Computer Graphics

Lecture-Introduction

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CSE, STCET

Pre-requisites

- CS 201 (Basic Computation and Principles of C)
- M101 & M201 (Mathematics) basics of set theory
- CS 302 (Data Structures and Algorithm)
- CS 501 (Design and Analysis of Algorithms)

Syllabus

- **Module I:**
- **Introduction to computer graphics & graphics systems [6L]:** Overview of computer graphics, representing pictures, preparing, presenting & interacting with pictures for presentations; Visualization & image processing; RGB color model, direct coding, lookup table; storage tube graphics display, Raster scan display, 3D viewing devices, Plotters, printers, digitizers, Light pens etc.; Active & Passive graphics devices; Computer graphics software.
- **Scan conversion [8L]:** Points & lines, Line drawing algorithms; DDA algorithm, Bresenham's line algorithm, Circle generation algorithm; Ellipse generating algorithm; scan line polygon, fill algorithm, boundary fill algorithm, flood fill algorithm.

Syllabus

- **Module II:**
- **2D transformation & viewing [15L]:** *Basic transformations: translation, rotation, scaling; Matrix representations & homogeneous coordinates, transformations between coordinate systems; reflection shear; Transformation of points, lines, parallel lines, intersecting lines.* Viewing pipeline, Window to view port co-ordinate transformation, clipping operations, point clipping, line clipping, clipping circles, polygons & ellipse. Cohen and Sutherland line clipping, Sutherland-Hodgeman Polygon clipping, Cyrus-beck clipping method
- **3D transformation & viewing [5L]:** 3D transformations: translation, rotation, scaling & other transformations. Rotation about an arbitrary axis in space, reflection through an arbitrary plane; general parallel projection transformation; clipping, view port clipping, 3D viewing.

Syllabus

- **Module III:**
- **Curves [3L]:** Curve representation, surfaces, designs, Bezier curves, B-spline curves, end conditions for periodic B-spline curves, rational B-spline curves.
- **Hidden surfaces [3L]:** Depth comparison, Z-buffer algorithm, Back face detection, BSP tree method, the Painter's algorithm, scan-line algorithm; Hidden line elimination, wire frame methods , fractal - geometry.
- **Color & shading models [2L]:** Light & color model; interpolative shading model; Texture.
- **Introduction to Ray-tracing: [3L]**
- Human vision and color, Lighting, Reflection and transmission models.

Recommended Books

- D. Hearn, M. P. Baker – “Computer Graphics (C version 2nd Ed.)” – Pearson education
- J. M. Foley, A. V. Dam, S. K. Feiner, J. F. Hughes- Computer Graphics Principles and Practice- Pearson
- Z. Xiang, R. Plastock – “ Schaum’s outlines Computer Graphics (2nd Ed.)” – TMH
- D. F. Rogers, J. A. Adams – “Mathematical Elements for Computer Graphics (2nd Ed.)” – TMH
- S. Harrington – Computer Graphics, A Programming Approach
- D. P. Mukherjee – Fundamentals of Computer Graphics and Multimedia

Course Objective

Students should:

1. Understand the basics of computer graphics, different graphics systems and applications of computer graphics.
2. Discuss various algorithms for scan conversion and filling of basic objects and their comparative analysis.
3. Use of geometric transformations on graphics objects and their application in composite form.
4. Extract scene with different clipping methods and its transformation to graphics display device.
5. Explore projections and visible surface detection techniques for display of 3D scene on 2D screen.
6. Render projected objects to naturalize the scene in 2D view and use of illumination models for this.

Course Outcome

Upon successful completion of the course, the student will be able to:

1. The foundations of computer graphics and the basics of contemporary graphics hardware and applications.
2. To understand concept of geometric, mathematical and algorithmic concepts necessary for programming computer graphics.
3. To write programs to implement scan conversion and filling of basic objects, transformations of objects (2D and 3D)and clipping methods.
4. To understand the mathematical foundation curves and surfaces.
5. To demonstrate an understanding of the use of object hierarchy and color shading models in graphics applications.

Evaluation Details

- Attendance
- Internal Assessment
- Rest to be notified
- Micro project -> planning to provide
- Programming language: C, C++, Python, JAVA, SVG, OpenGL

Computer Graphics Packages

- LOGO
- COREL DRAW
- AUTO CAD
- 3D STUDIO
- CORE
- GKS (Graphics Kernel System)
- PHIGS
- CAM (Computer Graphics Metafile)
- CGI (Computer Graphics Interface)

What is Computer Graphics?

Computer graphics is the science and art of communicating visually via a computer’s display and its interaction devices. The visual aspect of the communication is usually in the computer-to-human direction, with the human-to-computer direction being mediated by devices like the mouse, keyboard, joystick, game controller, or touch-sensitive overlay

Importance of Computer Graphics

Medical imaging is another application where computer graphics has proven valuable. Recent advances in imaging technology such as computer tomography and magnetic resonance imaging allow physicians to take 3D Xrays of the human body. Interactive computer graphics allows the physician to interpret this large volume of data in new and useful ways.

Importance of Computer Graphics

Computer graphics has also expanded the boundaries of art and entertainment. Movies such as *Jurassiac Park* make extensive use of computer graphics to create images that test the bounds of imagination. The development of computer graphics has made possible virtual reality, a synthetic reality that exists only inside a computer. Virtual reality is fast becoming an indispensable tool in education. Flight simulators are used to train pilot for extreme conditions. Surgical simulators are used to train novice surgeons without endangering patients.

What is Computer Graphics?

- Computer graphics is a cross-disciplinary field in which physics, mathematics, human perception, human-computer interaction, engineering, graphic design, and art all play important roles.
- We use physics to model light and to perform simulations for animation. We use mathematics to describe shape.
- Human perceptual abilities determine our allocation of resources
- We don’t want to spend time rendering things that will not be noticed.
- We use engineering in optimizing the allocation of bandwidth, memory, and processor time.
- Graphic design and art combine with human-computer interaction to make the computer-to-human direction of communication most effective.

Computer Graphics… *more*

- model of the objects in a scene (a geometric description of the things in the scene and a description of how they reflect light)
- model of the light emitted into the scene (a mathematical description of the sources of light energy, the directions of radiation, the distribution of light wavelengths, etc.)
- producing a representation of a particular *view* of the scene (the light arriving at some imaginary eye or camera in the scene)

Computer Graphics- a glorified multiplication

- One multiplies the incoming light by the reflectivities of objects in the scene to compute the light leaving those objects’ surfaces and repeats the process
- treating the surfaces as new light sources and recursively invoking the light transport operation,
- determining all light that eventually reaches the camera
- In practice, this approach is unworkable, but the idea remains.

Computer Vision

- Given a view of a scene, the computer vision system is charged with determining the illumination and/or the scene's contents (which a graphics system could then "multiply" together to reproduce the same image).
- In truth, of course, the vision system cannot solve the problem as stated and typically works with assumptions about the scene, or the lighting, or both, and may also have multiple views of the scene from different cameras, or multiple views from a single camera but at different times.

Research Trends in Computer Graphics

- creating geometric models, methods for representing surface reflectance (and subsurface reflectance, and reflectances of participating media such as fog and smoke, etc.)
- the animation of scenes by physical laws and by approximations of those laws, the control of animation, interaction with virtual objects, the invention of nonphotorealistic representations,
- In recent years, an increasing integration of techniques from computer vision

