Reconstruction of Sculptured Shapes using Subdivision Surfaces in I-deas NX

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Agenda

- Company brief
- Motivation
- Meshing
- Geometric subdivision
- Process flow diagram
- Data and head scan example
- Why Ideas-NX?
- Few reconstruction examples
- References
- Further learning

Company Brief

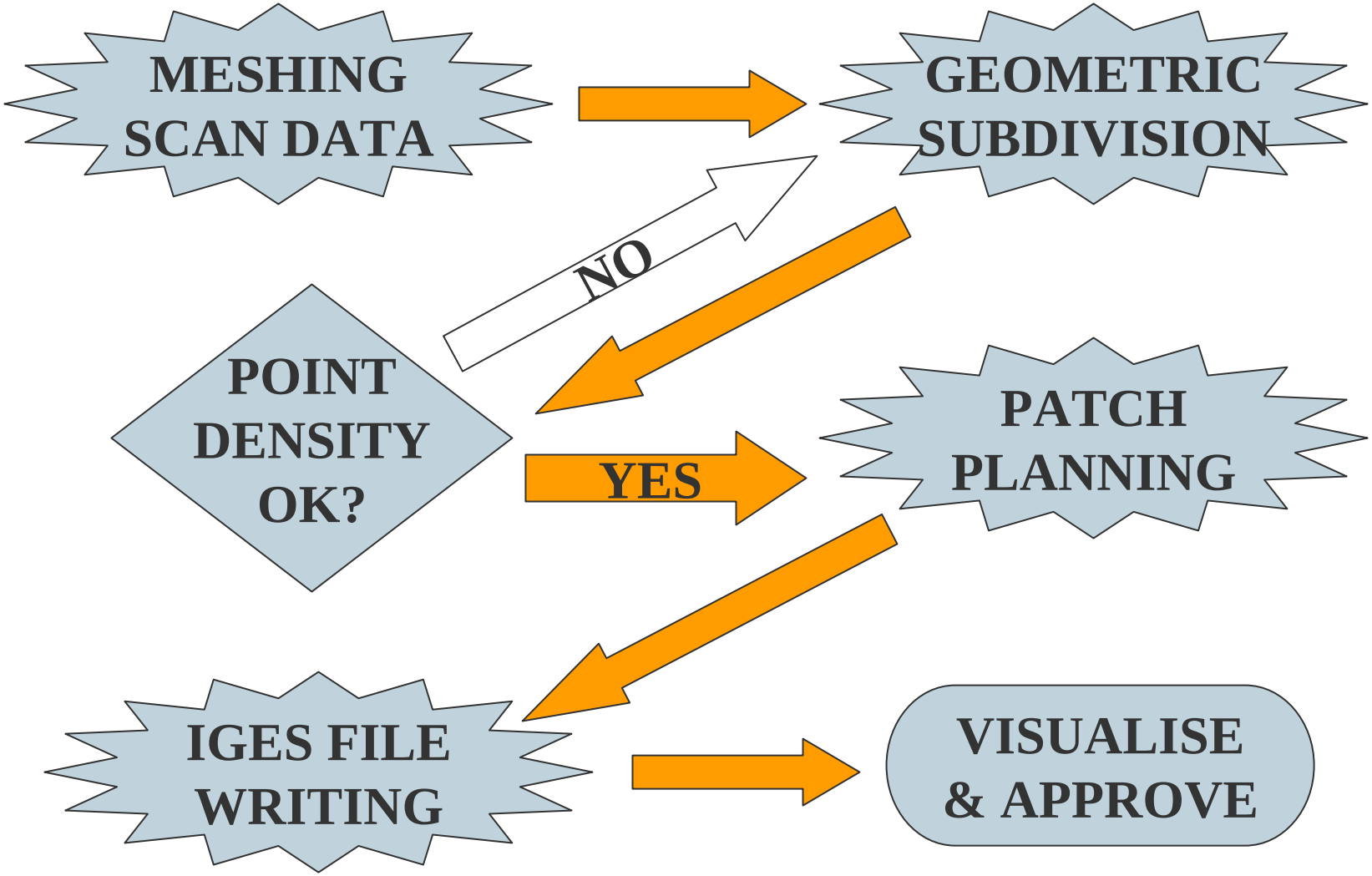
Tata Technologies Limited is

1. headquartered in Pune, India
2. offices in US, Europe and the Asia Pacific
3. specialised provider of strategic Engineering and Design (E&D) services and
4. an Engineering Process Outsource (EPO) hub for Global 500 and large domestic manufacturers especially automotive and aerospace majors
5. “trusted by the world”s leading manufacturers to provide continuing best-in-class services in IT enabled Engineering, Design, and Manufacturing,
6. employer of choice for the most capable talent in our industry.

Motivation

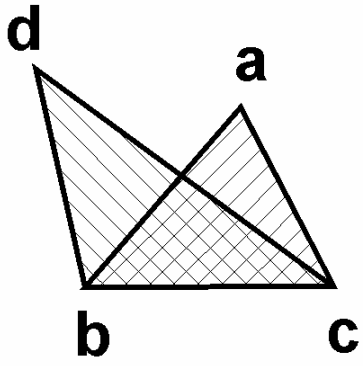
- More control on shape to reconstruct accurate shape
- Good understanding of classical CAGD techniques in NURBS area
- Good understanding of subdivision techniques to handle typical sculptured shapes
- In-depth understanding of subdivision surfaces reconstruction
- Ability to write IGES Interface files for NURBS surfaces

Process Flow Diagram

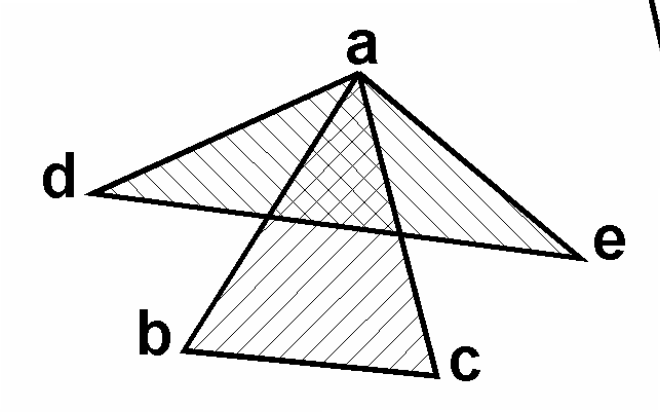


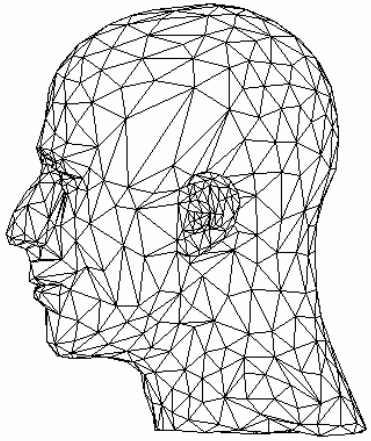
Meshing - problems

- Convex Hull

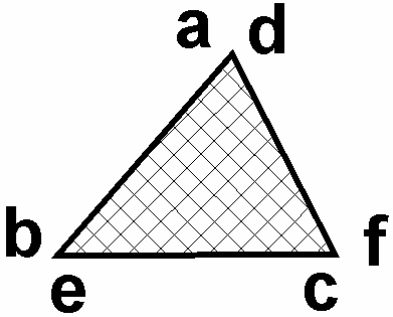


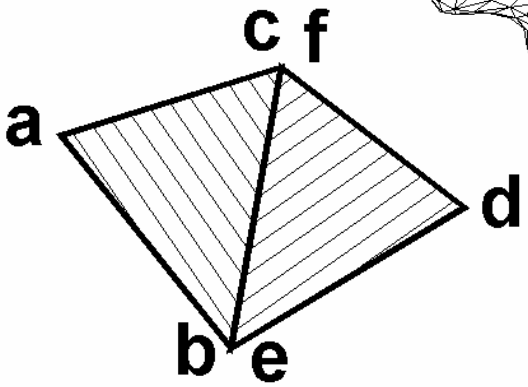
- Encroachment





- Duplicate

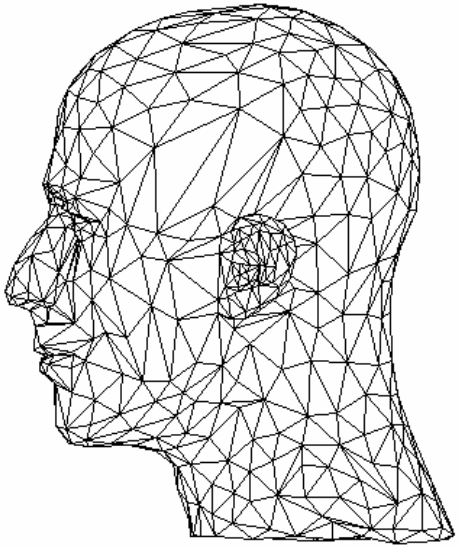




- Ideal

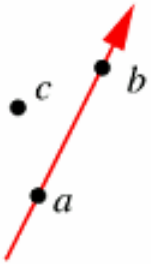
Meshing – tools (conventional)

