Multiresolution Point-set Surfaces

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GI 2008

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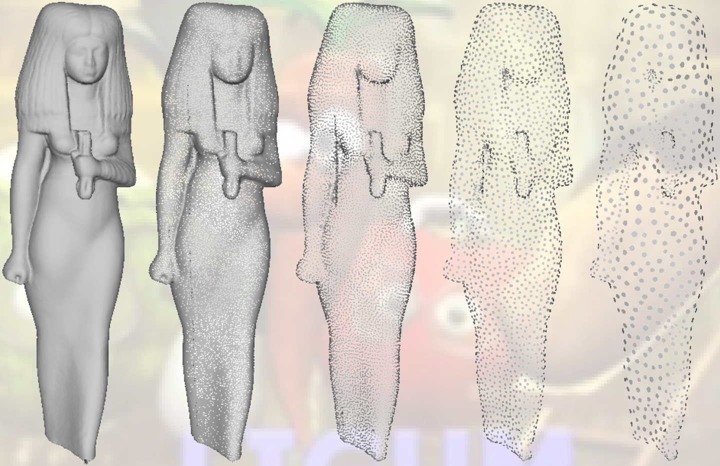
Outline

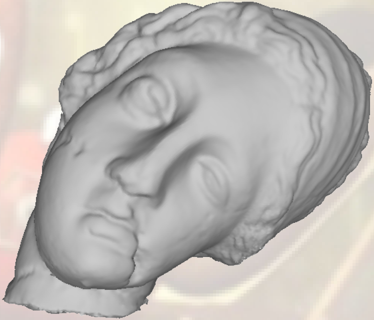
Point-set Surfaces and Surface Editing

- Point-set surfaces are becoming popular for shape modeling
- Surface editing in the presence of fine geometric details can be problematic
- Multiresolution representations for meshes are well known
- Interest for multiresolution representation for point-set surfaces

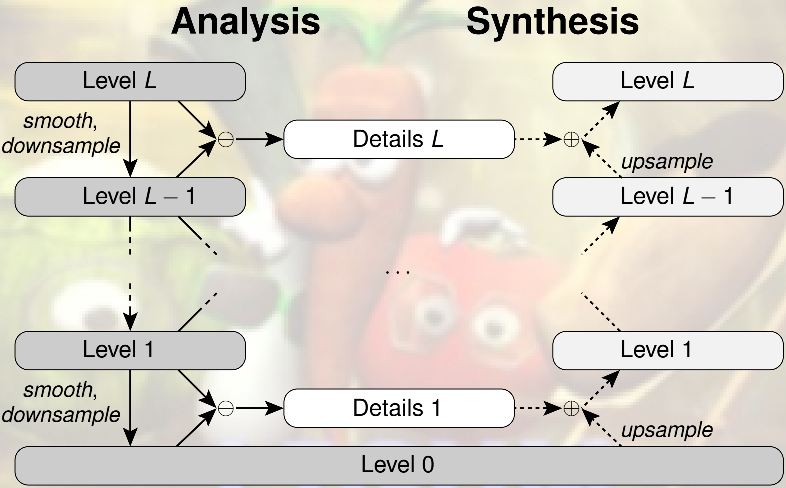
Decomposition



Surface Editing



Overview


Analysis
Synthesis
Level L
smooth,
downsample
Details L
upsample
Level $L-1$
...
Level 1
smooth,
downsample
Details 1
upsample
Level 0

Previous Work

- Multiresolution meshes

  [Eck+ 95] [Lounsbery+ 97] [Zorin+ 97] [Kobbelt+ 98] [Guskov+ 99] [Lee+ 00] [Guskov+ 00] [Hubeli-Gross 01] ...

- "Multiresolution" for points: mostly hierarchical structures geared for rendering

  [Pfister+ 00] [Rusinkiewicz+ 00] [Botsch+ 02] [Pajarola 03] [Park+ 04] [Pajarola+ 05] [Wu+ 05] ...

Previous Work

- Progressive point-set surfaces
  [Fleishman+ 03] [Singh-Narayanna 06]
- Triangle fans
  [Linsen-Prautzsch 03]
- Multiscale point-set surfaces
  [Pauly+ 06] [Zhang+ 05]

Previous Work

- Progressive point-set surfaces
  [Fleishman+ 03] [Singh-Narayanna 06]
- Triangle fans
  [Linsen-Prautzsch 03]
- **Multiscale point-set surfaces**
  [Pauly+ 06] [Zhang+ 05] + [Boubekeur+ 07]

Outline

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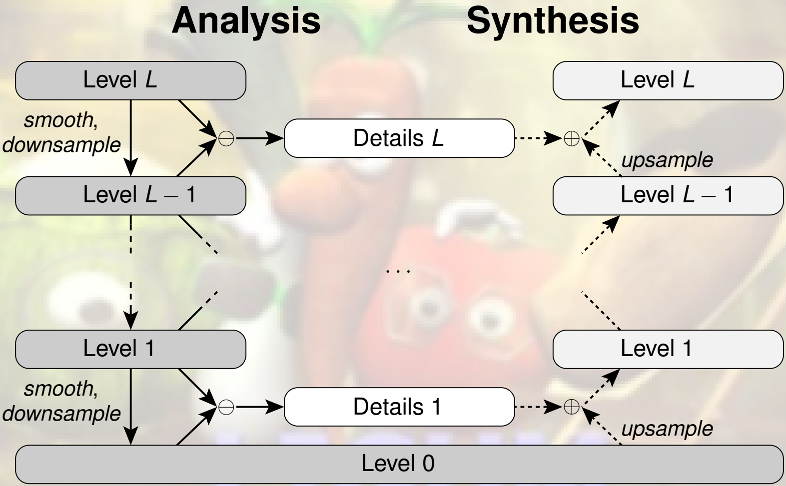
Analysis