Research Trends in Computer Graphics

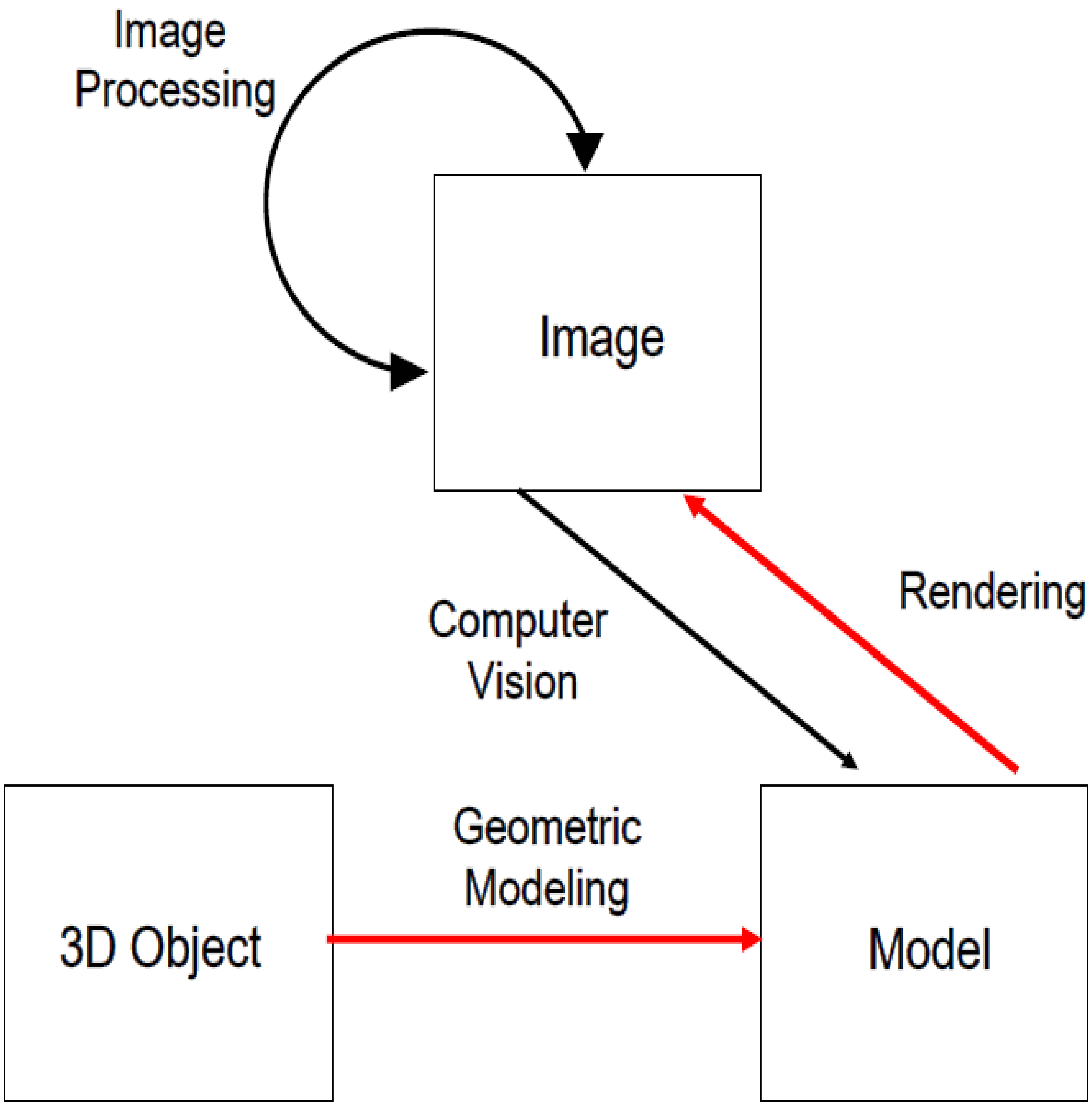
Computer Graphics- Model

- In the field of computer graphics, the word “model” can refer to a geometric model or a mathematical model
- A **geometric model** is a model of something we plan to have appear in a picture: We make a model of a car, or a house.
- The geometric model is enhanced with various other attributes that describe the color or texture or reflectance of the materials involved in the model.
- Starting from nothing and creating such a model is called **modeling,** and the geometric-plus-other-information description that is the result is called a **model.**

Computer Graphics- Models

- A **mathematical model** is a model of a physical or computational process.
- We also have models of how objects move and models of things like the image-acquisition process that happens in a digital camera.
- Such models may be faithful (i.e., may provide a predictive and correct mathematical model of the phenomenon) or not; they may be physically based, derived from first principles, or perhaps empirical or phenomenological, derived from observations or even intuition.

Computer Graphics



Computer Graphics

Image Processing:

From Images to Images

Computer Vision:

From Images to Models

Computer Graphics:

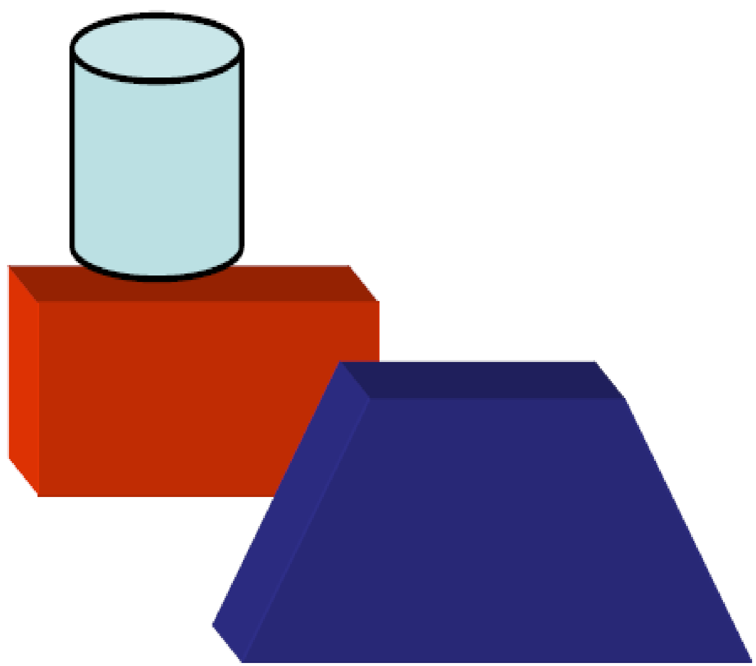
From Objects to Models (Geometric Modeling).

From 2D/3D Models to Images (Rendering).

From 4D Models to Images (Animation).

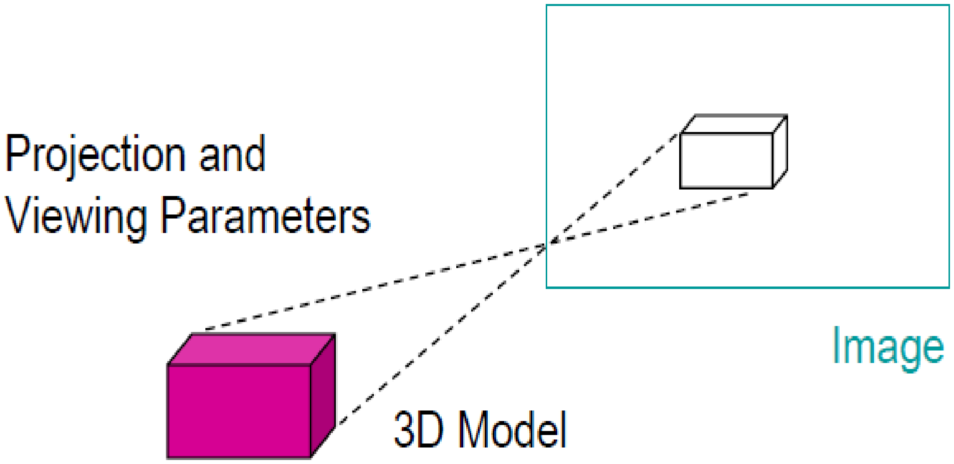
Geometric Modeling

- From a concept (or a real object) to a geometric representation on a computer
- Example: a sphere can be described as (x, y, z, r)
- Complex objects can be constructed from simpler ones



Rendering

- Given a scene and viewing parameters, produce an image
- Images are a 2D array of pixels
- Important sub problems:
  - Which pixels are covered by each object ? (Scan Conversion)
  - What is visible at each pixel ? (Visible Surface Algorithm)
  - What color should a pixel be ? (Illumination, Shading Algorithms).



Animation

• Definition of complex time-dependent behavior of objects

•Issues with rigid and elastic joints

•Realistic rendering of collective behaviors

•Examples:

–Automatic interpolation between key-frames

–Physics based simulation

Computer Graphics Area

- **User interaction** deals with the interface between input devices such as mice and tablets, the application, and feedback to the user in imagery and other sensory feedback. Historically, this area is associated with graphics largely because graphics researchers had some of the earliest access to the input/output devices that are now ubiquitous.

- **Virtual reality** attempts to *immerse* the user into a 3D virtual world. This typically requires at least stereo graphics and response to head motion. For true virtual reality, sound and force feedback should be provided as well. Because this area requires advanced 3D graphics and advanced display technology, it is often closely associated with graphics.

- **Visualization** attempts to give users insight via visual display. Often there are graphic issues to be addressed in a visualization problem.

- **Image processing** deals with the manipulation of 2D images and is used in both the fields of graphics and vision.

- **3D scanning** uses range-finding technology to create measured 3D models. Such models are useful for creating rich visual imagery, and the processing of such models often requires graphics algorithms.

Applications

- CAD - Computer Aided Design (Mechanical, Architectural)
- Simulators (Flight, Driving, Sports)
- Advertising
- Virtual Reality
- Architectural Visualization
- Art and Entertainment
- Games
- Special effects
- Education
- Scientific visualization

Brief History

- Although the punched card was first used in 1801 to control textile looms, they were first used as an input medium for “computing machines” in 1941. Special typewriter-like devices were used to punch holes through sheets of think paper. These sheets could then be read (usually by optically based machines) by computers. They were the first input device to load programs into computers.
- Salustri used punched cards in 1980 in his first-year Introduction to Computing course at the University of Toronto.

Brief History

- 1950: Ben Laposky created the first graphic images, an Oscilloscope, generated by an electronic (analog) machine. The image was produced by manipulating electronic beams and recording them onto high-speed film.
- 1951: The Whirlwind computer at the Massachusetts Institute of Technology was the first computer with a video display of real time data.
- 1955: The light pen is introduced.

Brief History

- 1960: Although known since the 1940's, the first serious work on finite element methods of analysis is now published. FEA allows us to test products *virtually* and produce results that are as accurate as physical tests - at far less cost and time. The results of such an analysis was, back then, hundreds of pages of numbers that humans had to interpret. These days, thanks to computer graphics, we can literally see what would happen to our products in real-time.

Brief History

1961

The first video game, SpaceWar, ran using an oscilloscope as a display.

Oscilloscopes are vector displays.

Ivan Sutherland writes the first computer drawing program - SketchPad - which included things like pop-up menus.

To generate one GFLOPS of processing power with 1961 technology, you would need to spend over *$8 trillion* (in 2013-adjusted US dollars).

Brief History

1963

Doug Engelbart invents the computer mouse

1965

Jack Bresenham invents the “ideal” line-drawing algorithm.

NASTRAN FEA software released.

1970

Size of CAD market estimated at $25 million.

ANSYS founded.

1972

Nolan Kay Bushnell creates Pong, video arcade game.

Raster displays begin to appear.

Introduction of the CT scanner

Brief History

1975

K. Vesprille's PhD dissertation “Computer-Aided Design Applications of the B-Spline Approximation Form” develops the mathematical representation of arbitrary curves suitable for computation.