- Fast robust floating point geometric predicates



Orientation

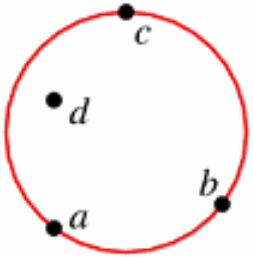
Does c lie on, to the left of, or to the right of $\overrightarrow{ab}$?



$$\begin{vmatrix} a_x & a_y & 1 \\ b_x & b_y & 1 \\ c_x & c_y & 1 \end{vmatrix} = \begin{vmatrix} a_x - c_x & a_y - c_y \\ b_x - c_x & b_y - c_y \end{vmatrix}$$

Incircle

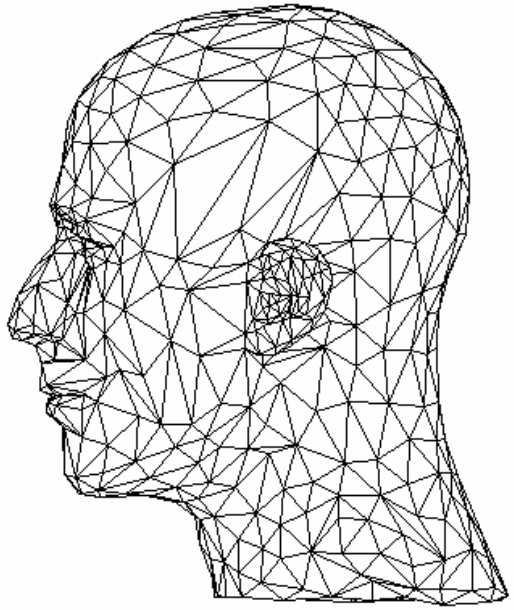
Does d lie on, inside, or or outside of abc?

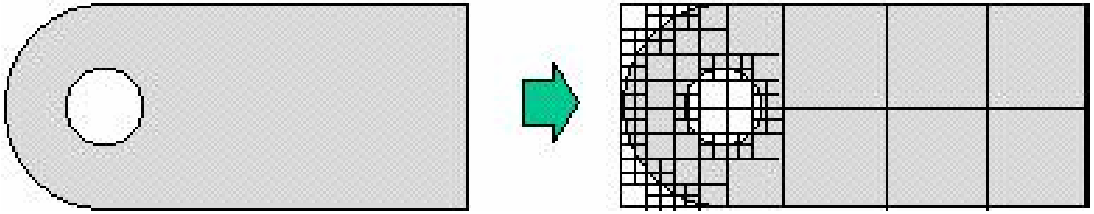


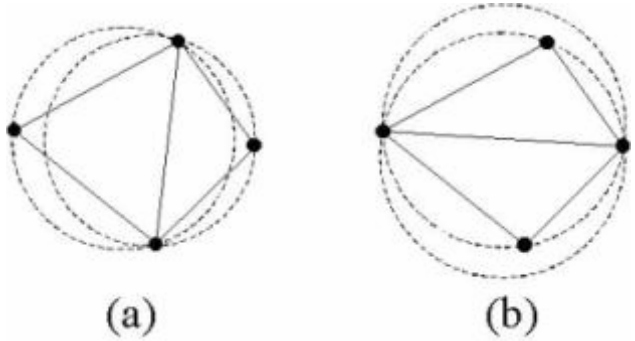
$$\begin{vmatrix} a_x & a_y & a_x^2 + a_y^2 & 1 \\ b_x & b_y & b_x^2 + b_y^2 & 1 \\ c_x & c_y & c_x^2 + c_y^2 & 1 \\ d_x & d_y & d_x^2 + d_y^2 & 1 \end{vmatrix} = \begin{vmatrix} a_x - d_x & a_y - d_y & (a_x - d_x)^2 + (a_y - d_y)^2 \\ b_x - d_x & b_y - d_y & (b_x - d_x)^2 + (b_y - d_y)^2 \\ c_x - d_x & c_y - d_y & (c_x - d_x)^2 + (c_y - d_y)^2 \end{vmatrix}$$

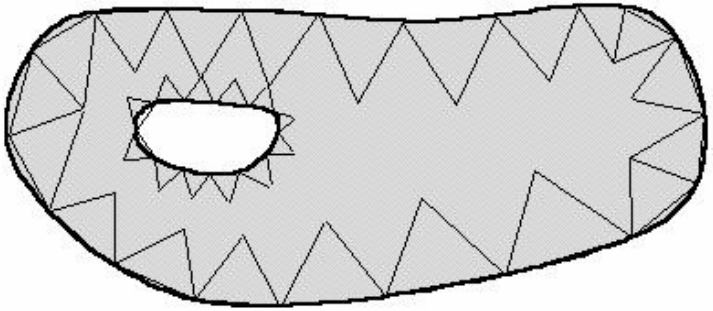
Meshing – Conventional techniques

- Octree
- Delaunay
- Advancing Front



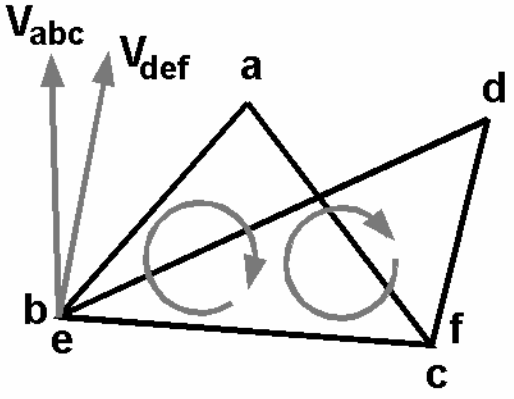


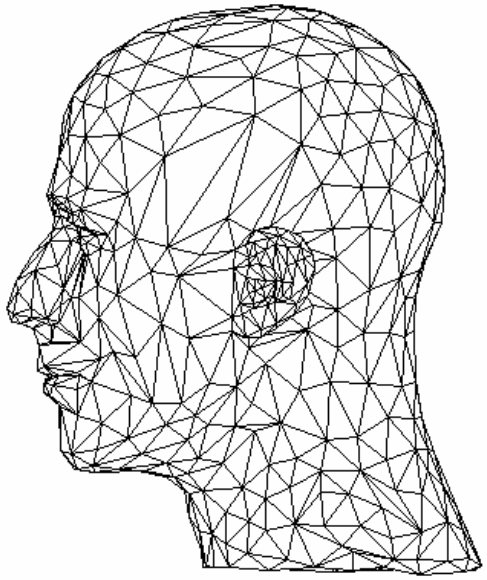


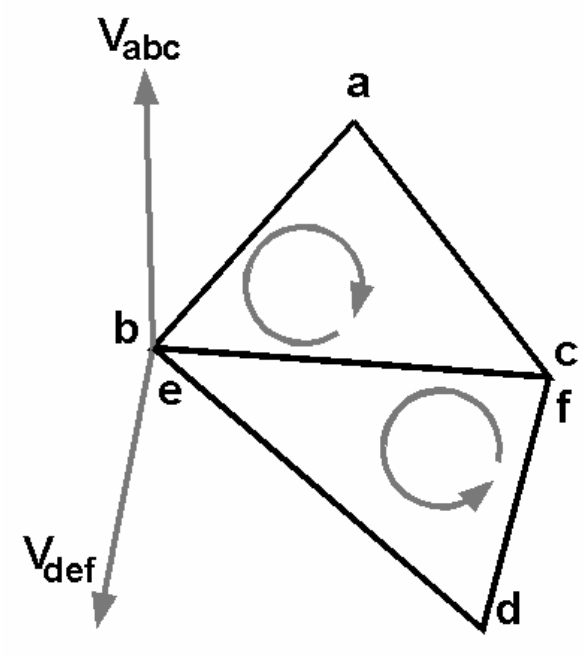


Meshing – tools (our approach)

- A variant of Advancing Front has been adopted
- To detect convex hull, compared vector cross products in adjacent triangles