Analysis
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Level L
smooth,
downsample
Details L
upsample
Level $L-1$
. . .
Level 1
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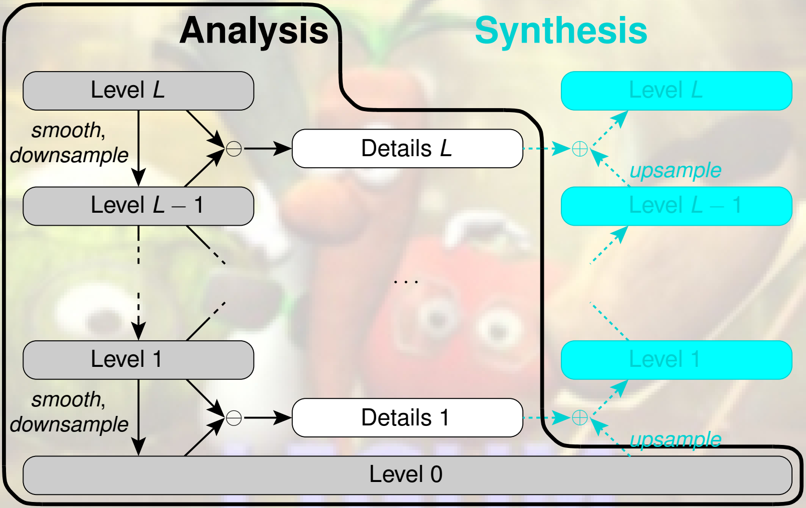
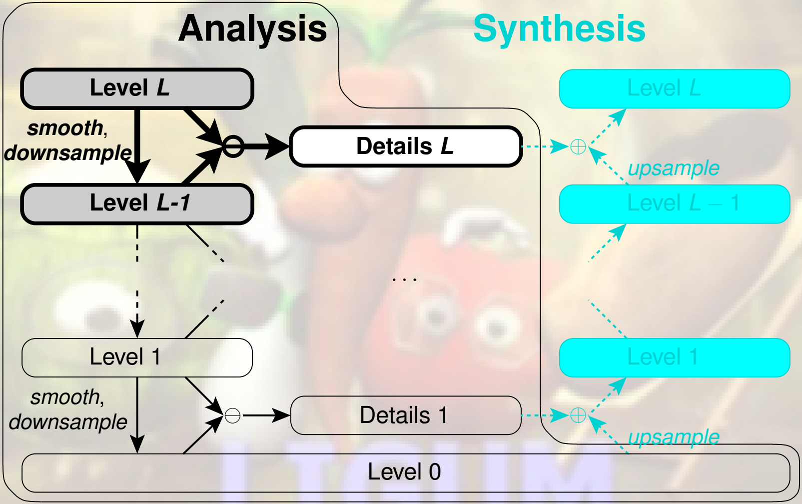
downsample
Details 1
upsample
Level 0

Analysis

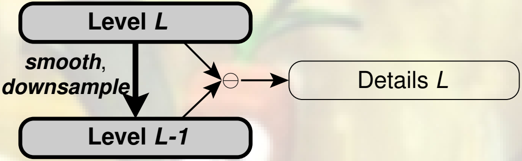

Analysis
Synthesis
Level L
smooth,
downsample
Details L
upsample
Level $L-1$
. . .
Level 1
smooth,
downsample
Details 1
upsample
Level 0
Level L
Level $L-1$
Level 1

Analysis



Analysis
Synthesis
Level *L*
smooth,
downsample
Details *L*
upsample
Level *L*-1
Level $L-1$
...
Level 1
smooth,
downsample
Details 1
upsample
Level 0

Coarser Level Generation



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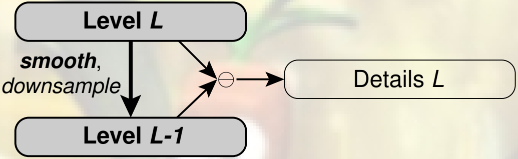
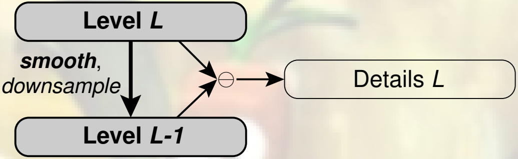
Coarser Level Generation



- MLS surfaces $\Rightarrow$ smoothing by MLS projection

Coarser Level Generation



- MLS surfaces $\Rightarrow$ smoothing by MLS projection
- Downsample point set before projection

