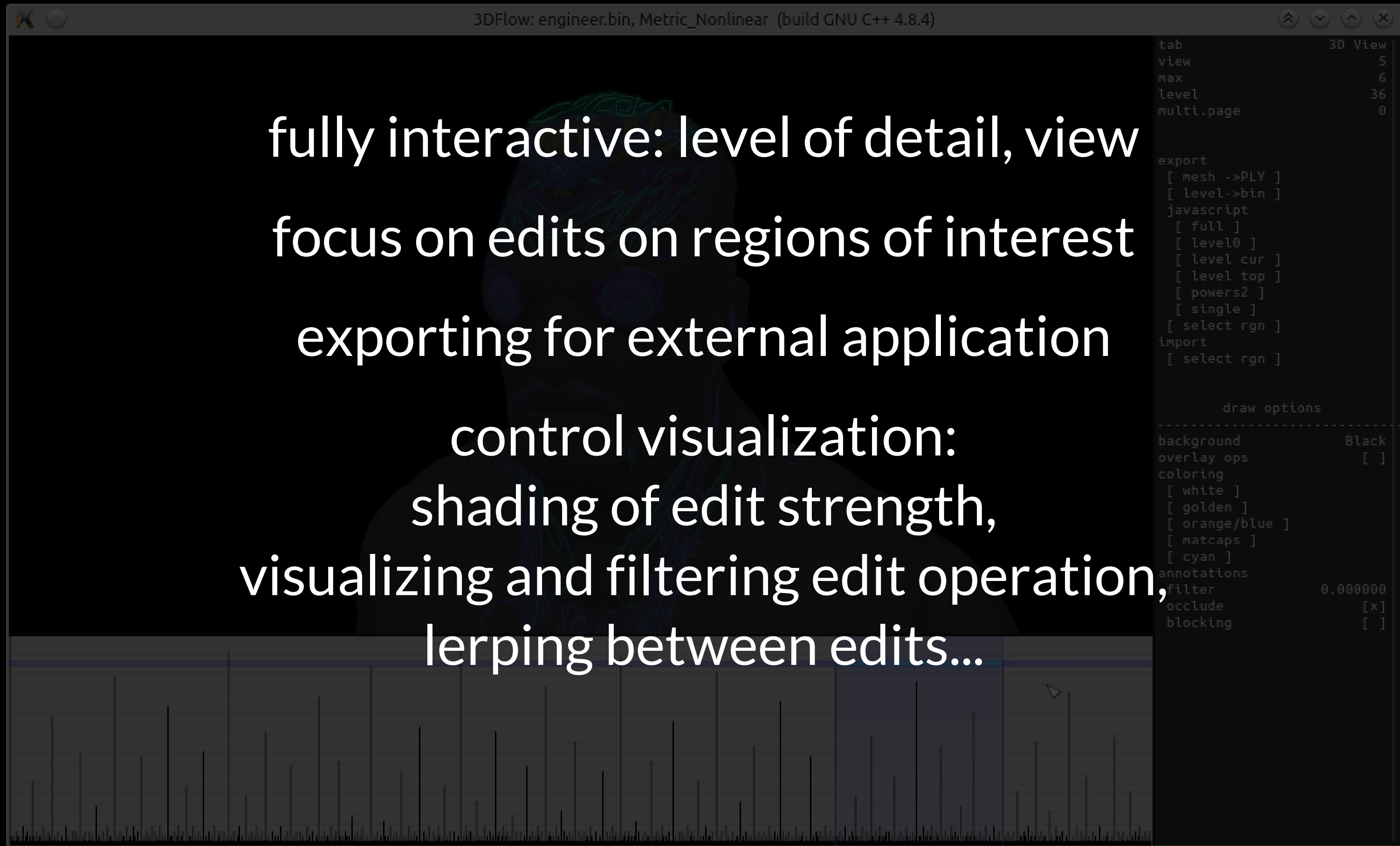
export
[ mesh ->PLY ]
[ level->bin ]
javascript
[ full ]
[ level0 ]
[ level cur ]
[ level top ]
[ powers2 ]
[ single ]
[ select rgn ]
import
[ select rgn ]

-----
draw options
background Black
overlay ops [ ]
coloring
[ white ]
[ golden ]
[ orange/blue ]
[ matcaps ]
[ cyan ]
annotations
filter 0.000000
occlude [x]
blocking [ ]
```

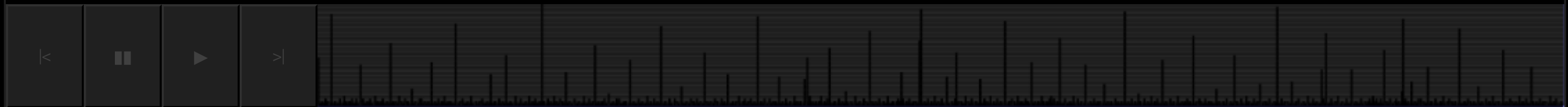


fully interactive: level of detail, view
focus on edits on regions of interest
exporting for external application

control visualization:
shading of edit strength,
visualizing and filtering edit operation,
lerping between edits...