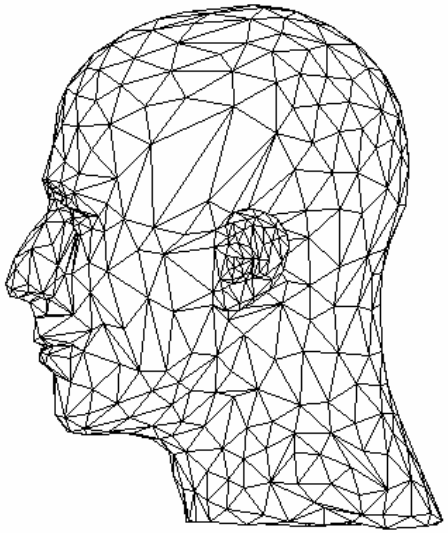


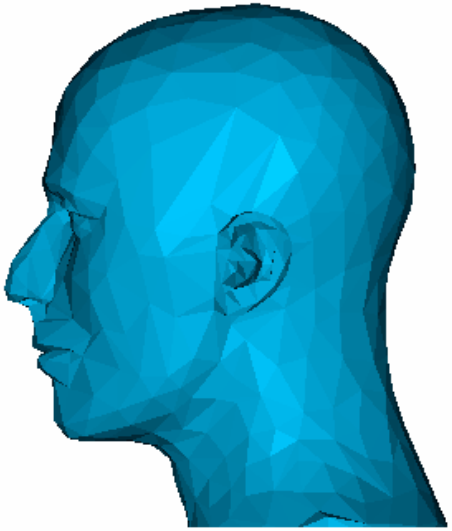


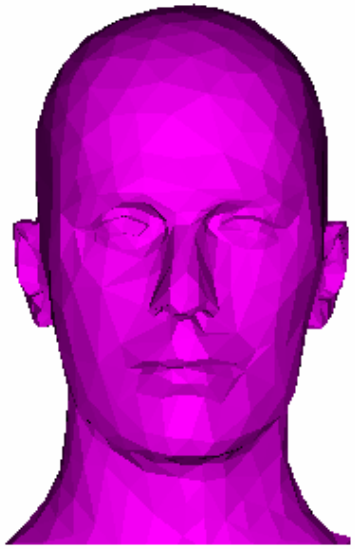


Meshing

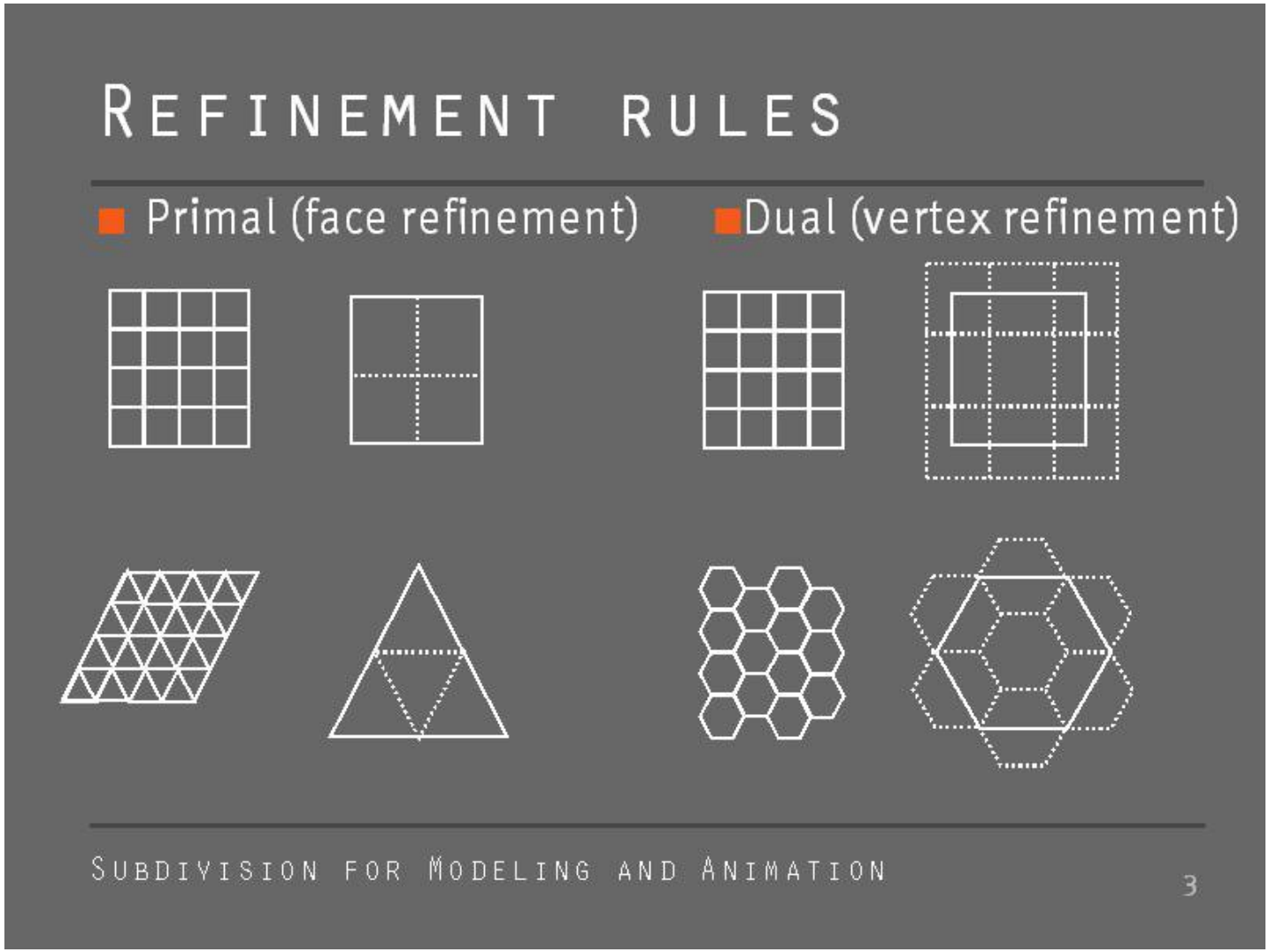
- Head scan point data
- First level of meshing
- Faceted representation of sculptured geometry







Geometric Subdivision refinement rules



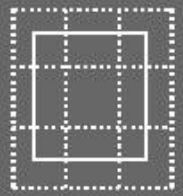
Subdivision Schemes

Subdivision Schemes

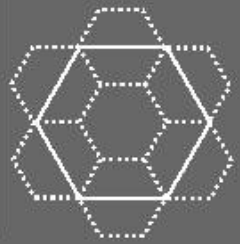
- Primal (vertex insertion)

	Approximating	Interpolating
	Catmull-Clark	Kobbelt
	Loop	Butterfly

- Dual (corner cutting)



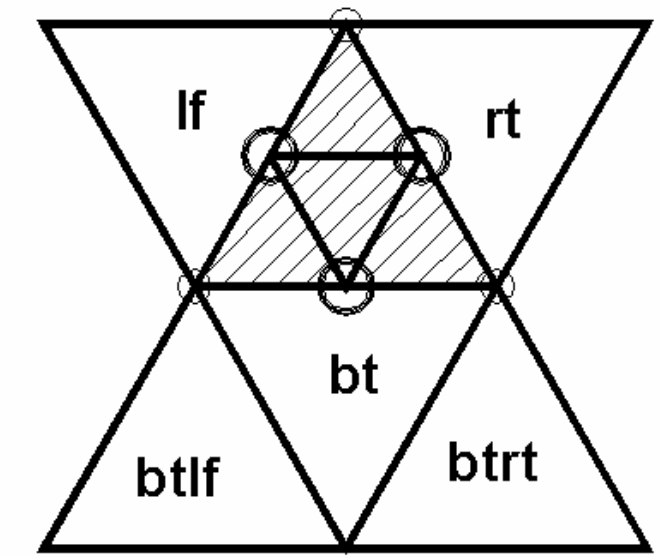
Doo-Sabin, Midedge



Dyn-Levin-Liu (non-linear)

Subdivision – Data Structure (Head Scan)

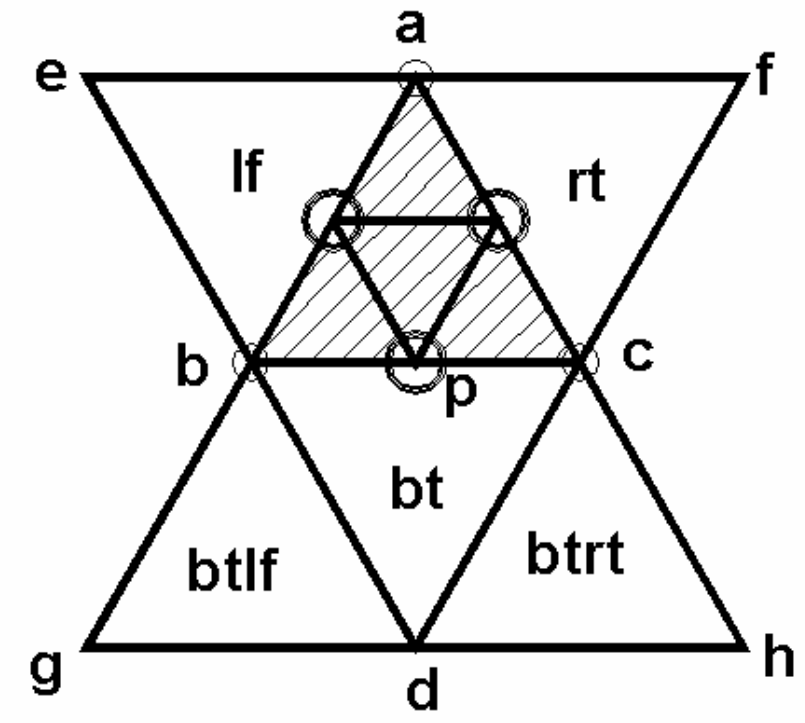
```
struct point {
  double x,y,z;
} pts1[400000];
```




```
struct triangle {
   double x1,y1,z1,x2,y2,z2,x3,y3,z3;
    int rt, lf, bt, btrt, btlf;
} tgl_init[1400], tgl[100000];
```