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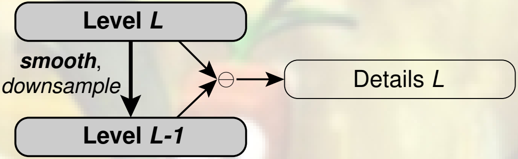
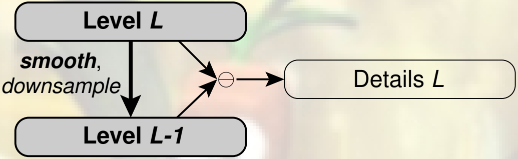
Coarser Level Generation



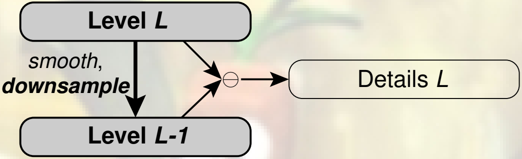
- MLS surfaces $\Rightarrow$ smoothing by MLS projection
- Downsample point set before projection
- Similar to [Pauly+ 06], but constant downsampling factor

Coarser Level Generation



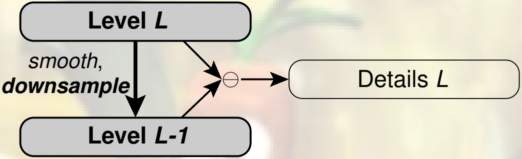
- MLS surfaces $\Rightarrow$ smoothing by MLS projection
- **Downsample** point set before projection
- Similar to [Pauly+ 06], but constant **downsampling** factor

Coarser Level Generation



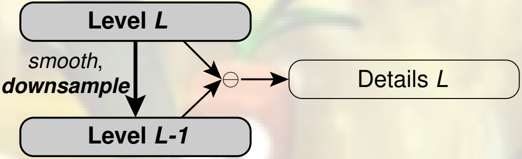
- Downsampling: same as smoothing

Coarser Level Generation



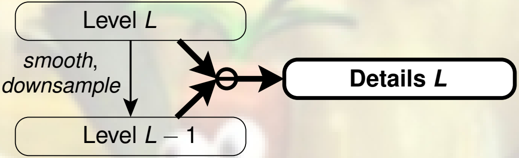
- Downsampling: same as smoothing
- However:

Coarser Level Generation



- Downsampling: same as smoothing
- However: 
- Add extra refinement step using heuristics based on k-neighborhood analysis

Detail Extraction



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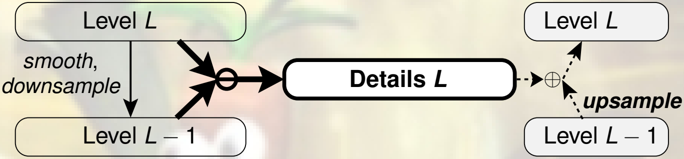
Detail Extraction



- Main difficulty: represent detail information coherently with upsampling procedure

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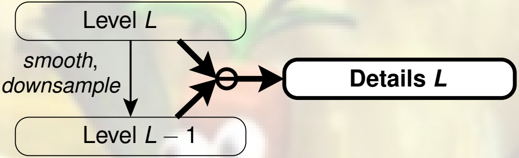
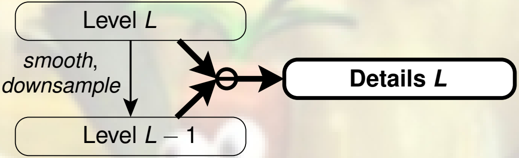
Detail Extraction



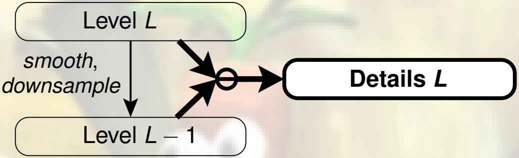
- Main difficulty: represent detail information coherently with upsampling procedure
- Meshes profit from explicit connectivity information

Detail Extraction



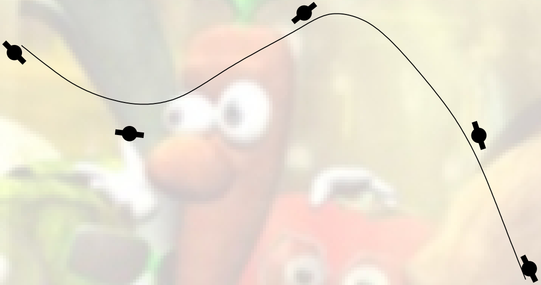
- Main difficulty: represent detail information coherently with upsampling procedure
- Meshes profit from explicit connectivity information
- [Linsen-Prautzsch 03]: store full k-neighborhood

Detail Extraction



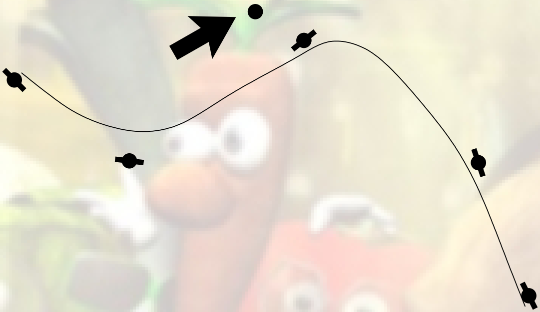
- Main difficulty: represent detail information coherently with upsampling procedure
- Meshes profit from explicit connectivity information
- [Linsen-Prautzsch 03]: store full k-neighborhood
- Intrinsic reformulation [Boubekeur+ 07]

