DesignMentor: A Pedagogical Tool for Computer Graphics and Computer–Aided Design

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Teaching curves and surfaces is a challenging task

Major obstacles: formidable mathematics
lack of pedagogical tools

Learning curves and surfaces is also a difficult task

The concepts are abstract and difficult to visualize; without knowing the details, writing programs to experiment is not easy; and some concepts and algorithms are simply too difficult to implement.

There is virtually no tools

Yes, there are tools. Most of them are libraries for programming or packages (e.g., MAPLE and Mathematica). These tools are not very helpful for illustrating the fundamentals.

So, we designed DesignMentor!
What DesignMentor Is?

- **DesignMentor** provides students with an interactive environment for learning, practicing, and visualizing most fundamental concepts and algorithms in curves and surfaces.

What DesignMentor Is Not?

- **DesignMentor** is *not* a production system for helping students learn design issues and practice design skills.
Overview of DesignMentor

- **DesignMentor** supports Bezier, rational Bezier, B–spline and NURBS curves and surfaces
- **DesignMentor** is portable and supports Windows 95/98/NT, SGI and Sun platforms
DesignMentor’s Curve System

- A student can click on the canvas for creating a number of control points and select a curve type (e.g., Bezier).
- DesignMentor generates the curve
- DesignMentor can display many important geometric properties

![Diagram of DesignMentor's Curve System](image.png)
De Casteljau’s and de Boor’s Algorithms

- **DesignMentor** can display the convex hull and a step-wise execution of de Casteljau’s/de Boor’s algorithm.

- The computation and visualization are updated on-the-fly as the curve is being traced.

![Diagram showing convex hull, de Boor net, and computed point. Computation of de Boor’s algorithm can be done step-wise.](image)
Shape Editing

**DesignMentor** supports shape editing

- Moving control points: all curves
- Changing weights of control points: Rational Bezier and NURBS
- Modifying knots: B–spline and NURBS

Shape editing is *global* for Bezier and rational Bezier curves

### Bezier

**before**

![Bezier before](image1.png)

**after**

![Bezier after](image2.png)

### B–spline

**before**

![B–spline before](image3.png)

**after**

![B–spline after](image4.png)
Modifying Weights (NURBS)

- Weights can also be modified for rational Bezier and NURBS curves
  - Increasing (resp., decreasing) the weight of a control point pulls (resp., pushes) the curve toward (resp., away from) that point

- A user selects a control point and changes its weight. The effect is shown on-the-fly.

NURBS curve of degree 5

Before

- $w = 1$

After

- $w = 0.3$
- $w = 1$
- $w = 4$
**Advanced Geometric Algorithms**

**DesignMentor** supports 3 advanced algorithms for B–spline and NURBS:

- **Knot insertion:** inserting a new knot
- **Subdivision:** dividing a curve into two
- **Degree Elevation:** increasing the degree by 1

_Before insertion_

_B–spline of degree 5_

_After insertion_
DesignMentor also supports curve interpolation and approximation.

- A user clicks data points on the canvas and DesignMentor constructs a B–spline curve that contains all points in the given order.

- Under *Global Interpolation* modifying a data point changes the curve globally. Under *Local Interpolation* modifying a data point only affects the curve locally.
DesignMentor’s Surface System

- **DesignMentor** supports Bezier, rational Bezier, B–spline and NURBS surfaces.

- A user indicates the type of a surface and its degrees. **DesignMentor** generates a flat surface.

- Then, a user creates the desired surface with shape editing operations.
Surface Shape Editing

To change the shape of a surface, a user can:

- move control points (all surfaces)
- modify knots (B-spline and NURBS)
- change weights (rational Bezier and NURBS)

A zero weight means no contribution to the creation of the surface.
De Casteljau’s and de Boor’s Algorithms

- De Casteljau’s/de Boor’s algorithm for curves can be extended to surfaces

- Apply the algorithm to each row of control points creating a set of new points, followed by one application of the algorithm to the new points.
Advanced Geometric Algorithms

- **DesignMentor** supports knot insertion, degree elevation and surface subdivision both $u$ and $v$ directions.

- Each subpatch is color coded
Cross–Sectional Design

Cross–Sectional Design is a technique of surface design using a number of curves (i.e., profile – cross section and trajectory curves)

DesignMentor supports the following surface types:

- Ruled surface: two curves
- Surface of revolution: one profile curve
- Swung surface: one profile and one trajectory curve
- Simple swept surface: one profile and one trajectory curve
- Skinned surface: a number of profile curves
- Swept by skinning: one trajectory and a set of (transformed) profile curves

The surface system activates the curve system for designing profile and trajectory curves
Ruled Surfaces

- It takes two curves for designing a ruled surface.
- The surface is created by joining corresponding points on curves with line segments.
Swung Surfaces

- A swung surface is very similar to a surface of revolution
- In addition to an axis of revolution, a trajectory curve is required
- As the profile curve rotates about the axis, it is *scaled* by the trajectory curve
A skinned surface requires a set of profile curves

DesignMentor constructs a B–spline surface to contain all given curves

Thus, skinning is a form of interpolation (of curves)
**Swept by Skinning**

- **DesignMentor** can construct complex swept surfaces via skinning.
- A master profile curve is required.
- Instances of this master curve are placed along the trajectory curve and can be rotated and scaled.
- Then, skinning is applied.

![Diagram showing master profile and transformed masters]

**Diagram Description:**
- The master profile is shown on the left side of the diagram.
- Transformed masters are depicted around the profile, indicating the application of skinning.
Interpolation and Approximation

DesignMentor supports global and local interpolation and global approximation for regular grid.

Compare the resulting surfaces.

<table>
<thead>
<tr>
<th>Data point grid</th>
<th>Global interpolation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local interpolation</td>
<td>Global approximation</td>
</tr>
</tbody>
</table>

Compare the resulting surfaces.
Curve Network Interpolation

- **DesignMentor** supports interpolation on a curve network.

- A user can design a curve network with **DesignMentor** or other system.

- Then, **DesignMentor** interpolates the curve network with a surface, the *Gordon Surface*.
Future Work

- More visualization of geometric properties (e.g., tangent plane, normal vector, curvature sphere, umbilic, Dupin indicatrix, ...)
- Triangular and multi-sided patches
- Curve and surface interrogation
- Subdivision scheme
- **The Blossoming Principle**
- Irregular data interpolation and approximation