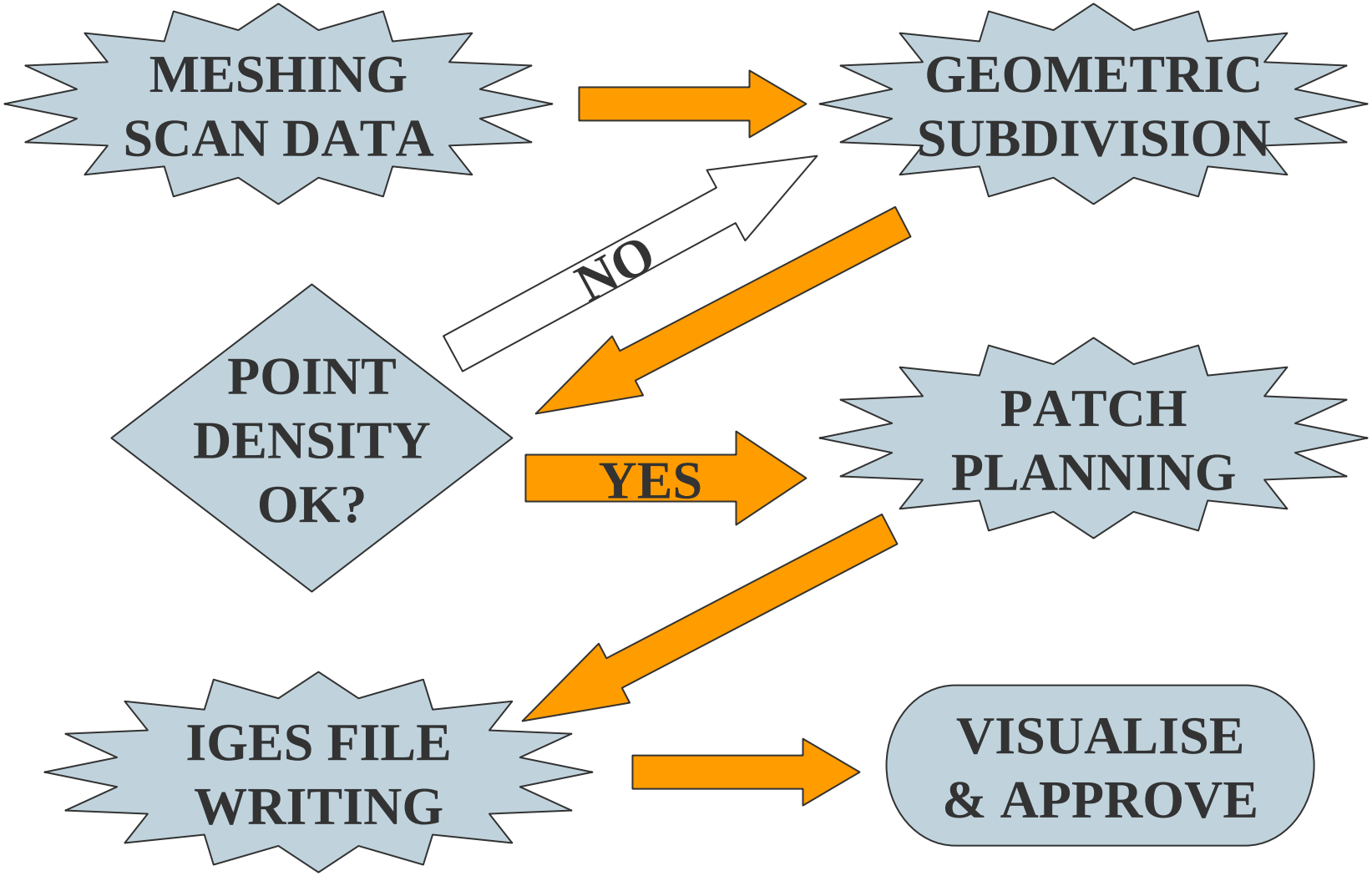
Subdivision Schemes - Butterfly

- d = op_point (b,c,a)
- e = op_point (a,b,c)
- f = op_point (a,c,b)
- g = op_point (b,d,c)
- h = op_point (c,d,b)



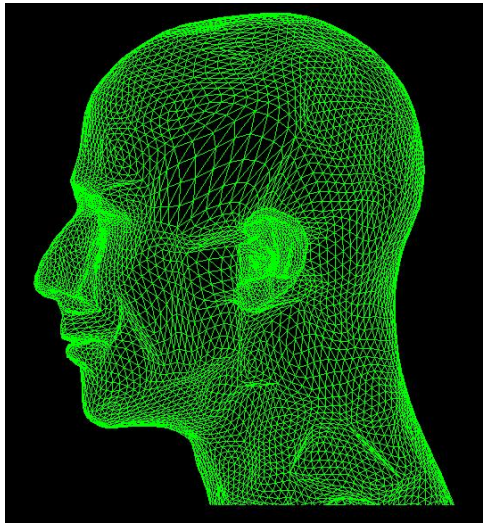

```
point newpt (point a,point b,point c,point d){
    point p;
    p.x=3.0/8.0*(b.x+c.x)+(a.x+d.x)/8.0;
    p.y=3.0/8.0*(b.y+c.y)+(a.y+d.y)/8.0;
    p.z=3.0/8.0*(b.z+c.z)+(a.z+d.z)/8.0;
    return p;
}
```

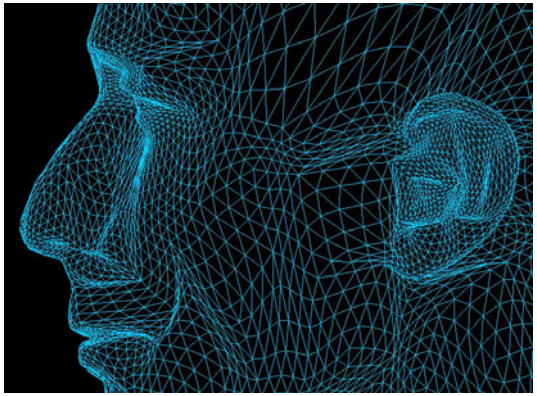
Process Flow Diagram

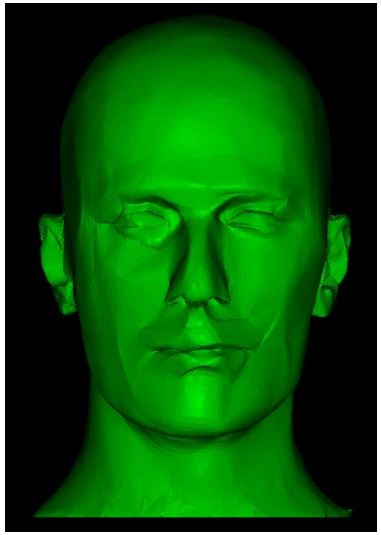


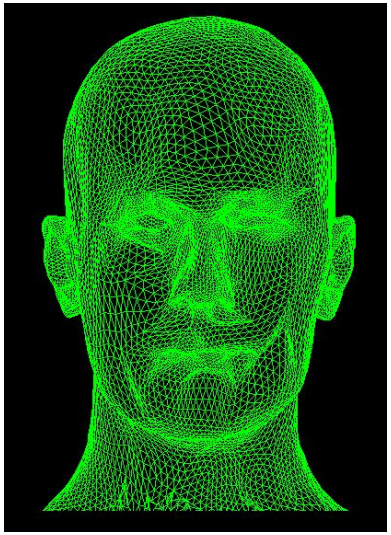
Subdivision –Second Level (Head Scan)

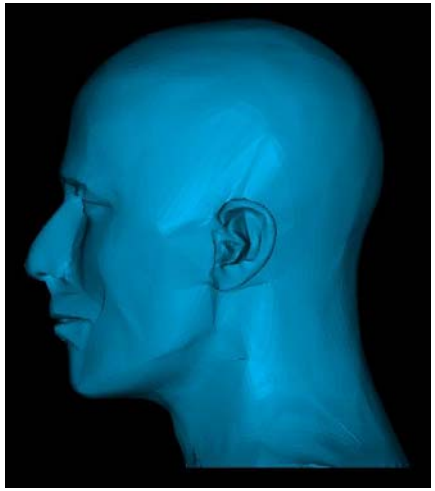
- Stage 0 SD
  - Triangles -1353
  - Points – 689
- Stage 1 SD
  - Triangles -5312
  - Points – 3100
- Stage 2 SD
  - Triangles - 21248
  - Points – 12,400
- Stage 3 SD
  - Triangles – 84992
  - Points – 1,70,000





