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Motivation

Mathematics education in e-Learning

- Limited to displaying texts and videos.
- Mathematical figures
  - Indispensable for conceptual understanding
  - Images? inconvenient for interactive learning
- Needs for efficient graph drawing
  - Easy, fast, and accurate drawing
  - Natural interface
Previous Systems

- Math packages - Mathematica, Maple
  - e.g., In[1]=plot[ sin[x], {x, 0, 2Pi}]
- Drawing tools - gnuplot, GraphEQ
  - No direct manipulation
- GeoGebra, Cinderella
  - Menu-driven Interface
- MS PPT - mainly for simple diagrams
Graphs in Engineering Textbooks

\[ \text{gnuplot} \quad \frac{\sin x}{x} \quad \text{Mathematica} \quad \sin ax \]
GeoGebra Screenshots
Graph Drawing by Equation
Graph Drawing by Equation

Simple keyboard input

- $y = 2x^2 + 3$
- $y = \sin(x)$, $y = 3^x$, $y = \log(x)$, $y = \sqrt{x}$
- $x^2 + y^2 - 1 = 0$
- $y = f(x) + g(x)$, $y = ax^2 + bx + c$
- $ax + by^2 + c = 0$
Graph Drawing by Equation

\[ y = x^2 + 2x + 1 \]
\[ y = \frac{e}{\log(x)} + x^2 - 3x \]
Graph Drawing by Equation
Graph Drawing by Sketch
Graph Drawing by Sketch

- Pen gesture recognition
  - Gesture set

- Fitting to a similar function/curve
  - Common in the middle/high school math

- Modification
  - Changing the equation of a graph
  - Moving the graph or its control points
<table>
<thead>
<tr>
<th>name of gesture</th>
<th>example</th>
<th>purpose</th>
<th>number of stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td>point</td>
<td>🌟</td>
<td>indicate vertex</td>
<td>1</td>
</tr>
<tr>
<td>solid line</td>
<td></td>
<td>generate straight line</td>
<td>1</td>
</tr>
<tr>
<td>delete</td>
<td>✗</td>
<td>delete</td>
<td>2</td>
</tr>
<tr>
<td>quadratic</td>
<td></td>
<td>generate quadratic func.</td>
<td>1</td>
</tr>
<tr>
<td>cubic</td>
<td></td>
<td>generate cubic func.</td>
<td>1</td>
</tr>
<tr>
<td>log</td>
<td></td>
<td>generate log. func.</td>
<td>1</td>
</tr>
<tr>
<td>exponential</td>
<td></td>
<td>generate exponential func.</td>
<td>1</td>
</tr>
<tr>
<td>ellipse</td>
<td></td>
<td>generate ellipse</td>
<td>1 or 2</td>
</tr>
<tr>
<td>hyperbola</td>
<td></td>
<td>generate hyperbola</td>
<td>2</td>
</tr>
<tr>
<td>parabola</td>
<td></td>
<td>generate parabola</td>
<td>2</td>
</tr>
</tbody>
</table>
Graph Drawing by Sketch

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Graph Drawing by Sketch
Graph Drawing by Search
Graph Drawing by Search

- Search in a DB of pre-drawn graphs
  - Query by sketch
  - Selection among candidates
  - Modification
  - Updating the DB with the new graph
  - Similarity matching
    - Types of graphs, coefficients of equations, etc
Graph Drawing by Searching
Graph Editing
Graph Editing

- Graph drawing in restricted domains
  - Different equations in different intervals

- Useful features in graph drawing
  - Drawing intersection points and tangent lines
  - Filling some bounded regions
  - Visualizing mensuration

- Additional features
  - Points on a graph, coordinate values, etc
$y = 0.5x^2 - 2x + 2$
$y = 0.5x^2 - 2x + 2$
$y = 0.5x^2 - 2x + 2$
The equation displayed in the image is:

\[ y = 0.5x^2 - 2x + 2 \]
The equation shown in the diagram is:

$$x^2 + y^2 - 4 = 0$$
The diagram shows a graph of a cubic function, which is represented by the equation:

\[ y = ax^3 + bx^2 + cx + d \]
Graph Editing
Conclusion

Contributions

• Efficient graph drawing for mathematics education in e-Learning
• Easy and fast generation of complicated math figures

Future work

• Presentation of graph construction
• Animation of graph generation