Extraction Procedure



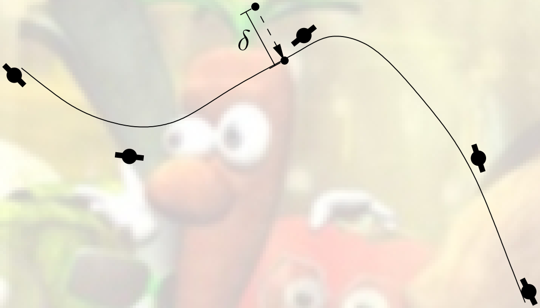
Level $L - 1$

Extraction Procedure



Point from level L

Extraction Procedure



1. Project on level $L - 1$
   δ = geometric detail information

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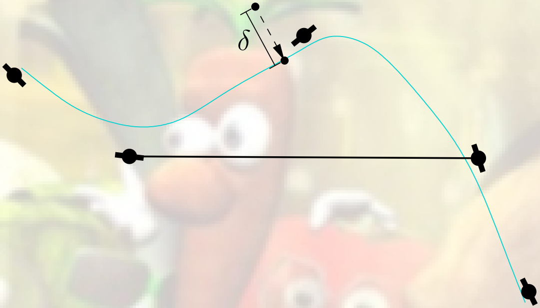
Extraction Procedure



1. Project on level $L-1$
2. Find a *surrounding* triangle

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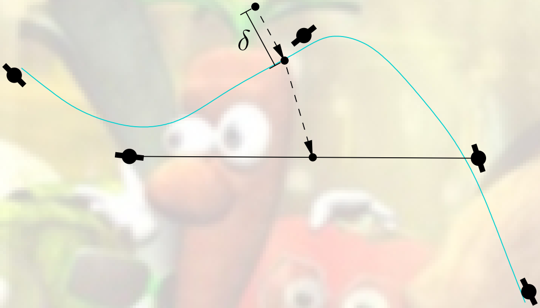
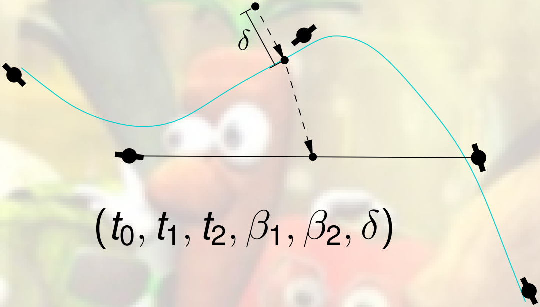
Extraction Procedure



1. Project on level $L - 1$
2. Find a *surrounding* triangle
3. Reformulate projection relative to the triangle

Extraction Procedure



$$(t_0, t_1, t_2, \beta_1, \beta_2, \delta)$$

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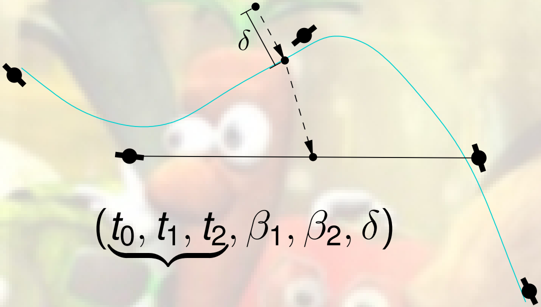

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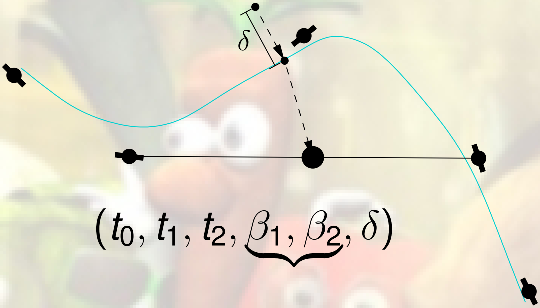

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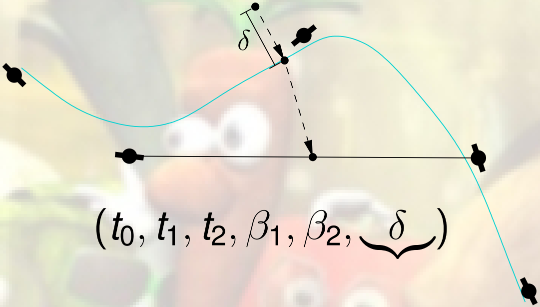