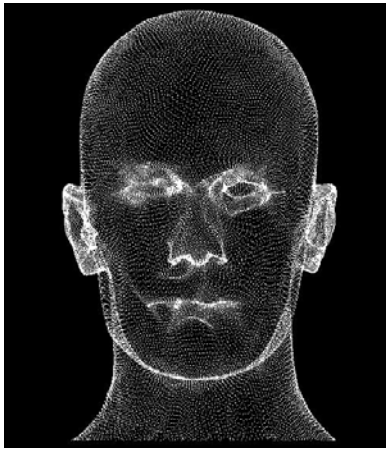
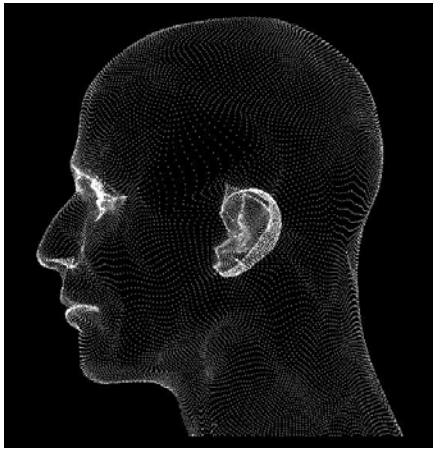
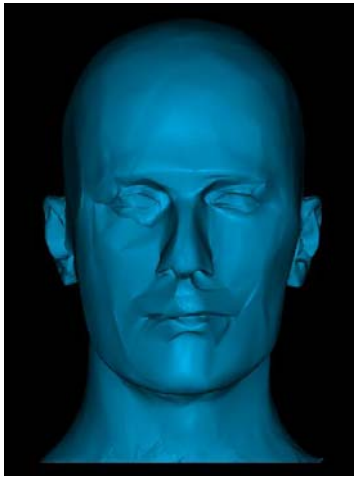
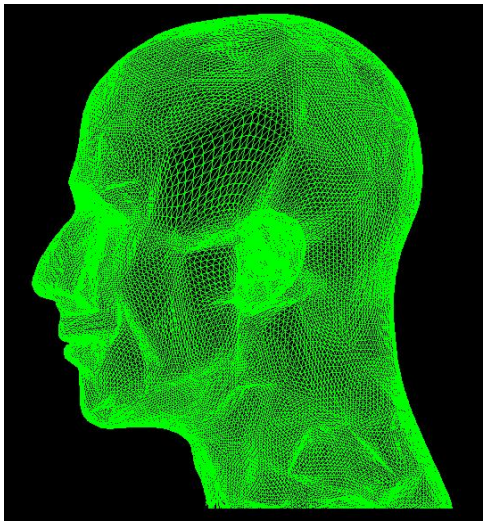
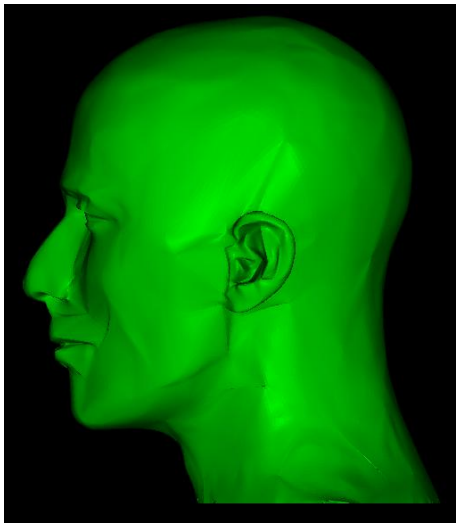






Subdivision – Third Level (Head Scan)

- Stage 1 SD
  - Triangles -5312
  - Points – 3100
- Stage 2 SD
  - Triangles - 21248
  - Points – 12400
- Stage 3 SD
  - Triangles - 84992
  - Points – 170000
- Stage 4 SD
  - Triangles - 339968
  - Points – 680000

Subdivision – Surface IGES file writing

- Start Section
- Global Section
- Directory Entry Section
- Parameter Data Section
  - 128 (IGES Entity Group code for NURBS)
  - Surface Degree, Dimension
  - Knot Vectors, Weight Vectors
  - Bi-directional Control net
- Terminate Section

Subdivision – NURBS Surface IGES file writing

```
                                                                                S0000001
IGES ROUTINE TO DISPLAY SUBDIVISION SURFACE                                     S0000002
IGES ROUTINE TO DISPLAY SUBDIVISION SURFACE                                     S0000003
                                                                                S0000004
,,IGES ENGINE WRITTEN IN TATA TECH.,,,,,,,,,,,2,2HMM,,,,,,,,,,;                  G0000001
     128       1       0       1       0       0       0       0              0D      1
     128       0       5     979       0                                      0D      2
128,37,37,3,3,0,0,1,0,0,0.00,0.00,0.00,0.00,0.03,0.06,                          1P      1
0.09,0.11,0.14,0.17,0.20,0.23,0.26,0.29,0.31,0.34,0.37,                         1P      2
0.40,0.43,0.46,0.49,0.51,0.54,0.57,0.60,0.63,0.66,0.69,                         1P      3
0.71,0.74,0.77,0.80,0.83,0.86,0.89,0.91,0.94,0.97,1.00,                         1P      4
1.00,1.00,1.00,0.00,0.00,0.00,0.00,0.03,0.06,0.09,0.11,                         1P      5
0.14,0.17,0.20,0.23,0.26,0.29,0.31,0.34,0.37,0.40,0.43,                         1P      6
0.46,0.49,0.51,0.54,0.57,0.60,0.63,0.66,0.69,0.71,0.74,                         1P      7
0.77,0.80,0.83,0.86,0.89,0.91,0.94,0.97,1.00,1.00,1.00,                         1P      8
1.00,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,                           1P      9
1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,                    1P     10
1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,                    1P     11
1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,                    1P     12
1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,                    1P     13
1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,                    1P     14

251.366000,162.567000,436.152000,251.123000,160.523000,                         1P    113
439.493000,251.293000,157.310000,443.281000,251.662000,                         1P    114
154.654000,445.983000,251.618000,151.928000,450.378000,                         1P    115
251.222000,150.913000,453.838000,251.756000,148.554000,                         1P    116
457.399000,251.731000,147.678000,461.281000,251.755000,                         1P    117
147.162000,464.924000,251.809000,146.958000,468.430000,                         1P    118
251.802000,147.079000,471.955000,251.753000,147.505000,                         1P    119
475.480000,251.384000,148.630000,479.750000,251.758000,                         1P    120
148.634000,483.903000,251.682000,148.920000,486.839000,                         1P    121
251.603000,148.842000,490.916000,251.712000,147.951000,                         1P    122
494.461000,251.412000,146.931000,497.933000,251.254000,                         1P    123
146.388000,501.772000,251.446000,145.998000,505.187000,                         1P    124
251.901000,145.472000,509.307000,251.431000,146.839000,                         1P    125
513.097000,251.523000,147.052000,516.546000,251.666000,                         1P    126
147.133000,519.945000,251.405000,147.867000,523.858000,                         1P    127

S      4G      1D      2P     979                                               T      1
```