1977

The Apple II is the first graphics personal computer.

Star Wars is released; its only computer effects were vector-based, and then filmed.

CADAM, the first commercial 2D CAD package, is released.

McDonnell Douglas buys United Computing, forming Unigraphics

Brief History

1978
First real standard for constructive solid geometry developed by H. Voelcker et al.
Charles Lang at Cambridge University develops the first real boundary representation modelling engine.
1979
Size of CAD market estimated at $1 *billion*.
1981
CATIA, one of the first 3D CAD packages, is developed, using constructive solid geometry

Brief History

1982

The Commodore 64 personal computer used raster graphics so that regular televisions could be display devices.

TRON is the first movie to make extensive use of computer graphics.

AutoCAD 1.0 is released - it uses wireframe representation only.

SDRC I-deas CAD package released.

Voelcker introduces the notion of a voxel

The Apple Lisa was a fantastic computer that failed. The Lisa was first introduced at a cost of 9,995US(9,995US(20,893 in 2007 dollars). It was one of the first commercial personal computers to have a GUI and a mouse. It used a Motorola 68000 CPU at a 5 MHz clock rate and had 512 KB or 1 MB RAM. This made it a quantum leap in technology.

But it was so innovative that it was wrong. It simulated hardware in software, so it's very powerful CPU *seemed* slow to users. Also, there was no real software for it - it was in some ways *too* powerful. And it was certainly too expensive.

Brief History

To generate one GFLOPS of processing power, you would need to spend over *$30 million* in 2013-adjusted US dollars. (Compare that to the 1961 data.)

The original Macintosh was in many ways a “stripped down” Lisa. It had 20% of the base memory of the Lisa, but it ran faster because it used conventional hardware configurations. In the design of the Macintosh, Apple recognized that computational power was only one of many aspects of computer use *by humans* and that if they wanted a good design, they would have to satisfy *human nature*.

The Macintosh set a new standard for computer design, and for design in general. This went to the point of establishing Apple as the “anti-IBM” (these days, the anti-PC) with a television advertisement originally aired during Superbowl XVIII

Brief History

1985:
•Pixar releases Luxo, Jr.
•Voxel technology is embedded in most medical imaging software.
1987
VGA graphics standard introduced. Pro/Engineer launched as first pure UNIX CAD software. Everyone laughed. 18 months later, all major CAD vendors were developing CAD for UNIX.
1988
CATIA selected as CAD package for Boeing 777 leading to a $1 *billion* revenue for Dassault.
1989
•SVGA graphics standard introduced.
•The Parasolid solid model engine standard released by Unigraphics; it is licensed to nearly every other vendor.
•Tim Berners-Lee creates the very first website ever (this is even the actual original URL). The version linked here is from 1993, as it seems older backups have gone missing.

Brief History

1991

EDS buys Unigraphics

1992

All major CAD packages run on UNIX. SMEs lead the change from mainframes to high-end UNIX workstations. IBM loses $5 *billion* because no one wants mainframes any more

1993

UIUC releases Mosaic, the first web browser for general usage. Mosaic's "codename" was *mozilla*.

Jurassic Park was the first big-budget CGI effects movie.

First public call made from a *cell phone*.

1994

Dragged kicking and screaming into the 20th Century,

Autodesk *finally* releases a 3D version of AutoCAD.

Key developers of the Mosaic browser found Netscape.

First flight of Boeing 777, tested entirely via ANSYS.

Brief History

1995
Toy Story, the first fully CGI movie, is released.
Solidworks is released.
MS Internet Explorer 1.0 is released.
1997
To generate one GFLOPS of processing power, you would need to spend over *$40,000* 2013-adjusted US dollars.
1998
The Mozilla Foundation is created out of the remains of the Netscape.
2000
To generate one GFLOPS of processing power, you would need to spend about *$1,000* 2013-adjusted US dollars.
Sketchup, the first web-based CAD system, is released.

Brief History

2001

Final Fantasy movie is released.

Rendering tears and water are now possible; the movement of hair still un-renderable.

EDS buys SDRC; Unigraphics and I-deas CAD packages merged to for NX.

2003

Doom graphics engine for games.

ANSYS acquires CFX - computational fluids now begins to become popular.

Mozilla.org is registered as a non-profit organization.

2006

Google acquires Sketchup.

2008

Mozilla.org opens an office in Toronto.

2009

The state of the art of computer graphics, as of 2009, is summarized in this short video.

Brief History

2010

Computations fluids and *fluid structure interactions* now possible on laptop PCs.

2011

One GFLOPS of processing power costs about *$1.80*.

2012

Here's a summary of the state of the art in computer graphics, as of 2012, courtesy SIGGRAPH

2013

One GFLOPS of processing power costs about *$0.16*. That's about *100 trillion times cheaper* than in 1961 (when Fil Salustri was born).

It is now possible to create, on virtually any home computer, the kind of computer graphics that would have been unimaginable even just 10 years ago.

Brief History

2014

It's getting so easy to do interesting things with cheap computers - like a typical laptop - that developers are now starting to take advantage of *mistakes* in rendering as the foundation of new games, like this one by Pillow Castle, called *The Museum of Simulation Technology*.

2015

We're now getting into a period where “big data” is being used to construct animations that show us things we could not otherwise see/appreciate, like time-lapse changes in large structures.

Another new trend is the use of animation in UI design on mobile computing. For instance, here's what Google suggests in its Material Design language for web design

Brief History

2016

With enough preparation, we can now animate by mapping from a source to a target in real time. (With sometimes hilarious results.)

The last 10-15 years of CAD have mostly been about product lifecycle management which is much more than just CAD. CAD developments themselves have been relatively minor.

2017

That research on real-time face animation (reported in 2016) works at "production level" and is used by game developers.

2018

It is now possible to do fascinating and "realistic" graphics on phones. For instance: We can also now generate entirely CGI-based human faces in real time.

2019

Remember that bug that let you play with objects' actual sizes based on their apparent sizes on the screen. Well, an actual game came out in 2019, Superliminal, that leverages that "bug" to create a very interesting game.

Picture Elements in Computer Graphics

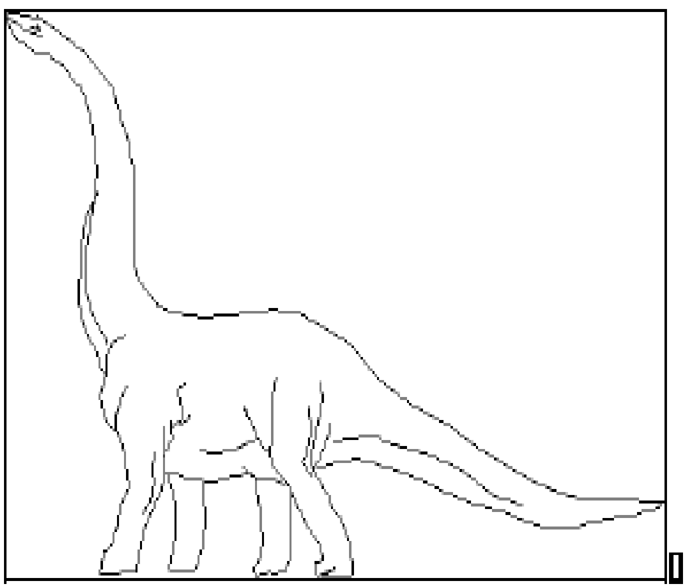
The basic objects out of which such pictures are composed are called **output primitives**.

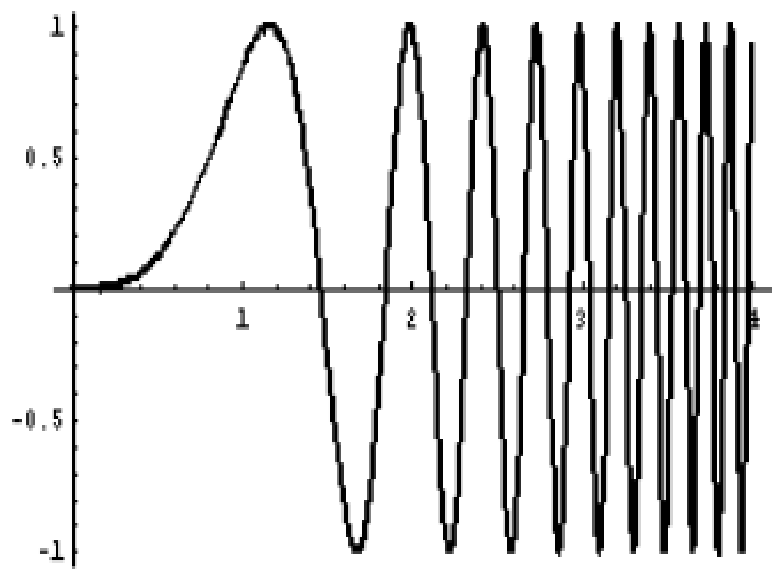
One useful categorization of these is:

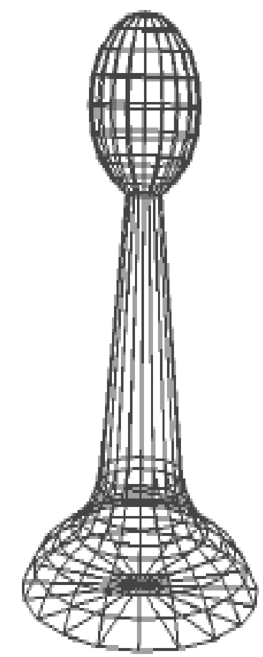
- polylines
- text
- filled regions
- raster images