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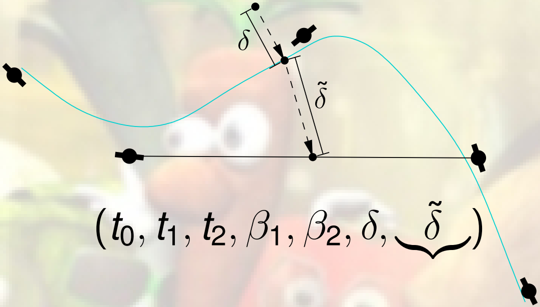
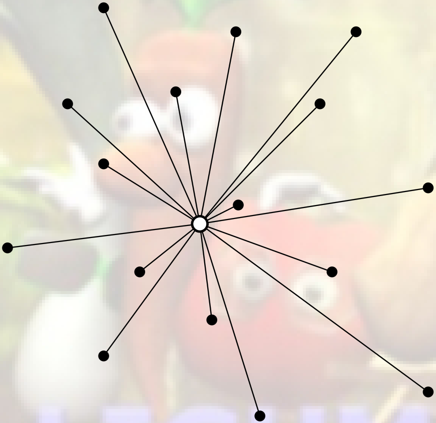


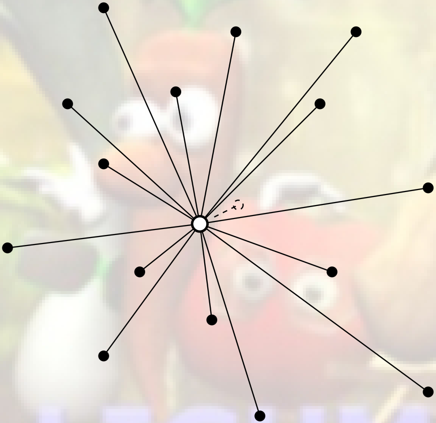
$$(t_0, t_1, t_2, \beta_1, \beta_2, \delta, \underbrace{\tilde{\delta}})$$

1. Project on level $L - 1$
2. Find a *surrounding* triangle
3. Reformulate projection relative to the triangle

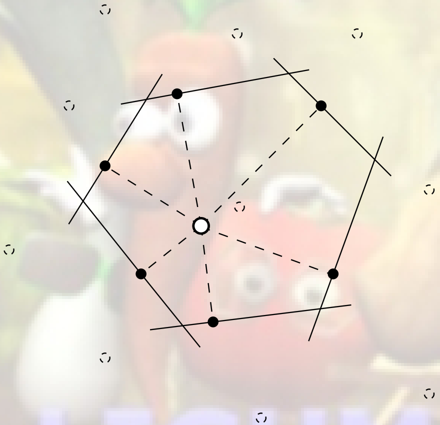
Triangle selection



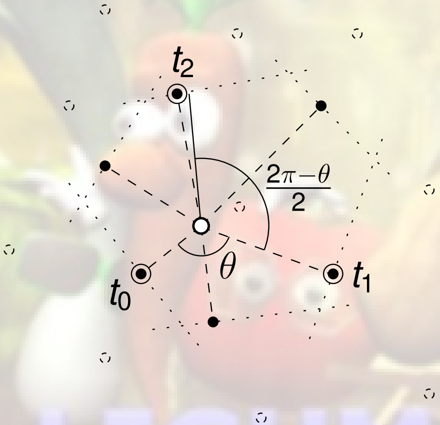
Triangle selection



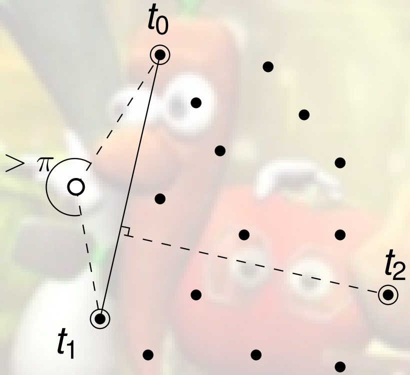
Triangle selection



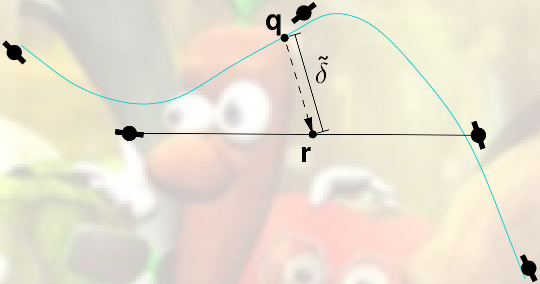
Triangle selection



Triangle selection



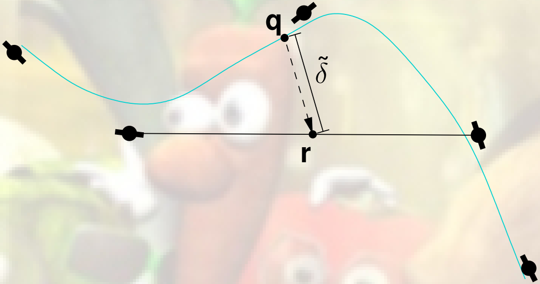
Reformulation



- Find a point **r** on the triangle such that $\mathbf{q} = \mathbf{r} + \tilde{\delta}\mathbf{n}(\mathbf{r})$ for some $\tilde{\delta}$

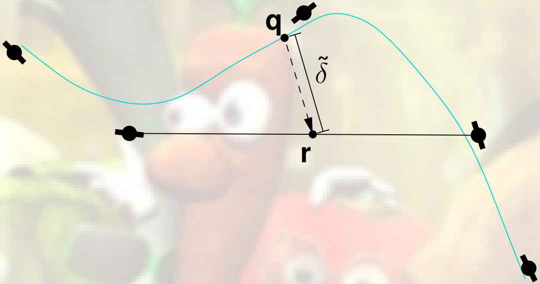
  $(\mathbf{n}(\mathbf{r}) =$ normal estimation at $\mathbf{r})$