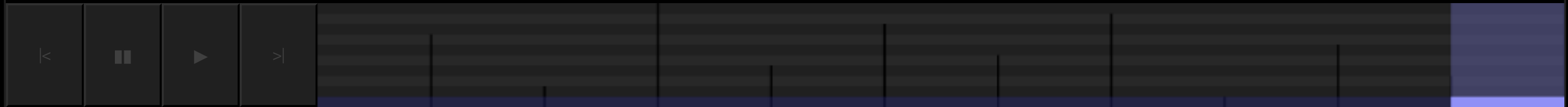
3dflow: shark.bin.metric_nonlinear



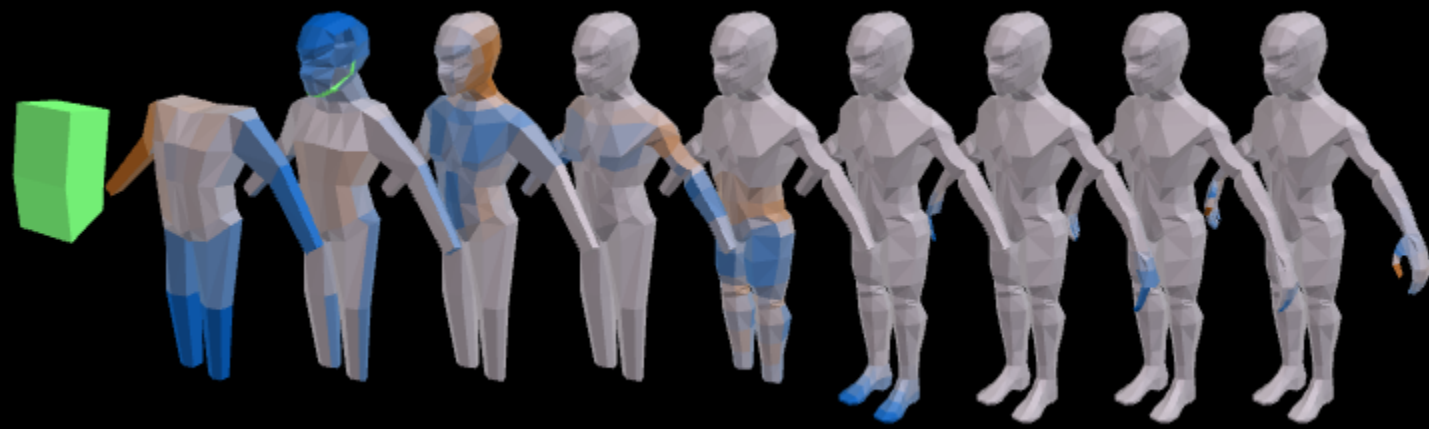
3dflow: gargoye.bin.metric_nonlinear



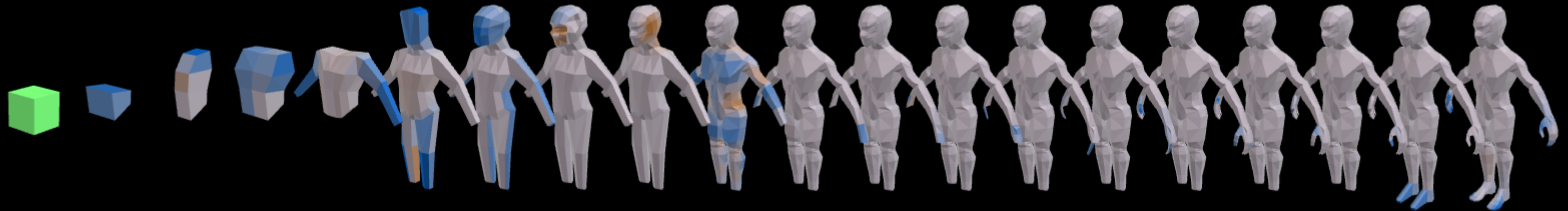
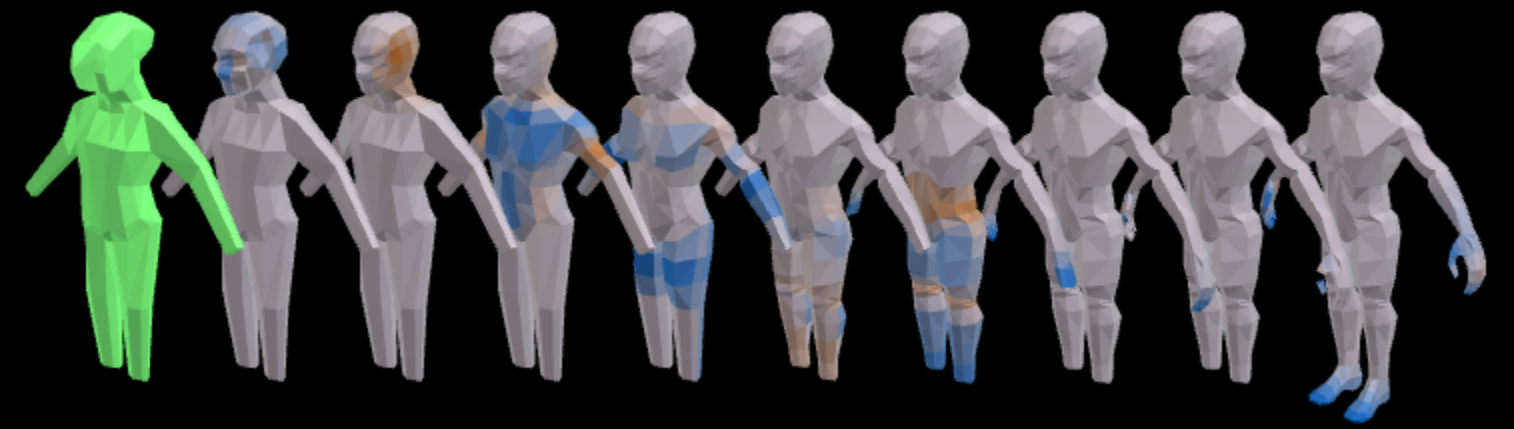
3dflow: durano.bin.metric_nonlinear



3dflow



uniform



meshflow

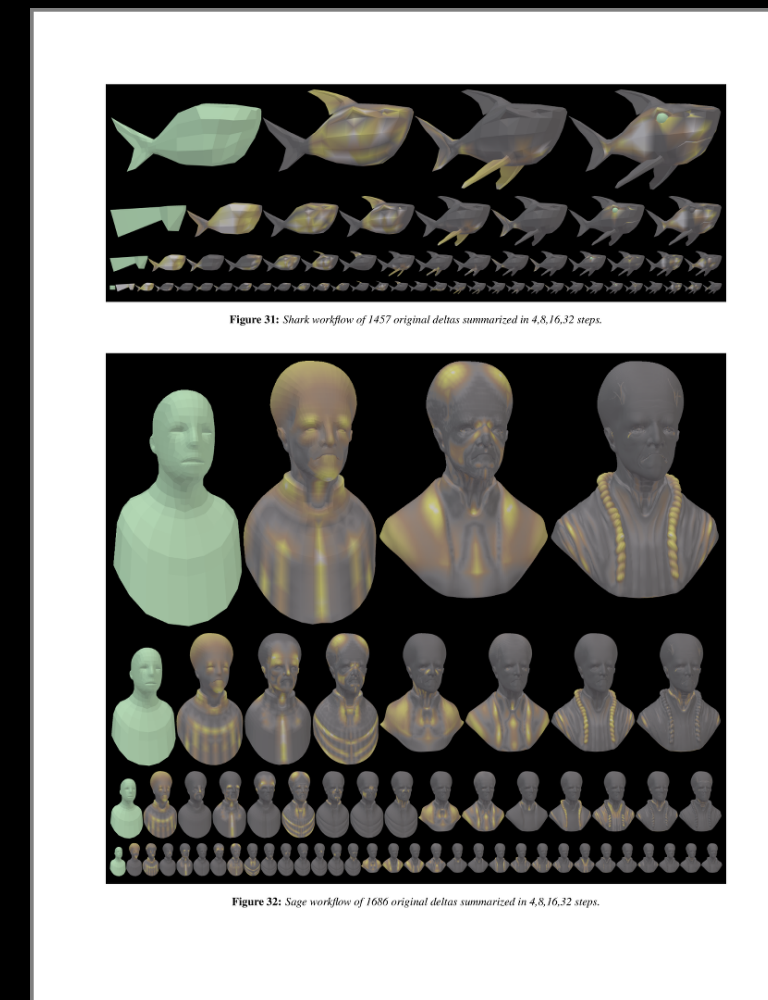
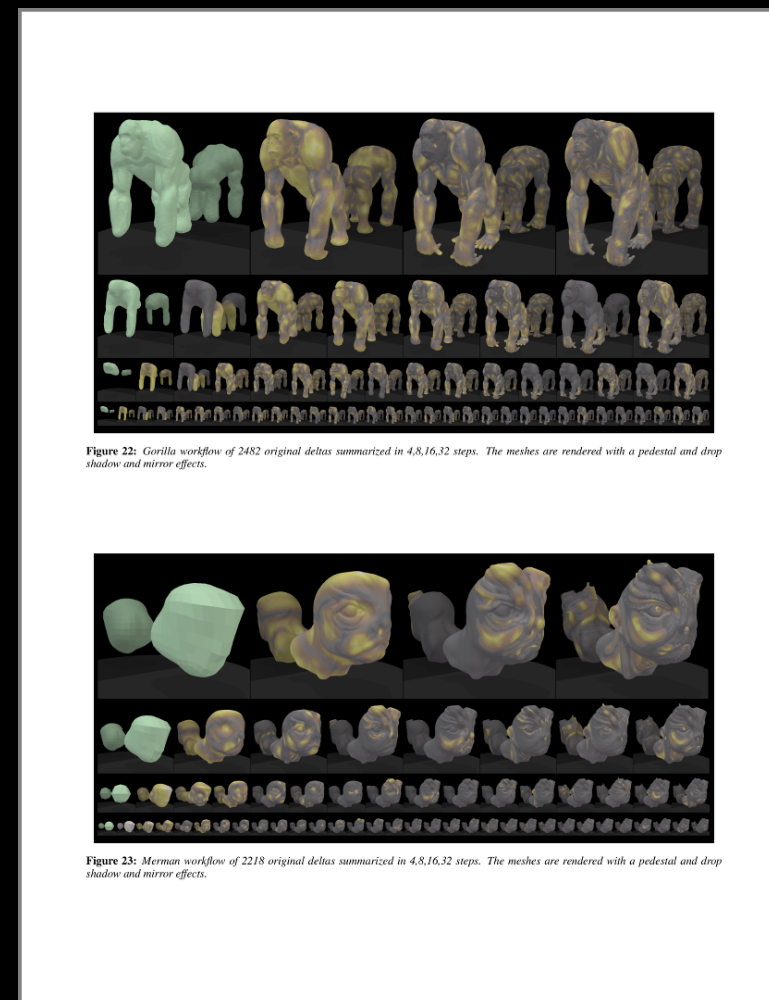
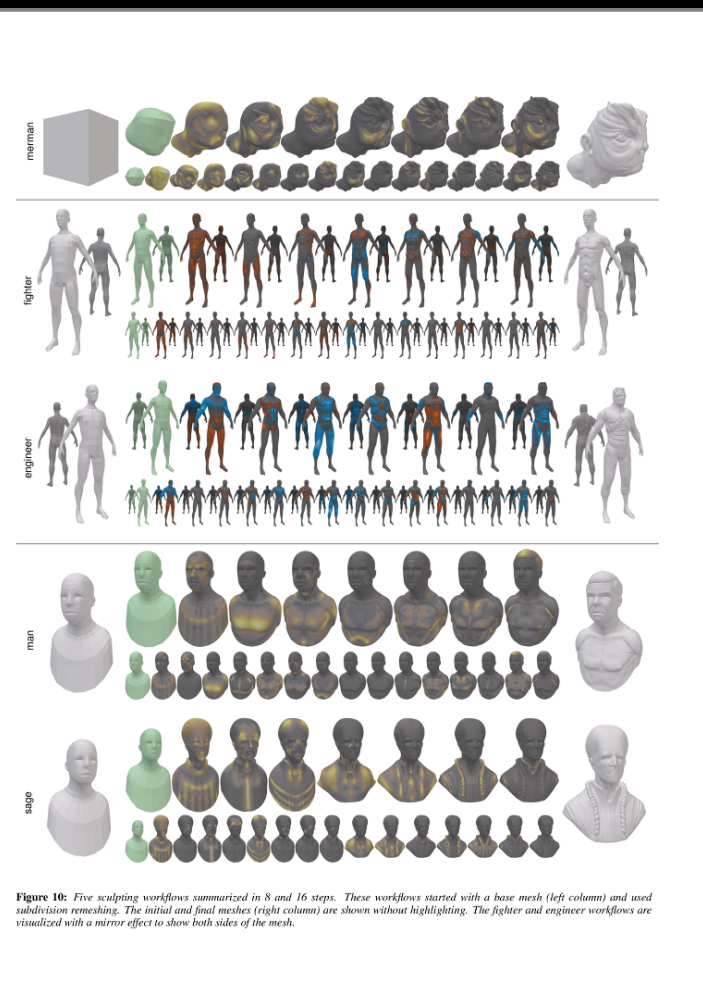
meshflow

polygonal modeling only /
edit patterns /
tight instrumentation /
fixed output size /
temporally linear /

3dflow

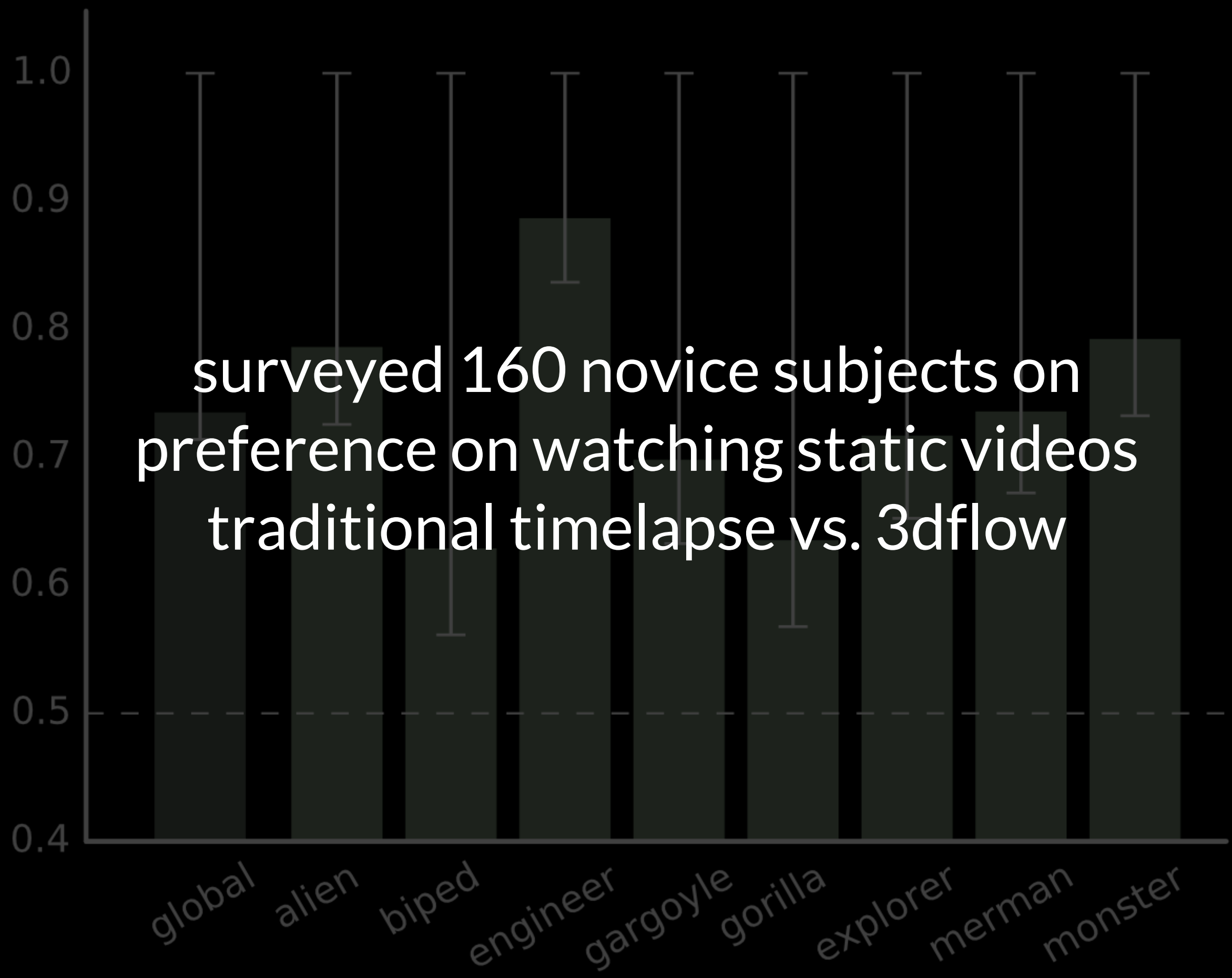