Polylines

A polyline drawing of a dinosaur
A plot of mathematical function
A wrireframe model

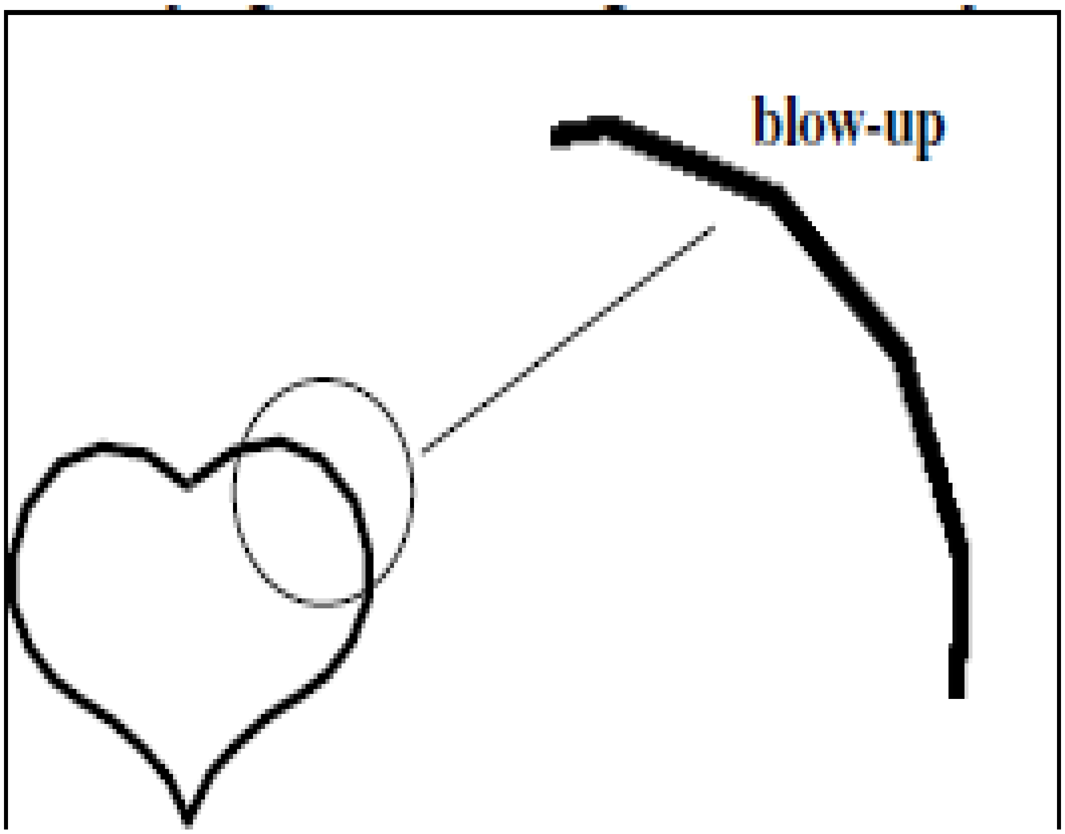




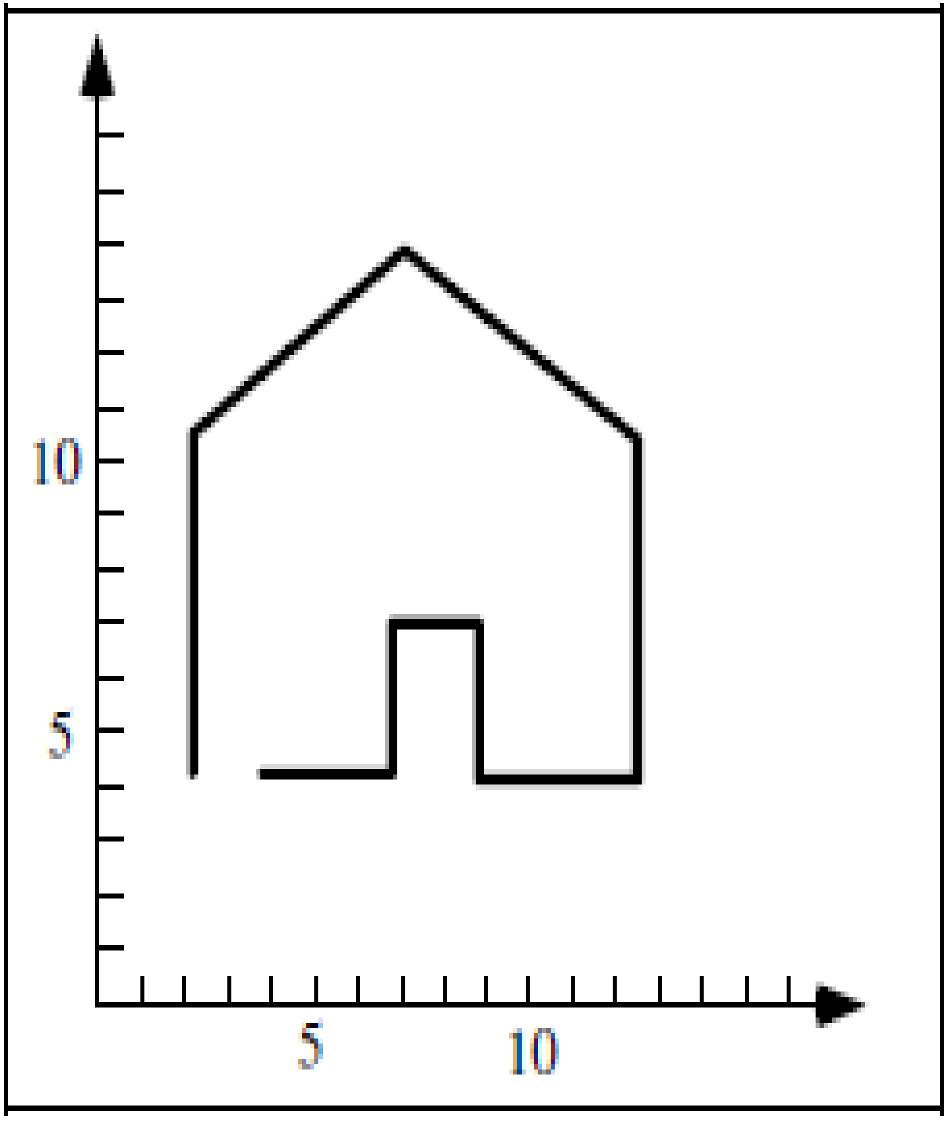


Polylines

Zoomed portion shows underlying short line segments

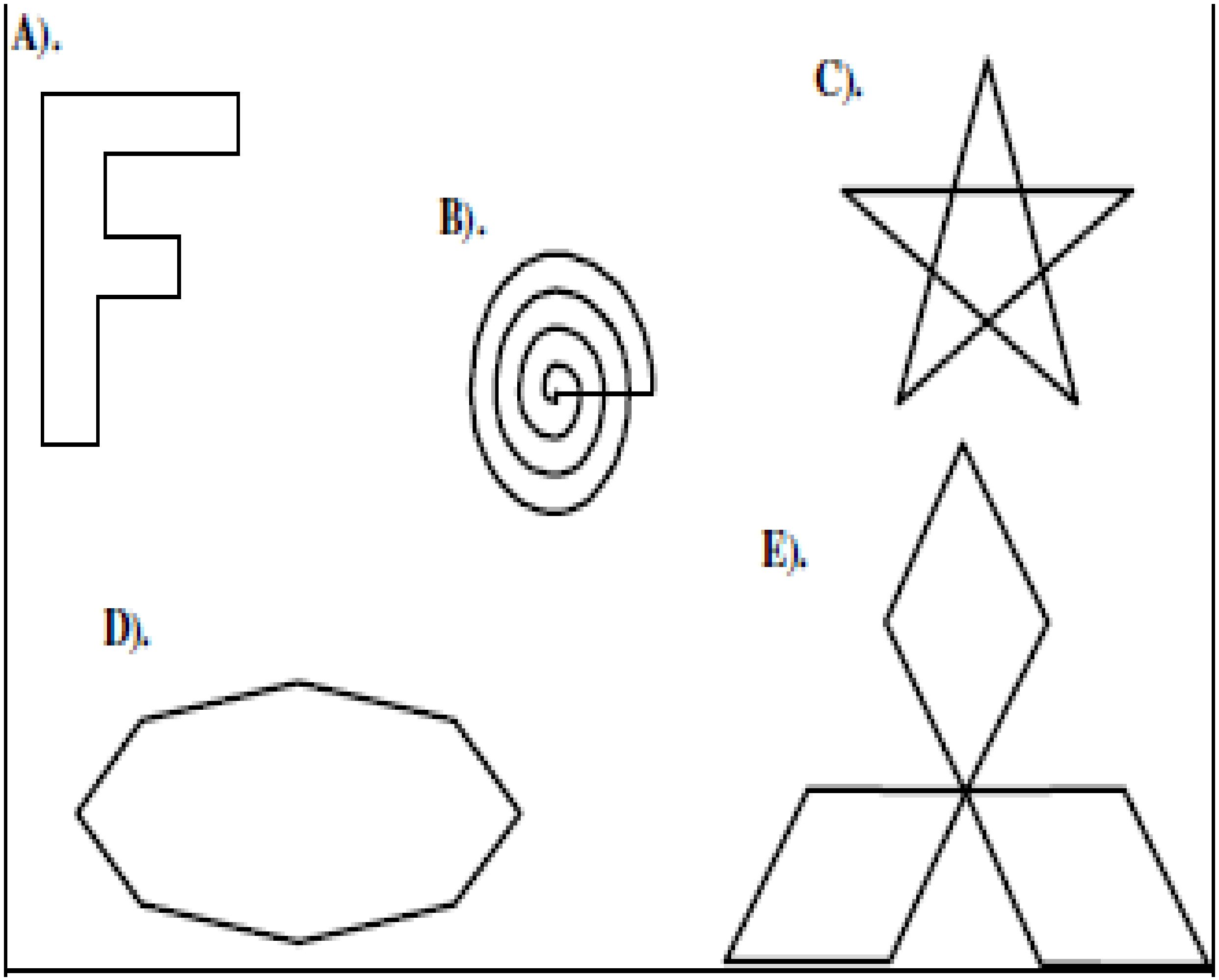


Polylines with sequence of vertices

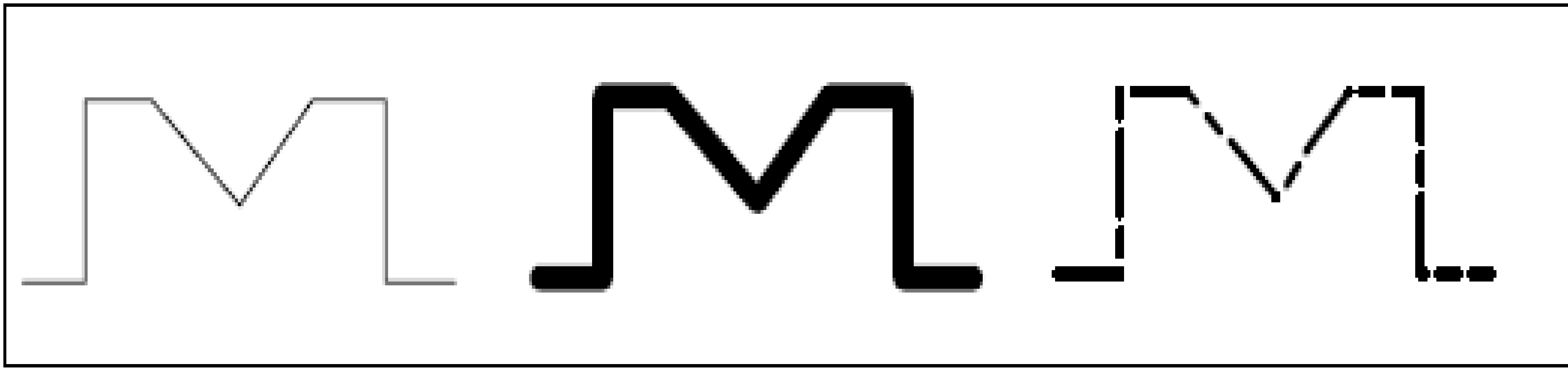


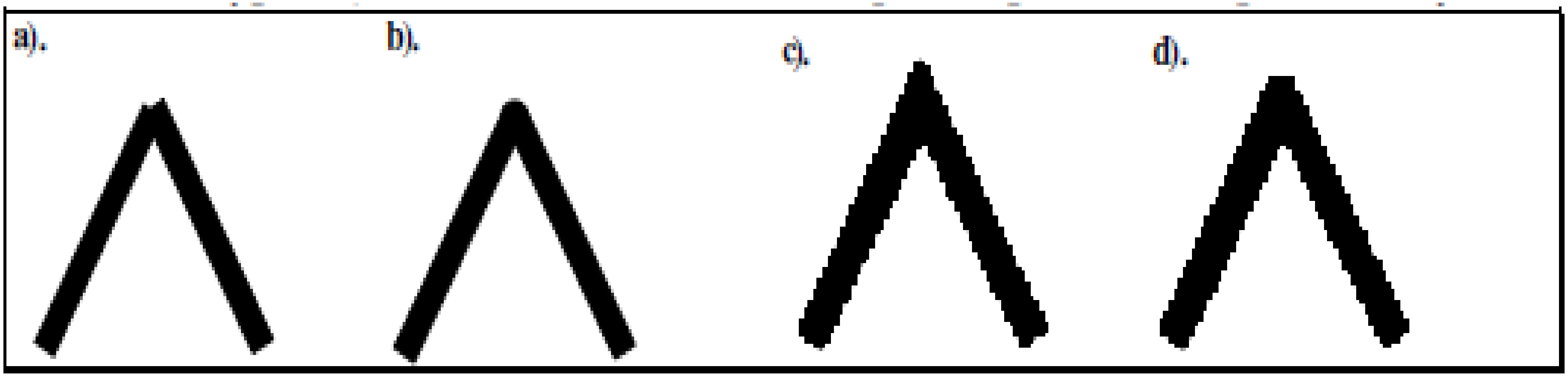
Polylines

A polyline need not form a closed figure, but if the first and last points are connected by an edge the polyline is a **polygon**.
If in addition no two edges cross, the polygon is called **simple.**