Reformulation



- Find a point **r** on the triangle such that $\mathbf{q} = \mathbf{r} + \tilde{\delta}\mathbf{n}(\mathbf{r})$ for some $\tilde{\delta}$
- Iterative procedure (gory details in the paper)

Reformulation



- Find a point **r** on the triangle such that $\mathbf{q} = \mathbf{r} + \tilde{\delta}\mathbf{n}(\mathbf{r})$ for some $\tilde{\delta}$
- Iterative procedure
- β_1, β_2 computed from **r**

Outline

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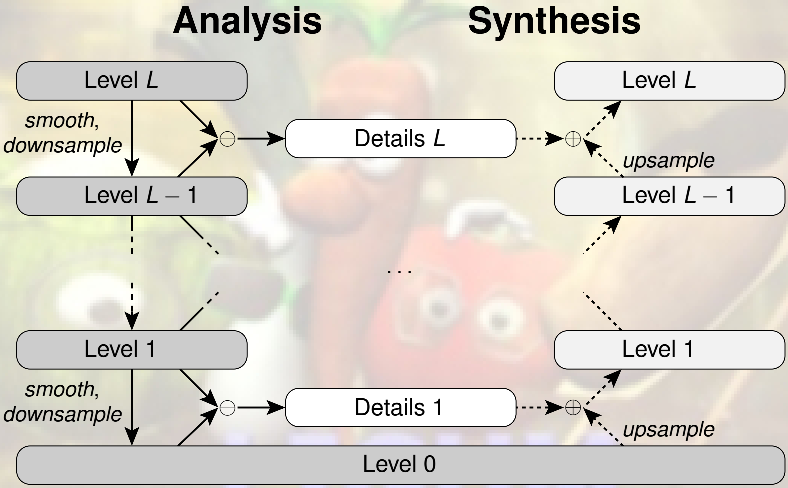
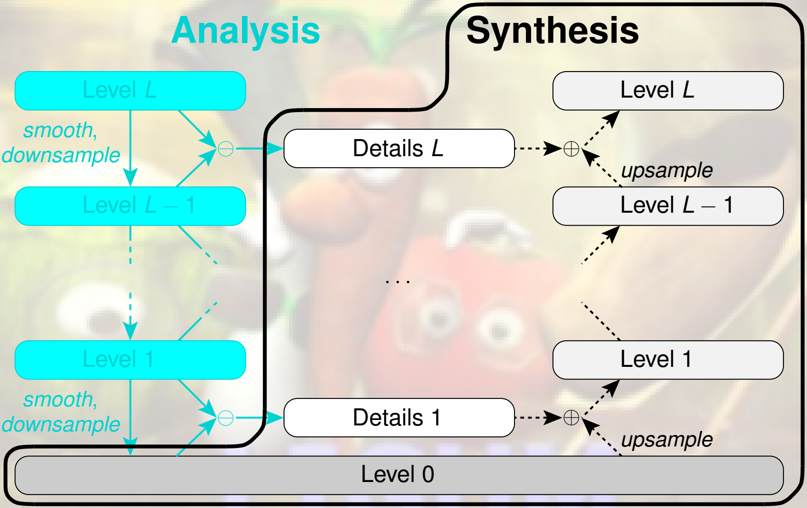
Synthesis


Analysis
Synthesis
Level L
smooth,
downsample
Level $L-1$
Details L
upsample
Level L
Level $L-1$
...
Level 1
smooth,
downsample
Details 1
upsample
Level 1
Level 0

Synthesis


Analysis
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Level L
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Level 1
smooth,
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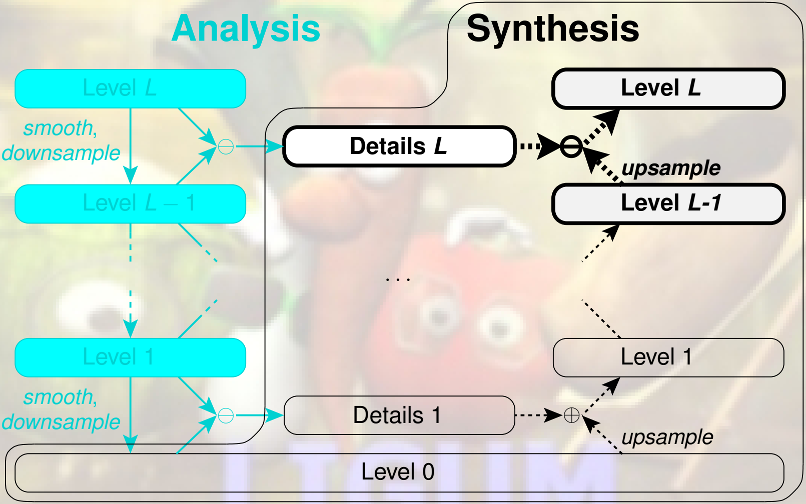
Details L
Details 1
Level L
upsample
Level $L-1$
. . .
Level 1
upsample
Level 0