mesh edit workflow
edit metric
any mesh sequence
continuous summarization
temporal or spatial

many results in paper and supplemental gfx.cse.taylor.edu



user studies
quantitative
qualitative

surveyed 160 novice subjects on preference on watching static videos traditional timelapse vs. 3dflow



formally interviewed five expert artists that are instructors

most mentioned problem with timelapses: selecting ideal speed
not uniform across editing sessions
varying from details to general changes

all experts confirmed they prefer using 3dflow,
useful for sharing workflow

“ This program has amazing application potential when it comes to 3D education. I would consider this for use in my classroom. ”

“This has a huge amount of potential for teachers and students alike.”

“ As a tutorial creator I've often thought that something like this would be helpful in addition to the regular tutorial media options. ”

“ This looks awesome! ”

informally conversed with sculpting authors and CEO of sketchfab,
the leading online platform for publishing and sharing 3d content

sculpting authors found summarizations captured workflows well
agreed 3dflow's interactive viewer is significant improvement
astonished to see how 3dflow breaks down the workflow process

“ I've recently finished working on the materials for a sculpting course I'm teaching. Having 3DFlow available would have allowed students to better visualize changes to the mesh. ”

continuous summarization

input	:	any sequence of snapshots
deltas	:	edits between snapshots
depgraph	:	capture dependence of edits
collapse/split	:	continuous summarization
edit metric	:	measure strength and distance

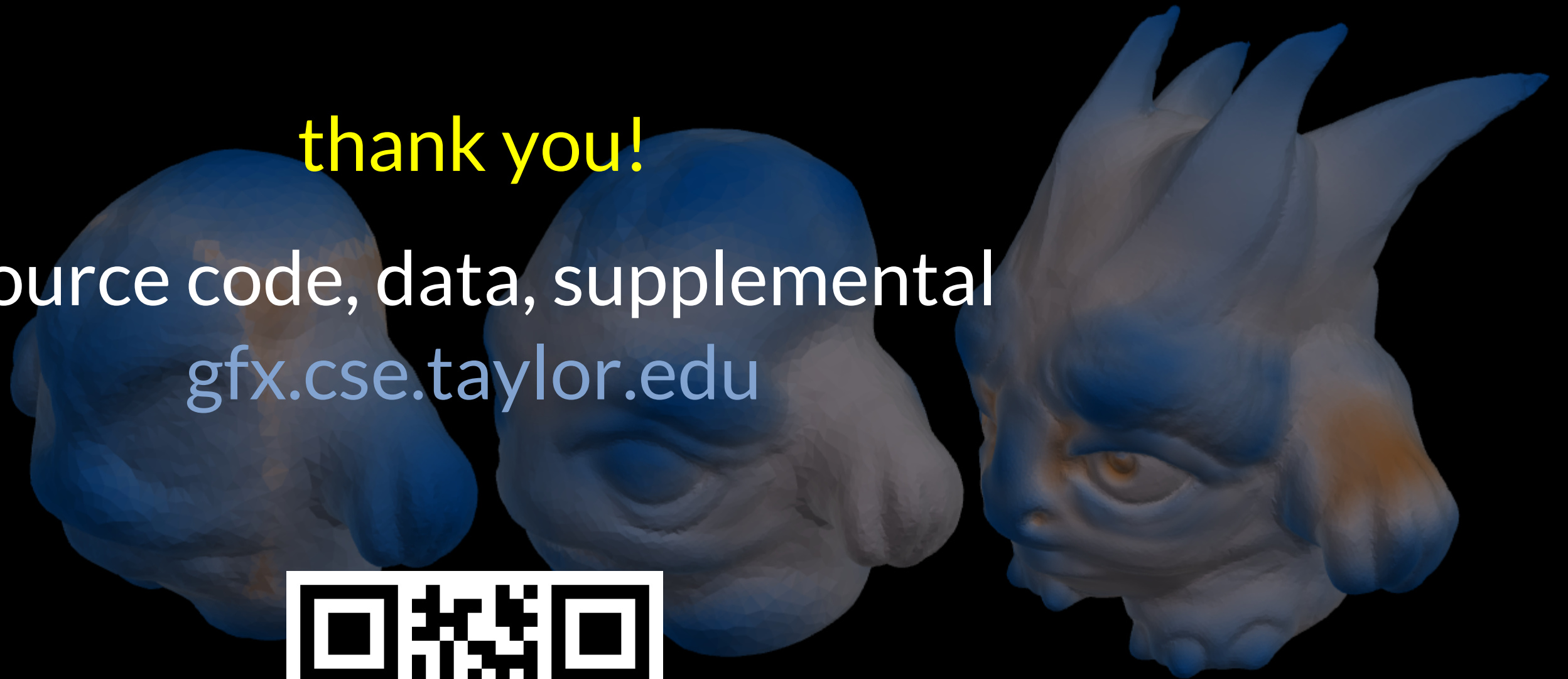
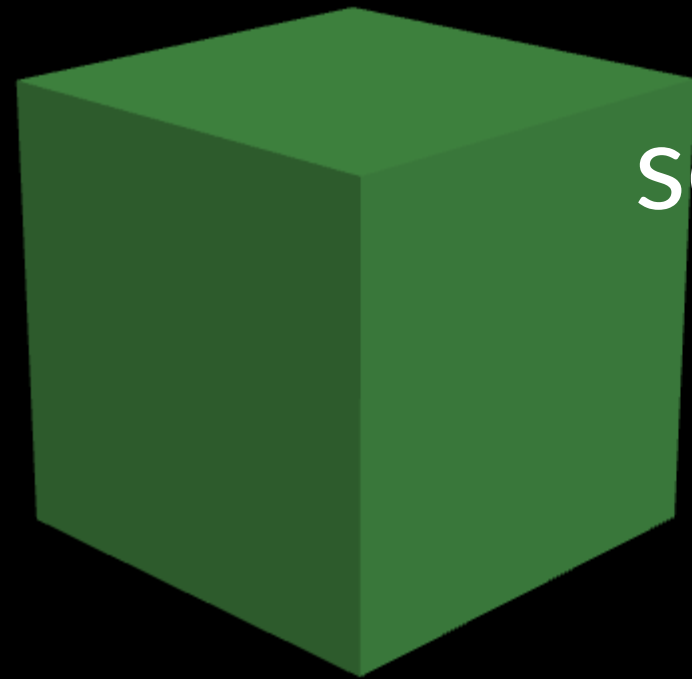