START SECTION

GLOBAL SECTION

DIRECTORY ENTRY SECTION

PARAMETER DATA SECTION

Knot Vectors

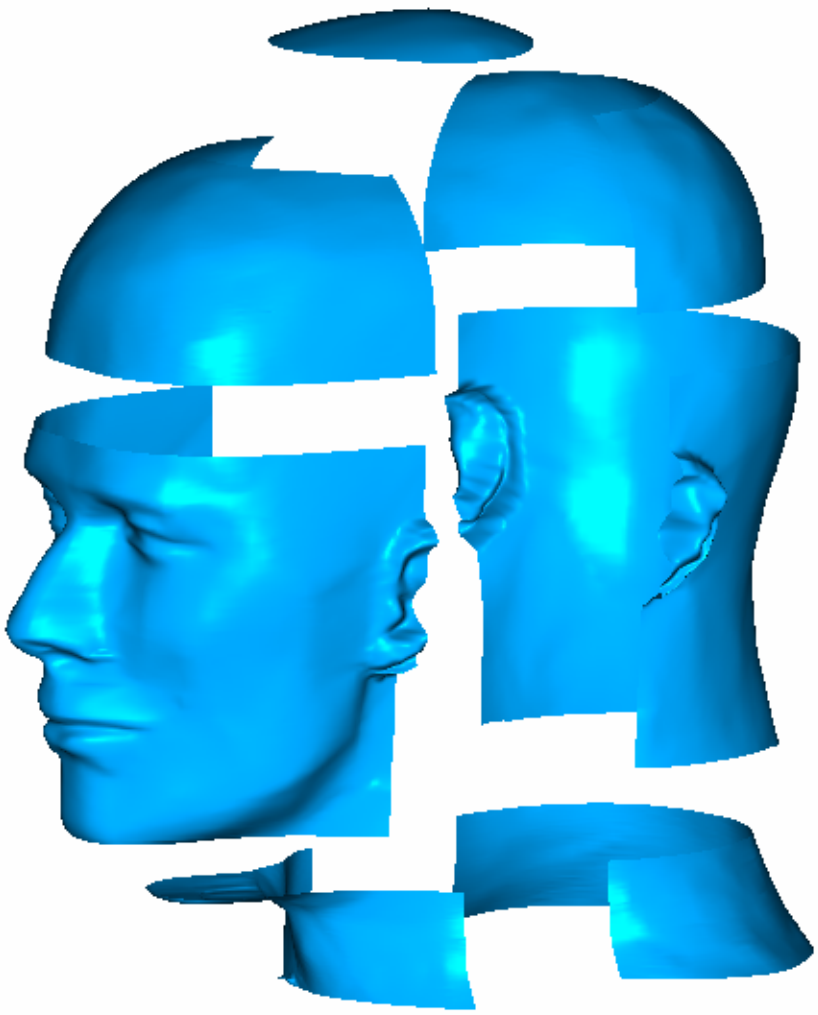
Weight Vectors

Bi-directional Control Net

TERMINATE SECTION

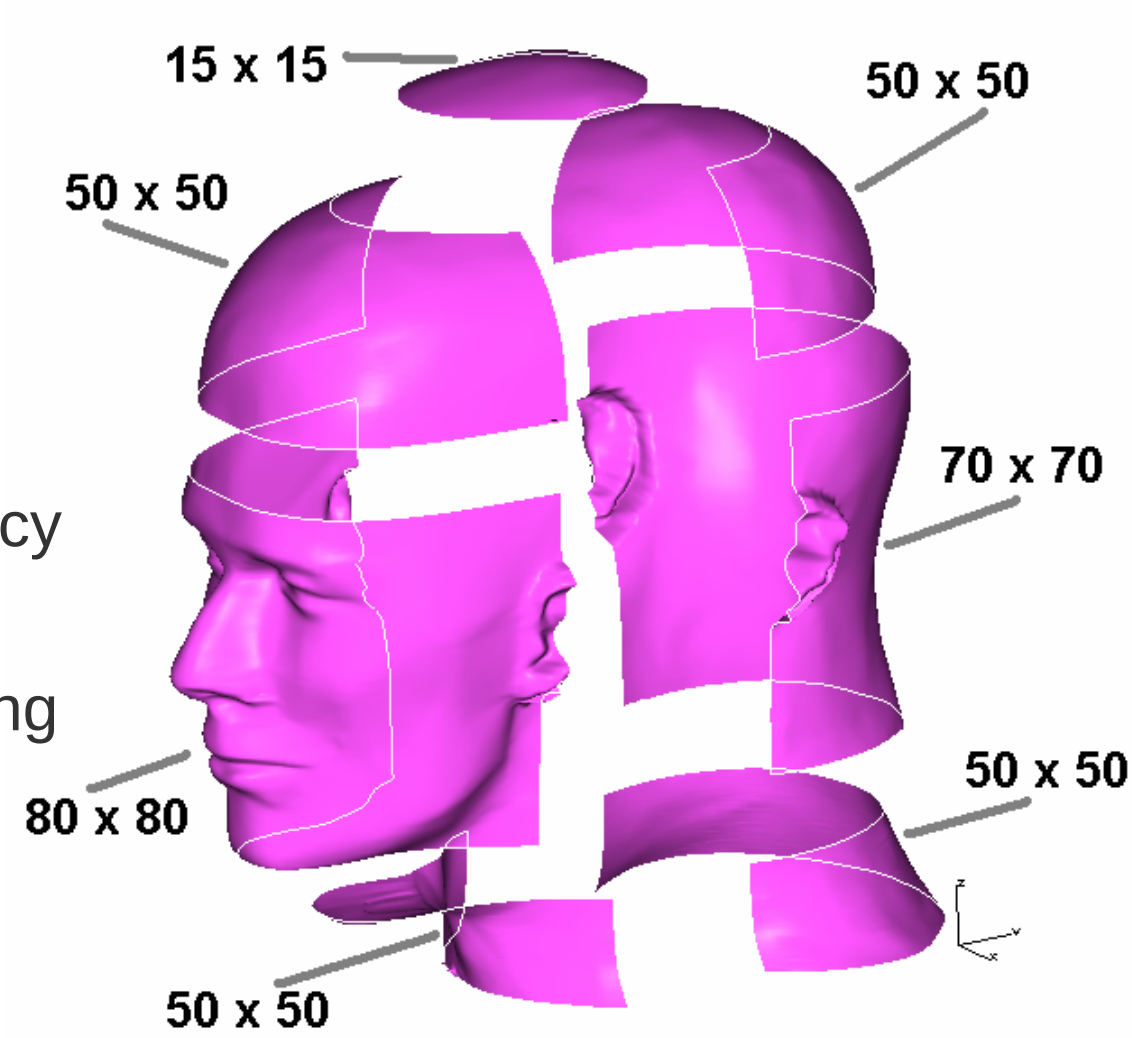
Subdivision – Patch Planning

- Four reconstruction regions
  - Neck
  - Face
  - Forehead
  - Top
- Decided Logical Center
- Decided Z-levels
- Decided view angles
- Decided patch type
  - Flat
  - Rotational
- Edge fixing



Subdivision – Patch Planning

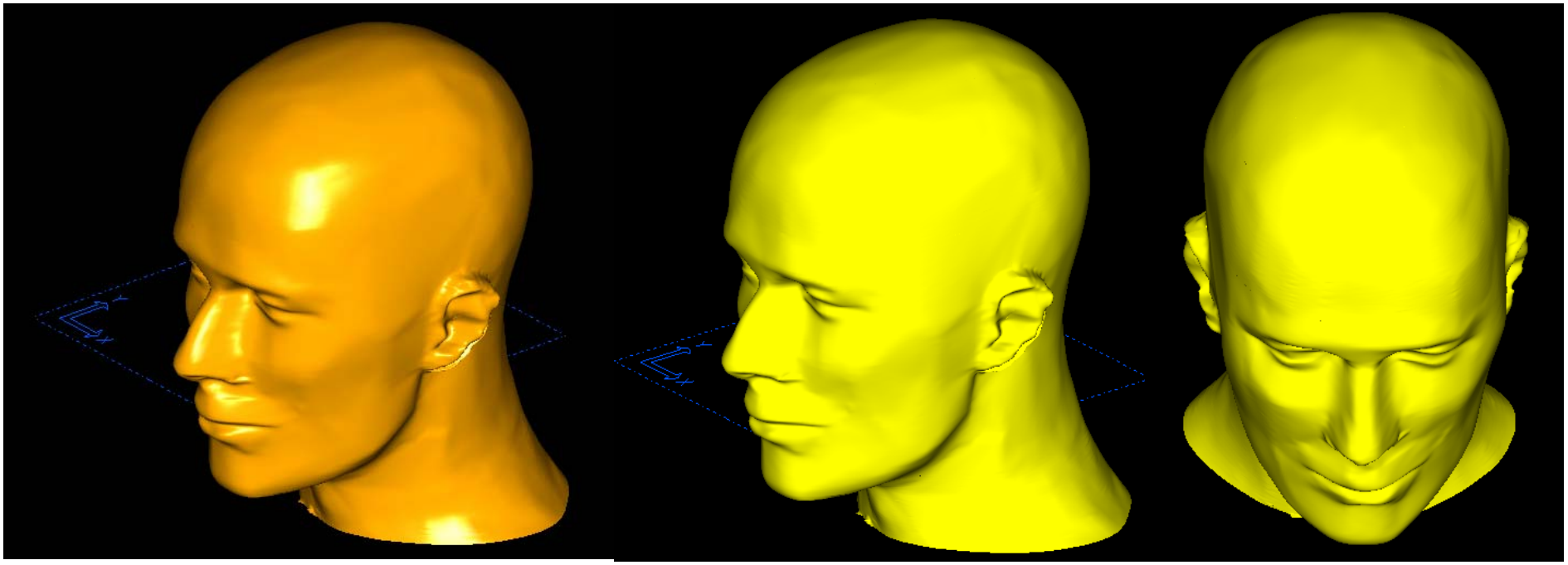
- Geometric complexity
- Control Net Density
- Smooth reconstruction
- Abrupt shape variation
- No overlap
- Adjacent patch tangency
- Patch add for VRML
- Patch coloring & viewing
- Analyze critical zones
- IGES file size
- Files import time



Subdivision Surface – Why I-deas NX

- I-deas Open Programming
  - To view point cloud in subdivision stages
  - To view faceted model (tessellated)
  - To check point density in subdivision stages
- Single IGES import to view IGES patches
- Multiple IGES import to view head model
- Check surface quality (Visual)
- Preparing WRL (VRML) file

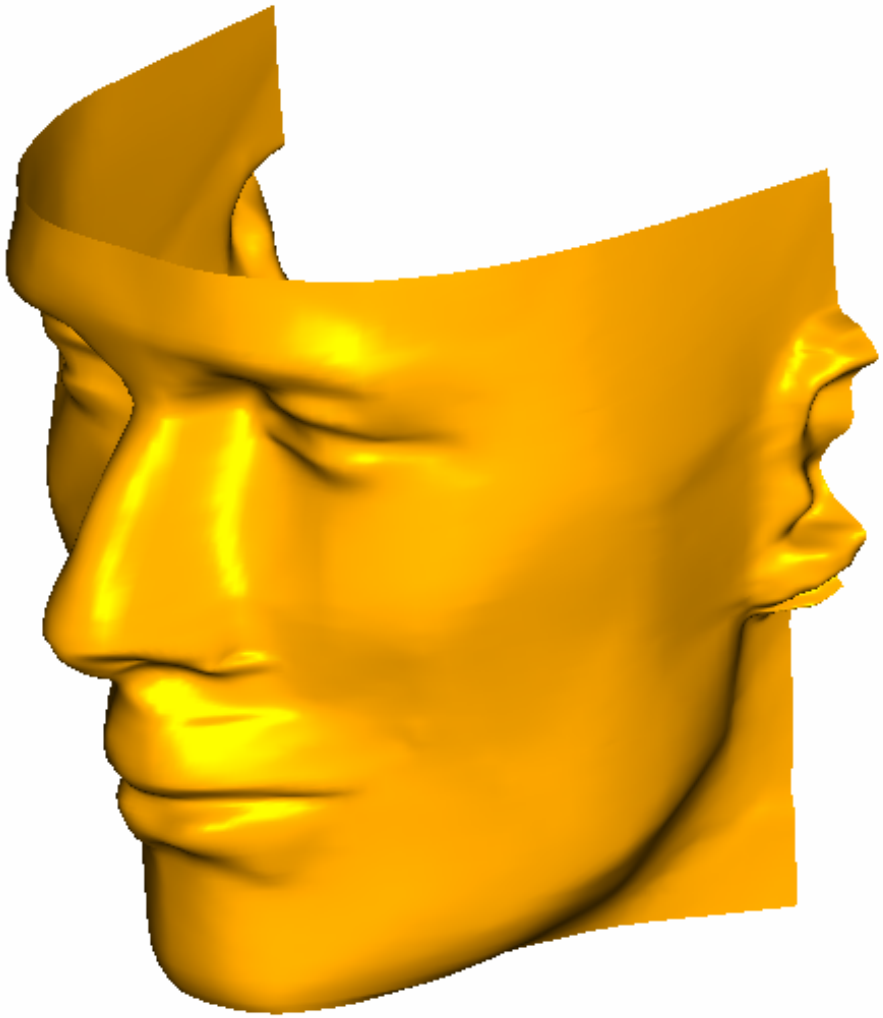
Subdivision Surface – Reconstructed Head



