modflows

methods for studying and managing mesh editing workflows

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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
websites dedicated to modeling and sculpting
medium is challenging
one-on-one / limited
tutorial / interrupt, practice
time-lapse / lost in details
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
(video: vids/biped/level00/video60.mov)
fully-automated approach to summarizing workflows
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
### Top 4 Bigrams

<table>
<thead>
<tr>
<th></th>
<th>5759</th>
<th>3781</th>
<th>3118</th>
<th>1843</th>
<th>225</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>cam,cam</strong></td>
<td>.33</td>
<td>.22</td>
<td>.27</td>
<td>.40</td>
<td>.20</td>
</tr>
<tr>
<td><strong>select,trans</strong></td>
<td>.15</td>
<td>.16</td>
<td>.20</td>
<td>.26</td>
<td>.17</td>
</tr>
<tr>
<td><strong>trans,select</strong></td>
<td>.11</td>
<td>.13</td>
<td>.15</td>
<td>.25</td>
<td>.16</td>
</tr>
<tr>
<td><strong>cam,select</strong></td>
<td>.09</td>
<td>.13</td>
<td>.14</td>
<td>.02</td>
<td>.12</td>
</tr>
</tbody>
</table>
summarizing by substitution regexs

2 \((\text{cam})^+ (\text{cam})^\circ \mapsto (\text{cam})^\circ\)

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

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

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

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

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

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

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

10 \((\cdot)^\circ (\text{view} \mid (\cdot)^\circ)^* (\cdot)^\circ \mapsto (\cdot)^\circ\)
levels of detail

...
case study

8 college students
modeling class
followed tutorial
I would love to 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

siggraph 13
exact matching

original
derivative
Surface correspondence

Original derivative

Kim et al. 2011
graph match

original
derivative

cour et al. 2006
adjacency matching

original
derivative

[eppstein et al. 2009]
string edit distance / mesh edit distance
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
\[ C(O) = C_u(O) + C'_g(O) + C_a(O) \]
\[ C(O) = C_u(O) + C_g(O) + C_a(O) \]

\[ C_u(O) = N_u + N'_u \]

\[ N : \text{number of unmatched faces and verts} \]
\[ C(O) = C_u(O) + C_g(O) + C_a(O) \]
\[ C(O) = C_u(O) + C_g(O) + C_a(O) \]
\[ C(O) = C_u(O) + C_g(O) + C_a(O) \]

\[ C_g(O) = \sum_{e \in E} \left[ \frac{d(x_e, x_{e'})}{d(x_e, x_{e'}) + 1} + (1 - n_e \cdot n_{e'}) \right] \]

\( E \): matched faces and verts
\( x \): position  \( n \): normal  \( d(x_e, x_{e'}) = |x_e - x_{e'}| \)
\[ C(O) = C_u(O) + C_g(O) + C_a(O) \]
\[ C(O) = C_u(O) + C_g(O) + C_a(O) \]
\[ C(O) = C_u(O) + C_g(O) + C_a(O) \]

\[ \{ e_1 \} \quad \{ e_2 \} \quad \{ e'_1 \} \quad \{ e'_2 \} \]

original \quad derivative
\[ C(O) = C_u(O) + C_g(O) + C_a(O) \]

\[ C_a(O) = \left\{ \begin{array}{l}
\sum_{(e_1,e_2) \in \{U,U'\}} \frac{1}{v(e_1) + v(e_2)} + \\
+ \sum_{(e_1,e_2) \in \{A,A'\}} \frac{w(e_1, e_2, e_1', e_2')}{v(e_1) + v(e_2)}
\end{array} \right. \]

\[ U, U' : \text{unmatched adj pair} \quad \quad A, A' : \text{matched adj pair} \]

\[ v(\cdot) : \text{valence} \quad \quad w(e_1, e_2, e_1', e_2') = \frac{|d(x_{e_1}, x_{e_2}) - d(x_{e_1'}, x_{e_2'})|}{d(x_{e_1}, x_{e_2}) + d(x_{e_1'}, x_{e_2'})} \]
\[ C(O) = C_u(O) + C_g(O) + C_a(O) \]
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
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  
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original
derivative
1. init
2. greedy
3. backtrack
4. repeat 2,3

original
derivative
1. init 2. greedy 3. backtrack 4. repeat 2,3
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
3-way diff

visualize edits from original to two independent derivatives
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
edit partitioning
reduce granularity of conflicts
choose a  neither  choose b

choose b  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
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)
delta: union graph

**Workflow 1**
- Desaturate
- Duplicate
- Find Edges
- Layer Mode

**Workflow 2**
- Duplicate
- Find Edges
- Desaturate
- Gaussian Blur
- Layer Mode

**Union graph**
- Duplicate
- Find Edges
- Desaturate
- Layer Mode
- Gaussian Blur
- Layer Mode
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
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
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
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.
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!