Synthesis


Analysis
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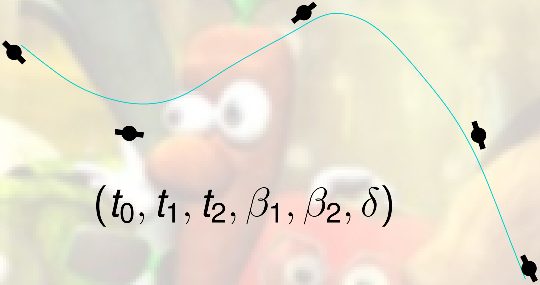
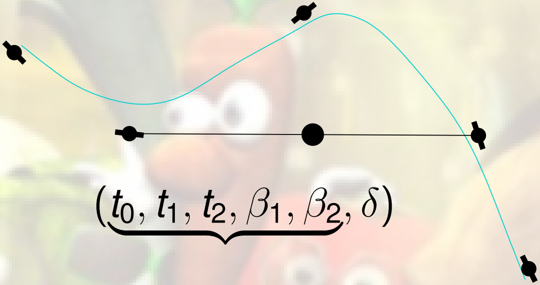
Level 1
smooth,
downsample
Details L
...
Details 1
Level 0
Level L
upsample
Level L-1
Level 1
upsample

Synthesis Procedure



$$(t_0, t_1, t_2, \beta_1, \beta_2, \delta)$$

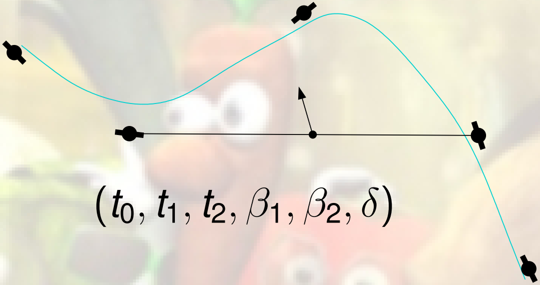
Synthesis Procedure



$$(\underbrace{t_0, t_1, t_2, \beta_1, \beta_2}, \delta)$$

1. Compute base position

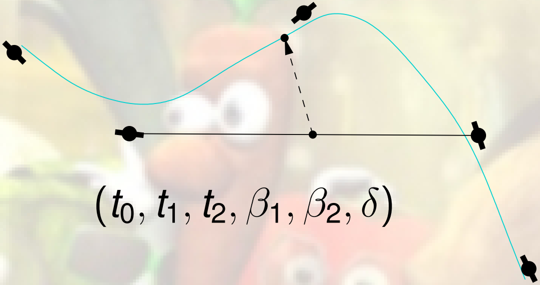
Synthesis Procedure



$$(t_0, t_1, t_2, \beta_1, \beta_2, \delta)$$

1. Compute base position
2. Estimate normal direction at base position

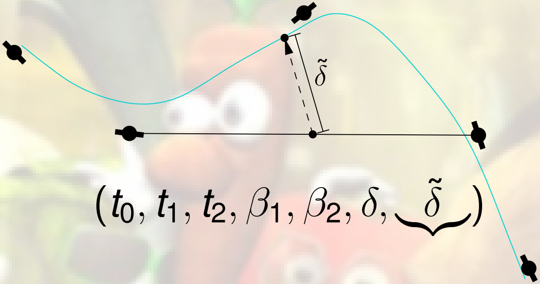
Synthesis Procedure



$$(t_0, t_1, t_2, \beta_1, \beta_2, \delta)$$

1. Compute base position
2. Estimate normal direction at base position
3. Intersect ray with surface (simplification of [Adamson-Alexa 04])

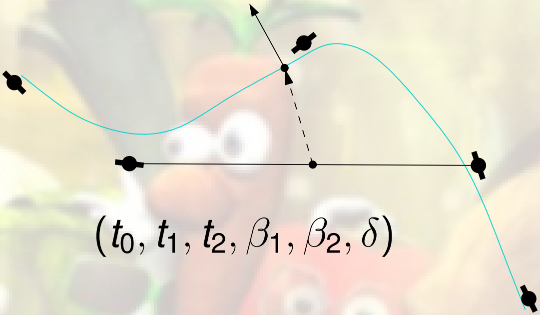
Synthesis Procedure



$$(t_0, t_1, t_2, \beta_1, \beta_2, \delta, \underbrace{\tilde{\delta}})$$

1. Compute base position
2. Estimate normal direction at base position
3. Intersect ray with surface
   (fast estimation with $\tilde{\delta}$)

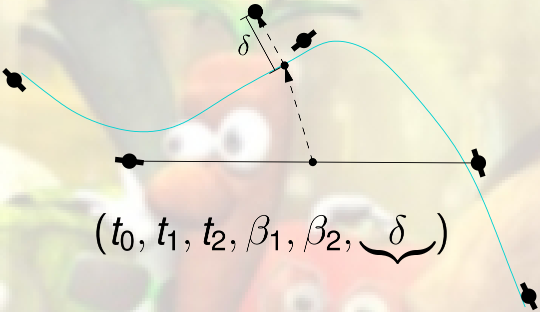
Synthesis Procedure



$$(t_0, t_1, t_2, \beta_1, \beta_2, \delta)$$

1. Compute base position
2. Estimate normal direction at base position
3. Intersect ray with surface
4. Estimate normal direction at intersection