- High Visibility
- High quality rendering in I-deas NX
- Easy rotate, zoom, pan with heavy surfaces in I-deas NX

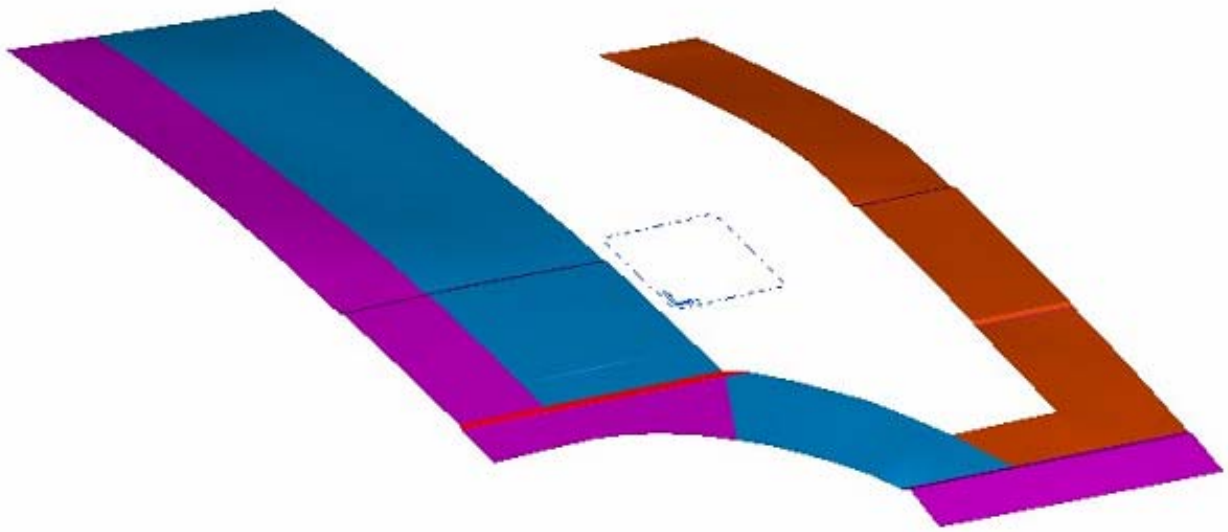
Subdivision Surface – Reconstructed Head

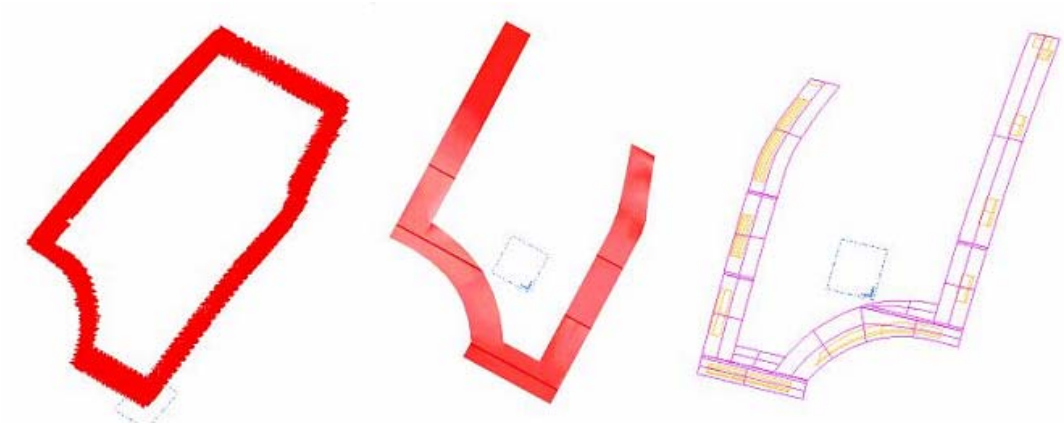
- Face patch is the most critical patch
  - Eye, Eyelids & Eyebrows
  - Nose and nostrils
  - Mouth and Lips
  - Chin
  - Cheeks
  - Ears (partial)
  - Forehead (partial)
  - Neck (partial)



Subdivision – Tooling example

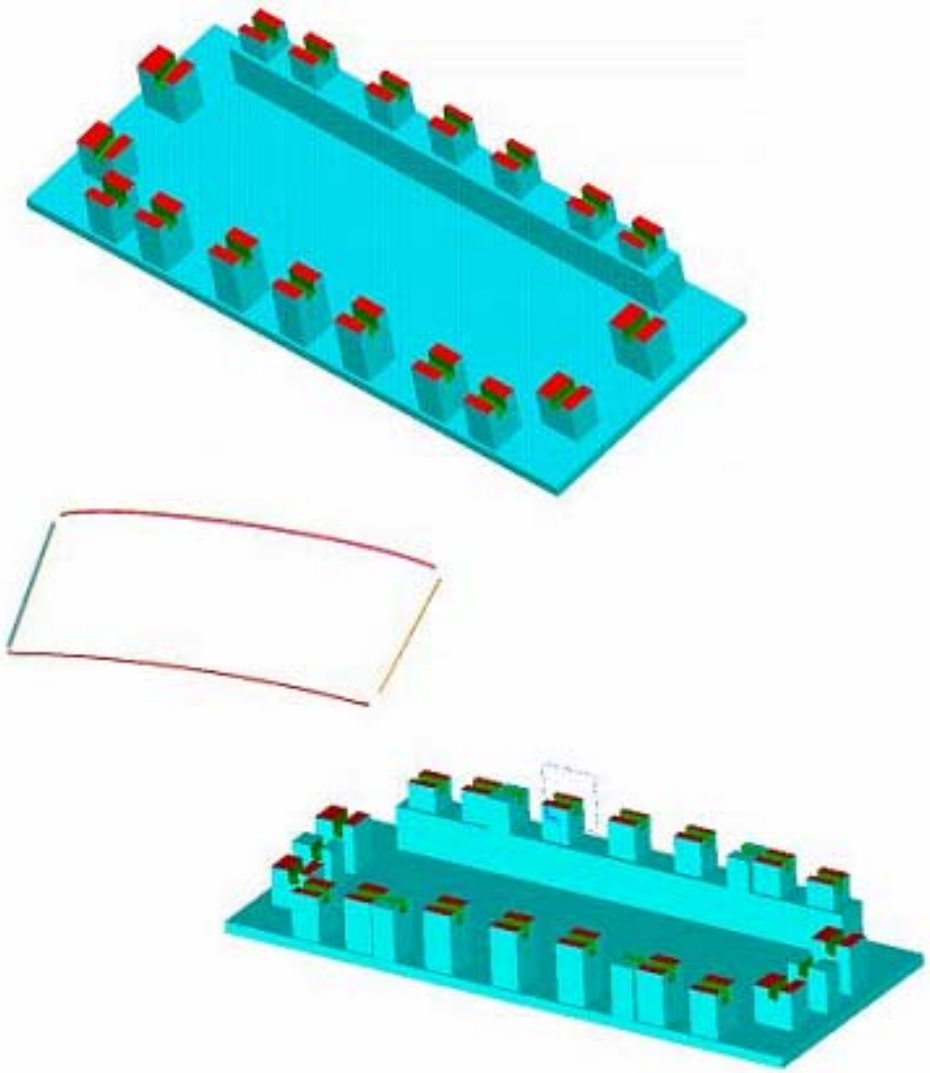
- Surface reconstruction for Automobile door clinching fixture manufacturing