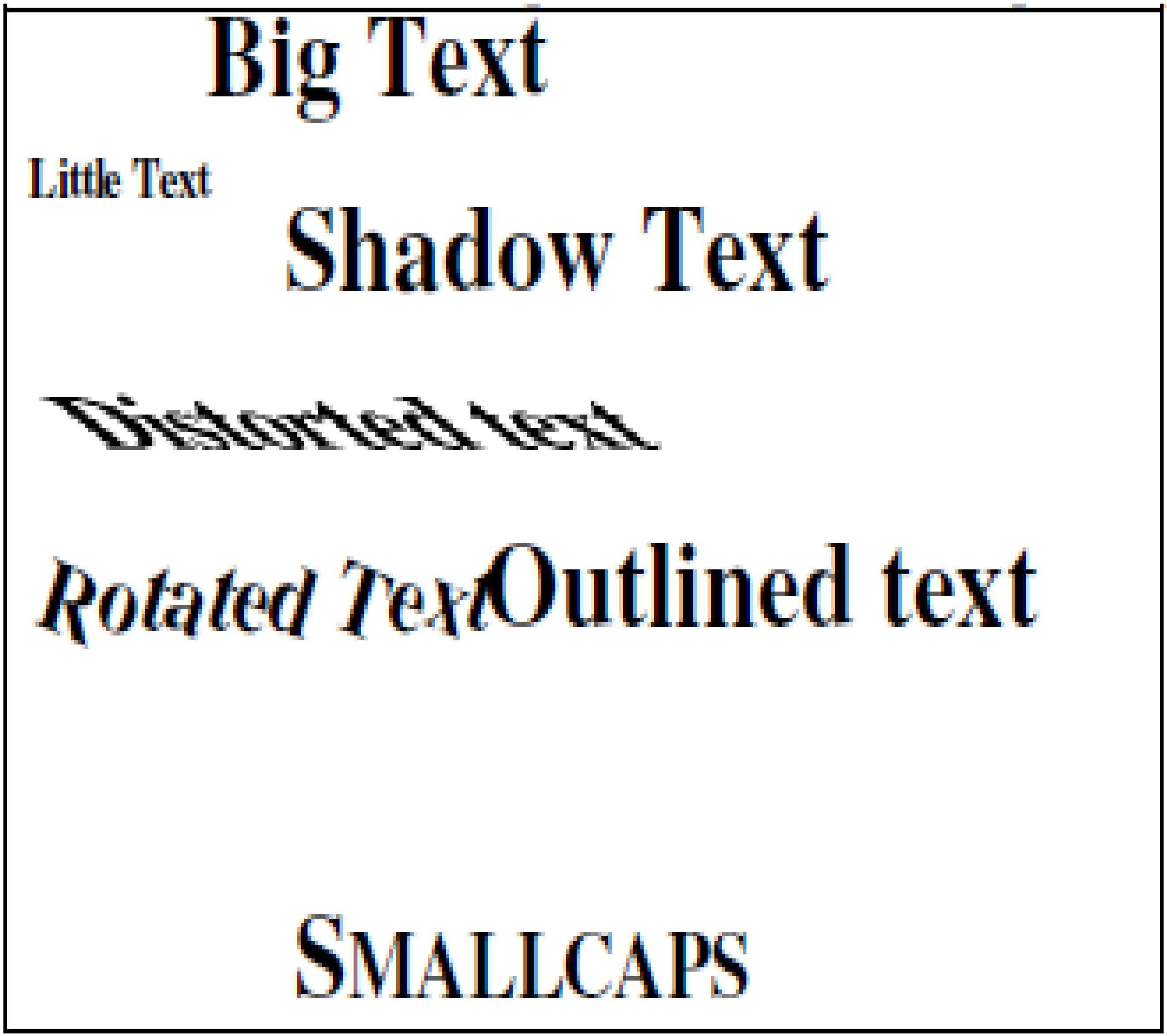


Polylines

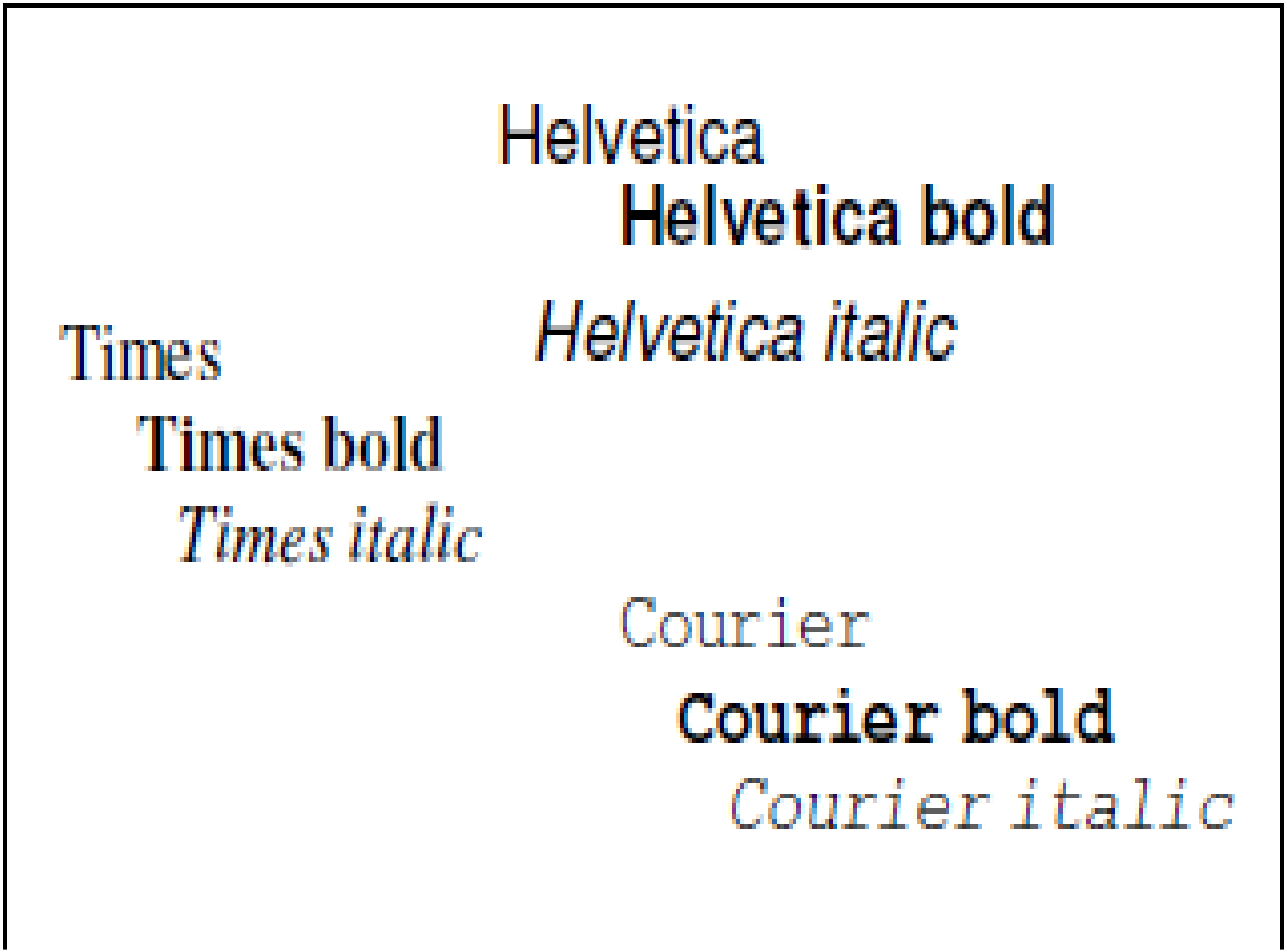




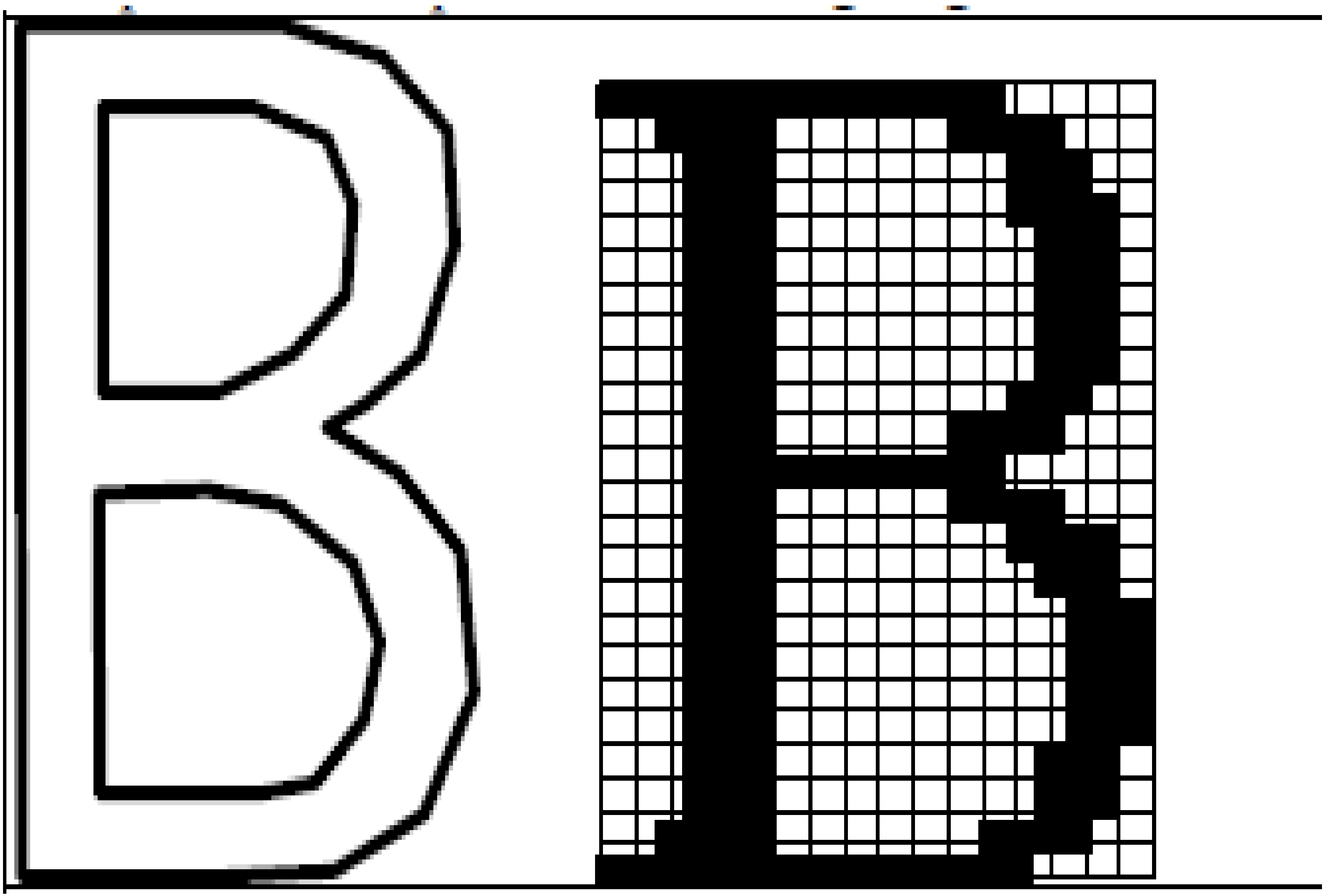
Text: Character Shapes