modeling, sculpting	/	animation, texturing
mesh editing	/	general workflows
single workflow	/	multiple workflows
interactive viewer	/	tutorial authoring

sculpting : roch, williamson
modeling : blender, goralczyk, vazquez,
culum, drincic, jack, tate, williamson

funding : nsf, sloan foundation, intel,
european commission 7th framework
programme (project TROPIC)

thank you!

source code, data, supplemental
gfx.cse.taylor.edu



additional material

$$S_t = \frac{|\Delta_t(A)| + |\Delta_t(B)|}{\text{avg}|\Delta_t|}$$

$$D_t = \min_{a,b \in \Delta_t(A) \times \Delta_t(B)} \frac{|a - b| - 1}{\text{avg}|\Delta_t|}$$

$$S_x = \frac{|\text{area}[\Delta_x^+(A \cdot B)] - \text{area}[\Delta_x^-(A \cdot B)]|}{\max(\text{area}[\Delta_x^+(A \cdot B)], \text{area}[\Delta_x^-(A \cdot B)])}$$

$$D_x = \min_{u,v \in \Delta_x(A) \times \Delta_x(B)} \text{min-dist}(u, v)$$

why keep temporal edges?

disconnected components do not overlap spatially, so depgraph would have disjoint subgraphs editing nearby components

processing time is comparable to time for encoding timelapse video
~2million unique faces takes less than 3minutes

could artists control summarization?

keep only delta, reconstruct full mesh