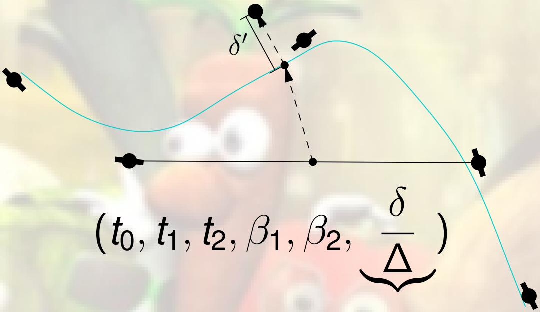
Synthesis Procedure



$$(t_0, t_1, t_2, \beta_1, \beta_2, \underbrace{\delta})$$

2. Estimate normal direction at base position
3. Intersect ray with surface
4. Estimate normal direction at intersection
5. Displace by δ

Synthesis Procedure

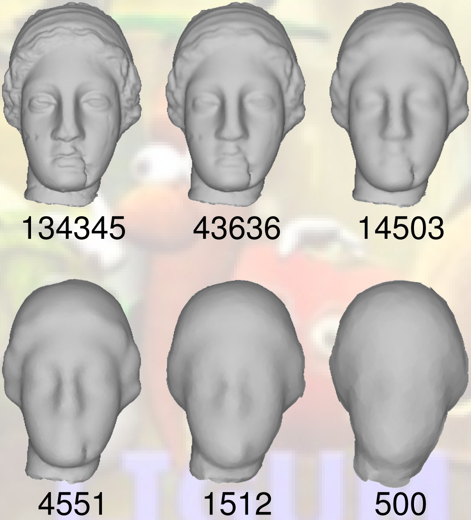


$$\left(t_0, t_1, t_2, \beta_1, \beta_2, \underbrace{\frac{\delta}{\Delta}}\right)$$

2. Estimate normal direction at base position
3. Intersect ray with surface
4. Estimate normal direction at intersection
5. Displace by $\delta' = \frac{\delta}{\Delta}\Delta'$ [Boubekeur+ 07]

Outline

Igea



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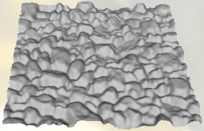
Armadillo

172974 48312 15218 6510

Bumps



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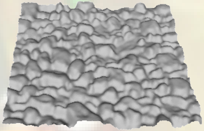

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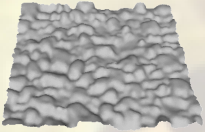
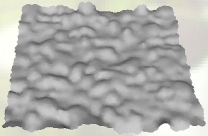
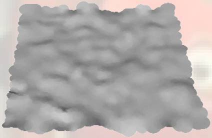


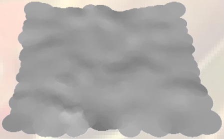
10395



3583

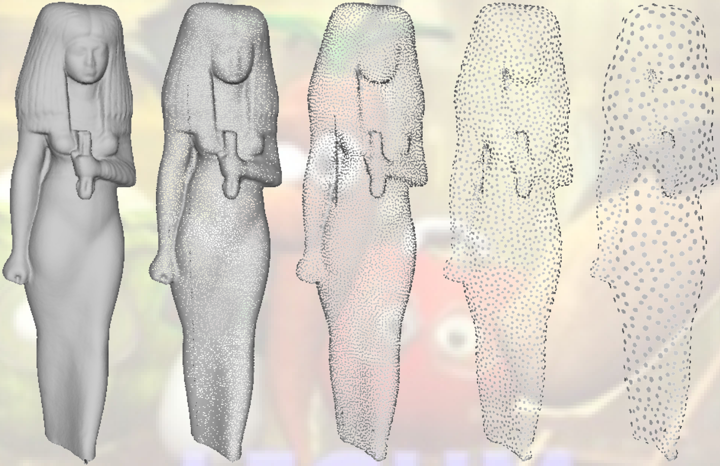


1140



374

Isis

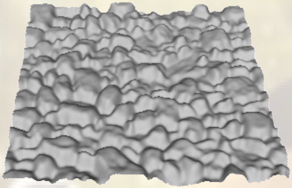


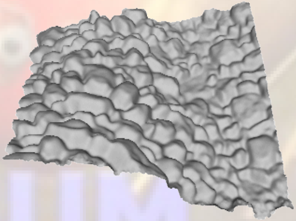
196256 53883 14953 4368 1600

Statistics

	Analysis	Synthesis	RMS error
Igea	27.4 / 60.1	7.6 / 12.2	2.64×10^{-4}
Armadillo	137.4 / —	9.5 / —	9.5×10^{-5}
Bumps	17.9 / 36.7	5.0 / 6.1	4.90×10^{-4}
Isis	39.9 / 67.3	10.5 / 14.4	1.75×10^{-4}

Deformation





Detail Emphasis

Université de Montréal

Outline

LIGUM

Conclusion

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- No connectivity information can be a pain
- Multiresolution point-set surfaces
  - Verify special conditions when downsampling
  - Detail information with partial topology information

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Future Work

- ... there is hope:
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