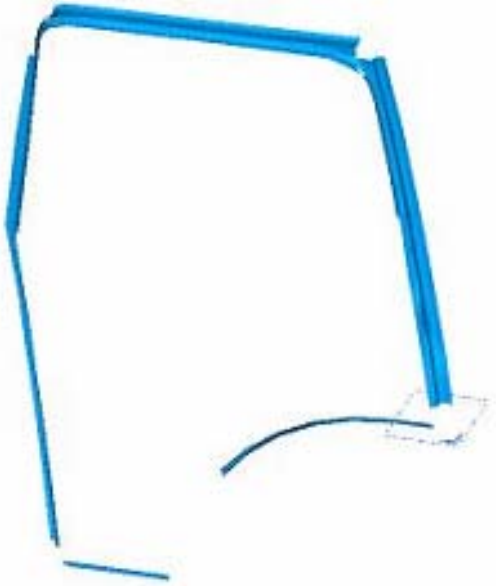
Subdivision – Tooling example

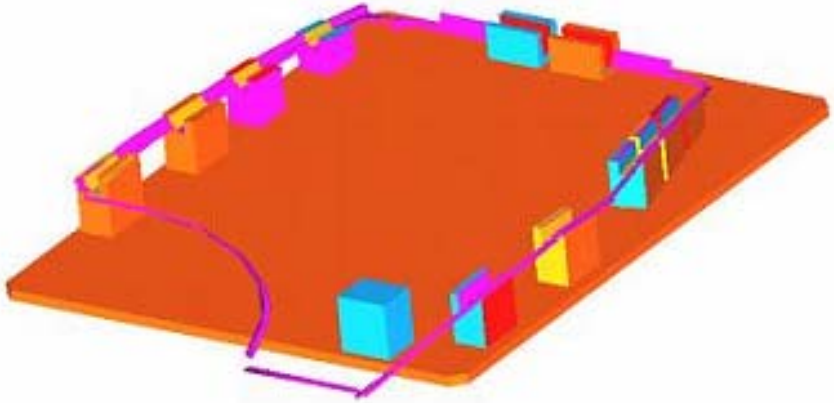
- Surface reconstruction for Automobile Windshield aperture checking fixture manufacturing



Subdivision – Tooling example

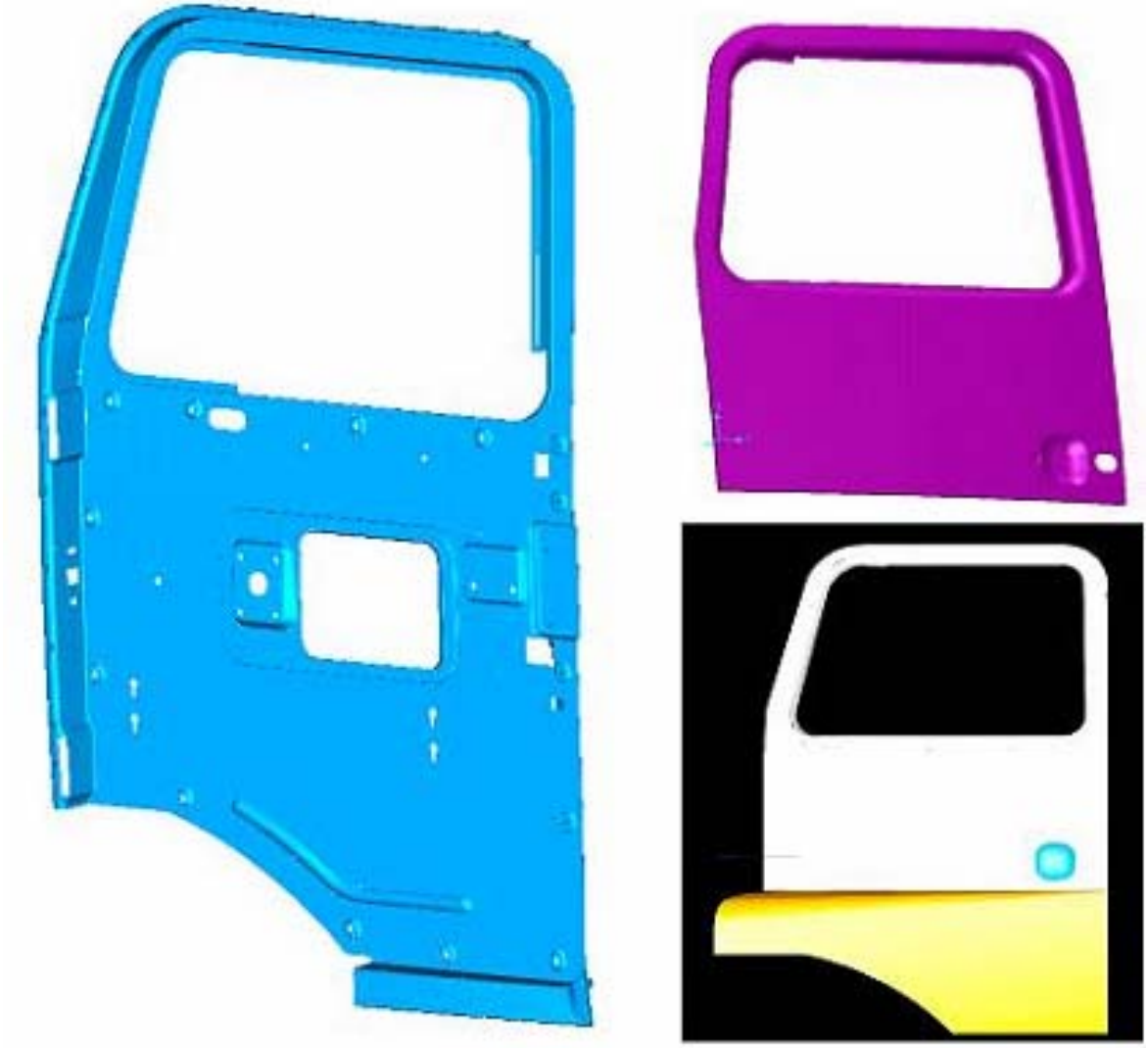
- Surface reconstruction for Automobile door aperture checking fixture manufacturing





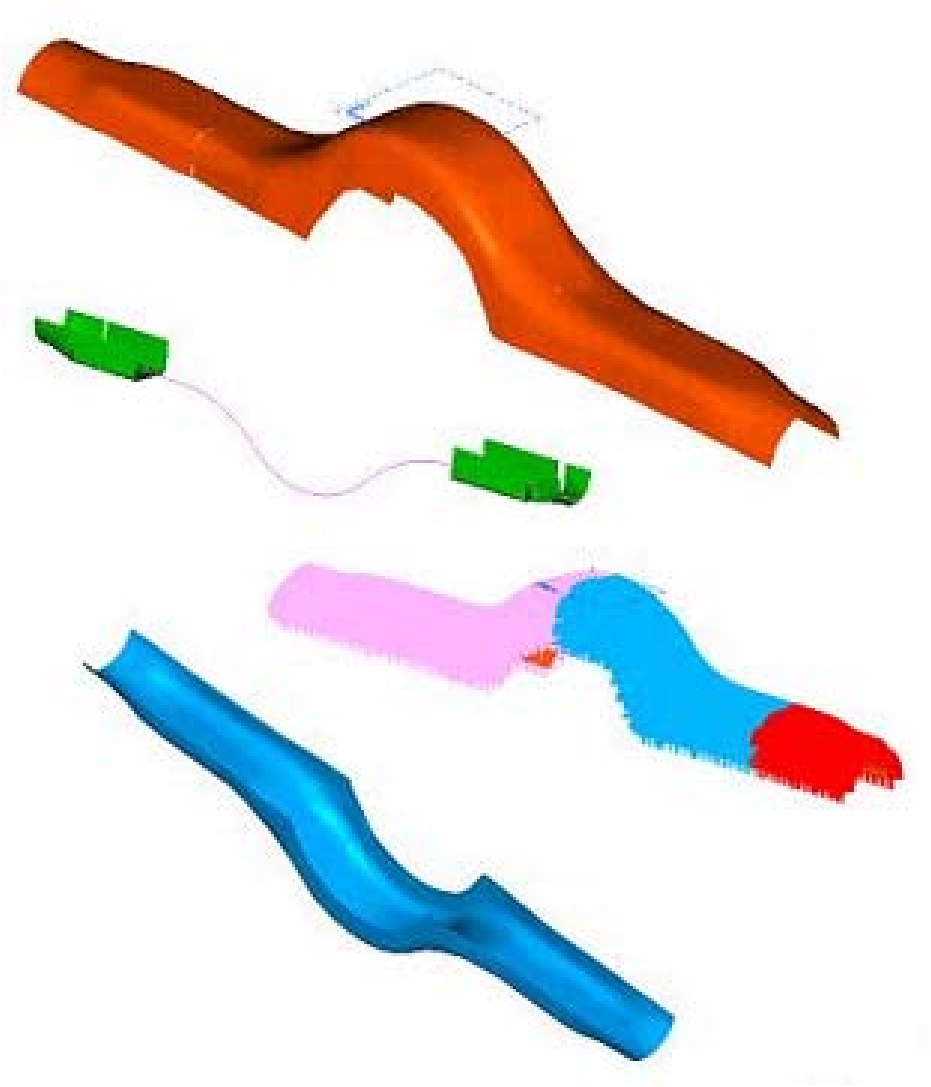
Subdivision – Tooling example

- Surface (patches) reconstruction for Automobile (HCV) door inner panels



Subdivision – Tooling example

- Surface reconstruction for Automobile dummy axle housing for bulk deformation simulation



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Questions?

Thank You.