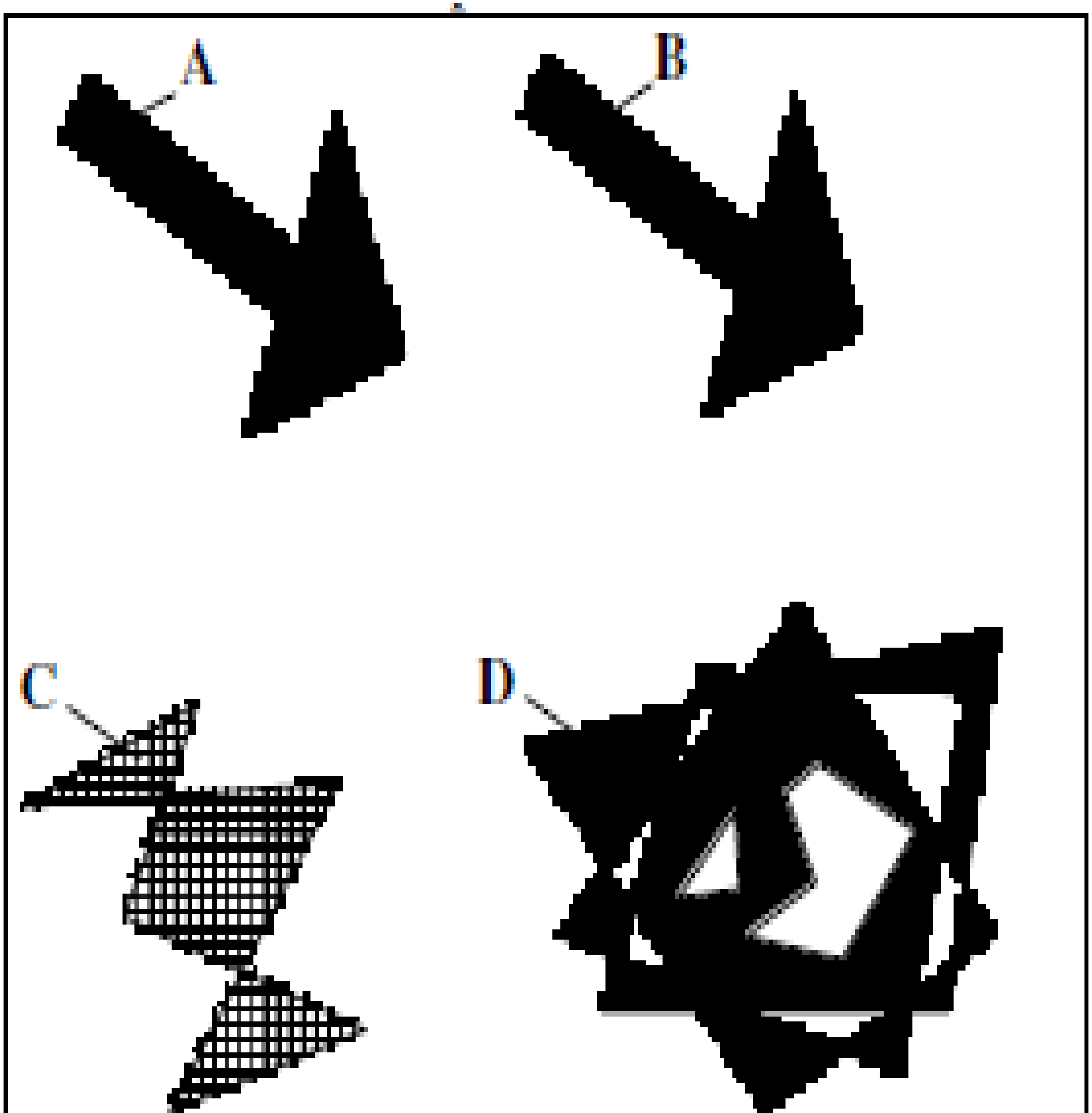
Text: Sample Fonts



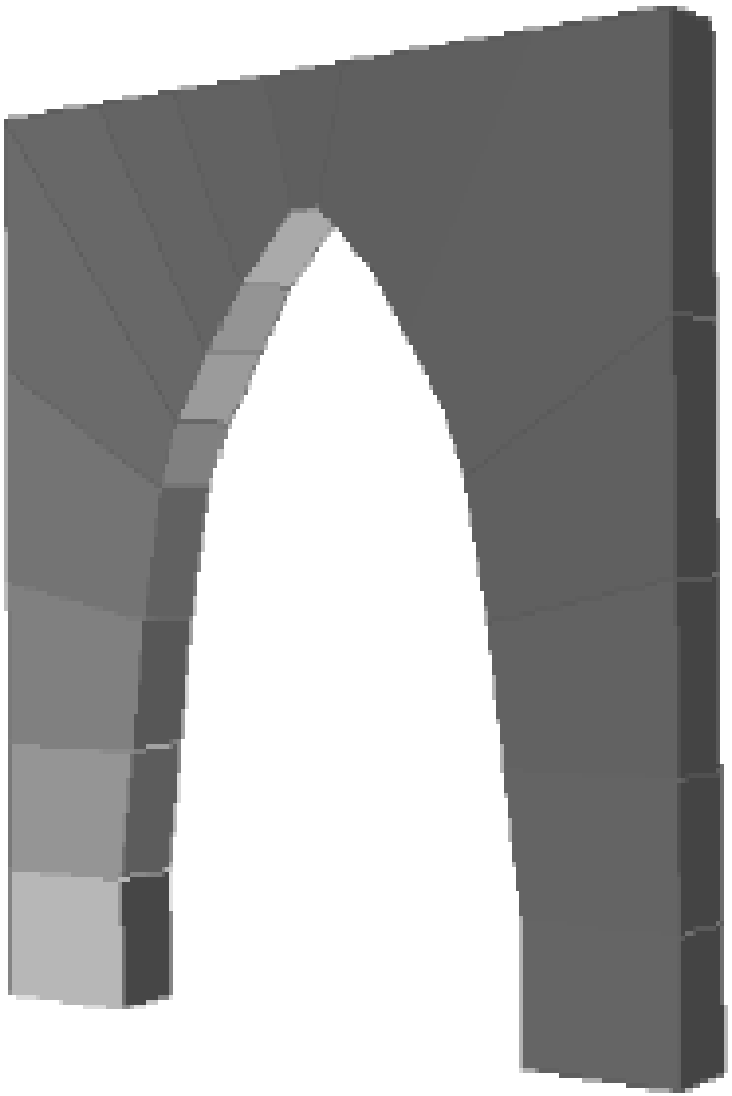
A character shape defined by a polyline and by a pattern of dots

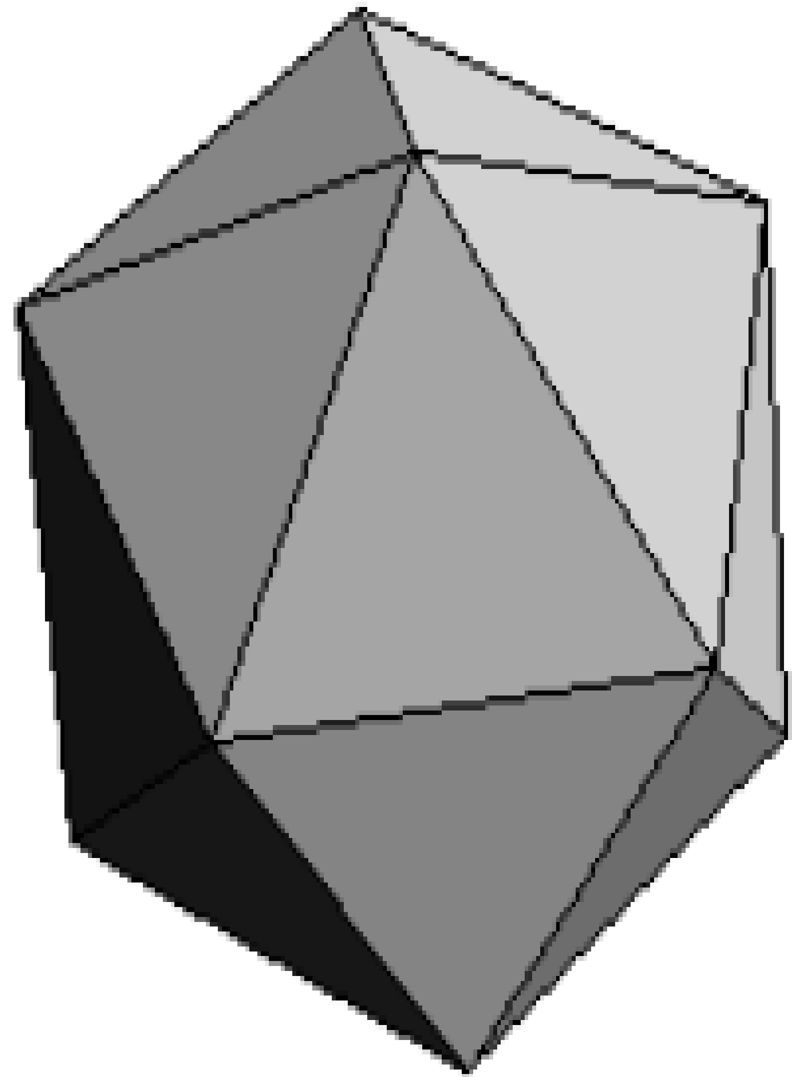


Filled Region

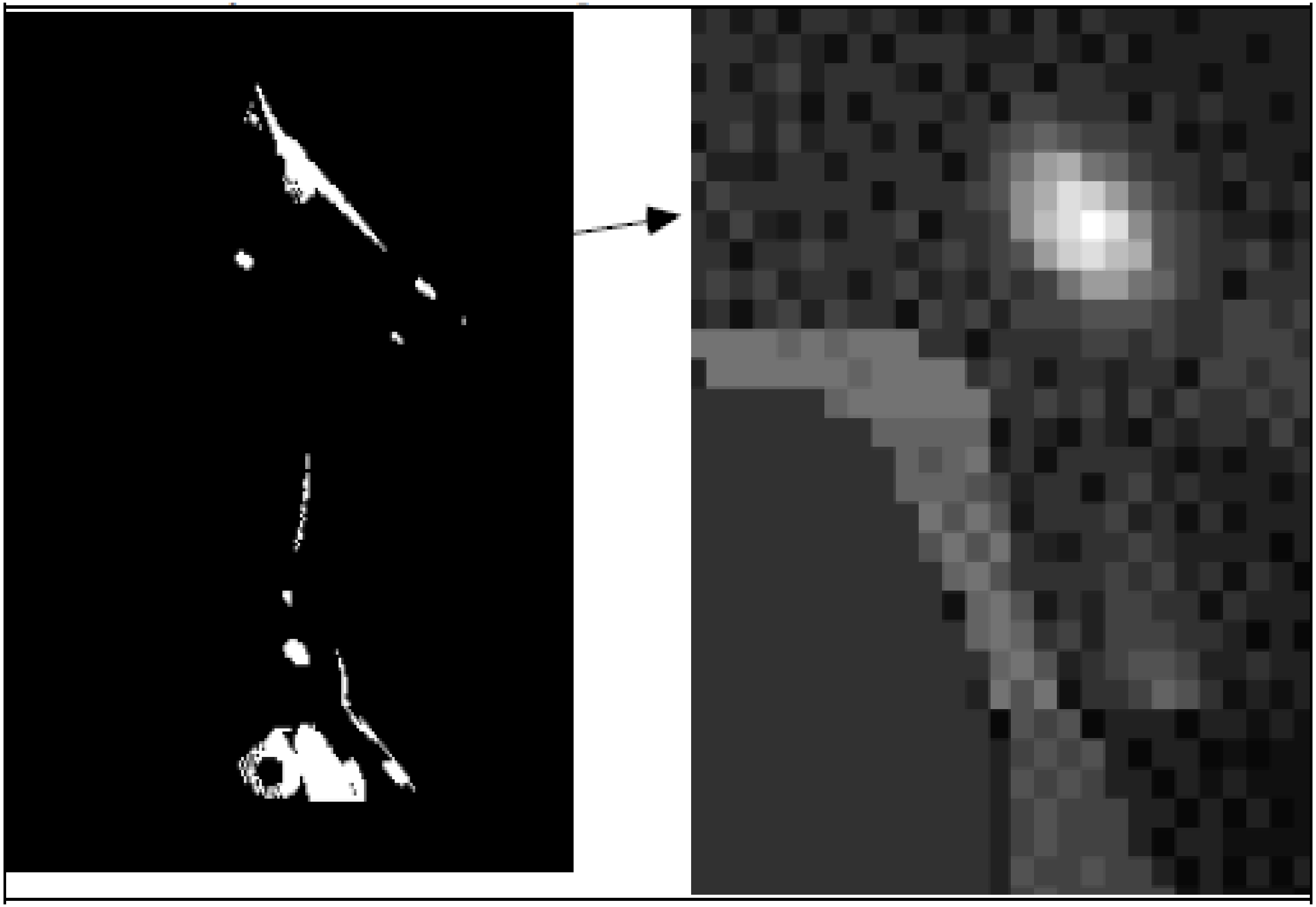


Filled Region – 3D

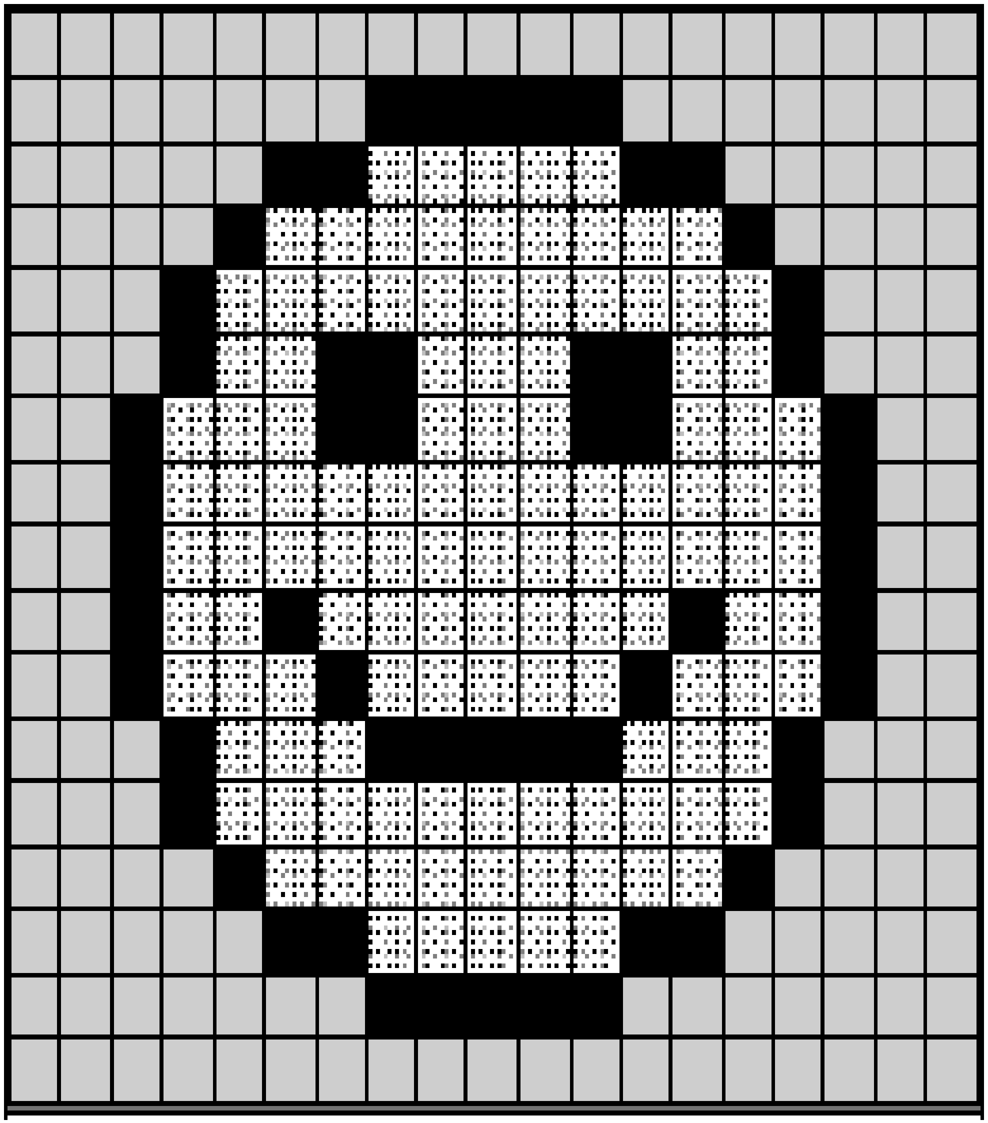




Raster Image and Zoomed one

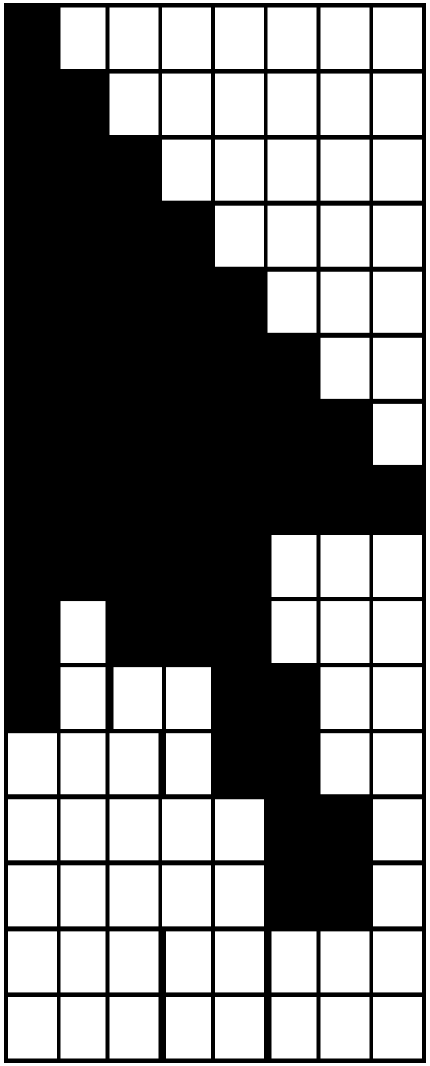


Raster Image



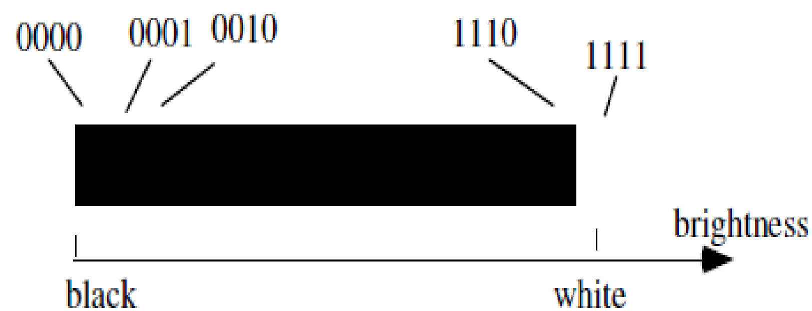
2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	7
2	2	2	2	2	7	7	1
2	2	2	2	7	1	1	1
2	2	2	7	1	1	1	1
2	2	2	7	1	1	7	7

Gray Scale Raster Image

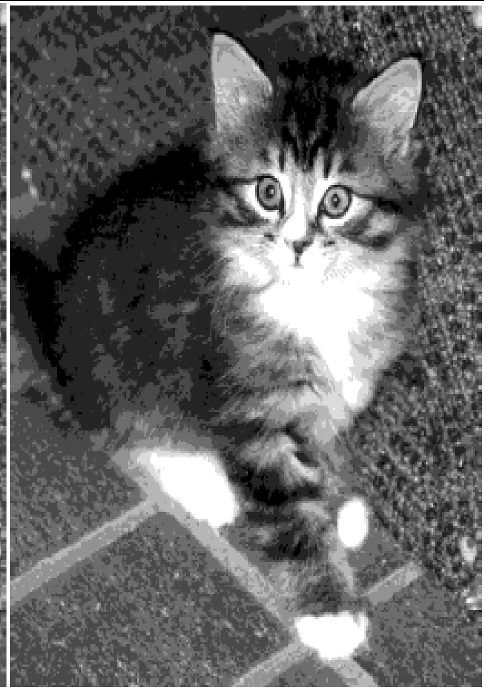


1	0	0	0	0	0	0	0
1	1	0	0	0	0	0	0
1	1	1	0	0	0	0	0
1	1	1	1	0	0	0	0
1	1	1	1	1	0	0	0
1	1	1	1	1	1	0	0
1	1	1	1	1	1	1	0
1	1	1	1	1	1	1	1
1	1	1	1	1	0	0	0
1	0	1	1	1	0	0	0
1	0	0	0	1	1	0	0
0	0	0	0	1	1	0	0
0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

- 2 bits/pixel produce 4 gray levels
- 4 bits/pixel produce 16 gray levels
- 8 bits/pixel produce 256 gray levels



Gray Scale Raster Image

Colors

color value	displayed
0,0,0	black
0,0,1	blue
0,1,0	green
0,1,1	cyan
1,0,0	red
1,0,1	magenta
1,1,0	yellow
1,1,1	white

The highest quality images, known as **true color** images, have a color depth of 24, and so use a byte for each component. This seems to achieve as good color reproduction as the eye can perceive: more bits don’t improve an image. But such images require a great deal of memory: three bytes for every pixel. A high quality image of 1080 by 1024 pixels requires over three million bytes!