Two-Dimensional Design

The Macintosh transformed design through introduction of a graphical user interface. The Macintosh included two graphical design programs: a paint program and a drawing program.
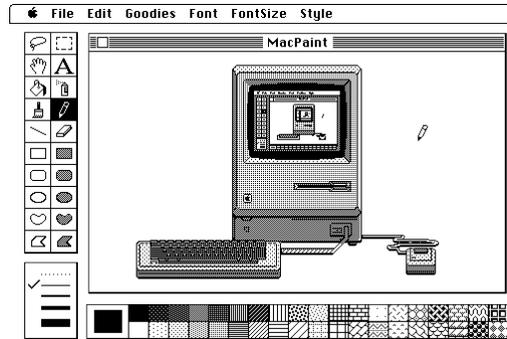

Figure 1. The Macintosh Paint Program

Although these programs appear to do similar things on the surface, dramatically different things occur inside the computer. Paint programs employ a bit-mapped format (Figure 2). The computer screen consists of a series of picture elements (*or pixels*). Paint programs record the status of each pixel in the memory of the computer. For example, a square drawn in a 10 x 10 block of pixels (left image below) is recorded as a "1" (black) or 0 (white) for each pixel. This drawing therefore consumes 100 bits of memory.
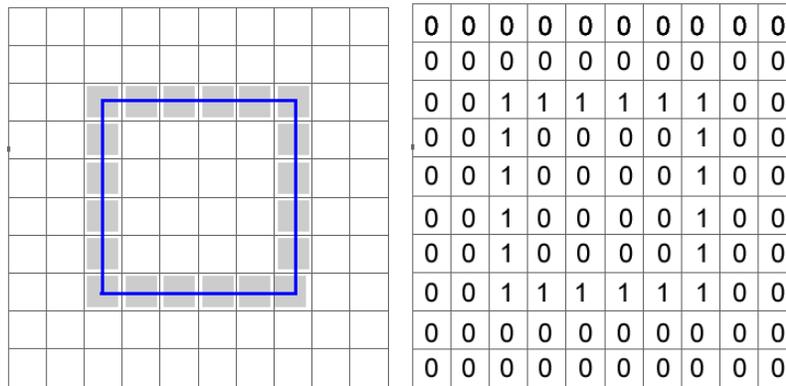

Figure 2. A Bit-mapped Representation of a Square

In contrast, drawing programs use vector information. A line is described in terms of its length and direction. Drawing the same four lines requires two pieces of information for each line.
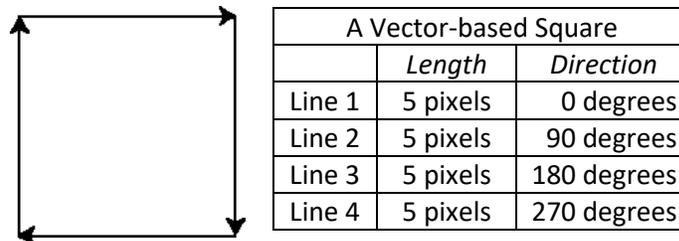
A Vector-based Square		
	Length	*Direction*
Line 1	5 pixels	0 degrees
Line 2	5 pixels	90 degrees
Line 3	5 pixels	180 degrees
Line 4	5 pixels	270 degrees

Figure 3. A Vector-based Square

This difference in the way in which each type of image is represented affects the outcomes of operations that appear to be similar. For instance, vector graphics can be resized without affecting the quality of the image. On the other hand, resizing a bit-mapped image can result in an image that is pixelated. As the size of a bitmapped image is increased, it becomes possible to see the individual picture elements. This gives the image a ragged or blurry appearance.

Figure 4. A Pixelated Image

As computers became more powerful with greater memory capacity, the distinctions between vector and bitmapped images became less evident. A bitmapped image with sufficiently high resolution can be enlarged without a perceptible effect on the quality of the image. Today many graphic design programs provide a combination of bitmapped and vector tools.

Digital Fabrication Tools

However the distinction between bitmapped and vector information is still crucial in the physical world. Digital fabrication tools such as digital cutters, laser cutters, and digital milling machines all employ a similar principle. A moving tool head guided by the computer follows a path that removes material. The information that guides the path of the tool head must be provided in a vector format.

1. *Digital Die Cutter*. A moving blade cuts out material such as cardstock or vinyl.
2. *Laser Cutter*. A moving laser cuts material such as wood or plastic.
3. *Digital Milling Machine*. A rotating bit removes material such as metal.

Digital fabrication machines that remove thicker and harder material cost more. A digital die cutter that cuts cardstock and vinyl can be acquired for less than $200. A laser cutter that cuts wood and plastic will cost $3,000 or more. A digital milling machine that can remove metal will cost thousands of dollars. Design principles learned with more affordable systems are still applicable to more capable systems.

Fabrication System	*Cost*
Digital Die Cutter	$100 to $200
Laser Cutter	$3,000 and above
Digital Milling Machine	$10,000 and above

In some cases, a programming language is used to guide the path of the tool head. In other cases, a computer-assisted design (CAD) program is used to generate the commands that direct the movement of

the tool head. In either case, a command transmitted by the computer ultimately directs the tool head to move from one point to another.

Digital die cutters provide a useful entry point into the world of 2D fabrication because they are affordable and widely available. They are often used as a kind of electronic scissors, cutting out patterns printed on card stock, vinyl, or cloth. Images and patterns can be obtained from hand-drawn or computer artwork, or from images either found on the web or acquired from a digital camera. Regardless of the means by which they are acquired, these images or illustrations are then imported into a 2D design program.

The examples in this chapter were developed using a Silhouette Portrait die cutter and the Silhouette Studio CAD software provided with this die cutter. The business edition of Silhouette Studio can export files for use with laser cutters. This makes it possible to prototype projects with an inexpensive die cutter and later use a laser cutter to implement the project with more durable materials such as wood or plastic.

The edges of the imported image must be traced, either by a person or by a computer algorithm, before the graphic can be cut out of the desired material. The proficiency with which this is done can yield very different results. The crab below was drawn on a sheet of paper by hand. The hand-drawn image was then imported into the computer by using a digital camera to take a picture of the drawing.
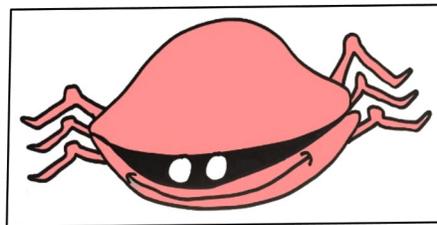

Figure 5. A Hand-drawn Crab

The autotrace function in the Silhouette Studio 2D design program was used to detect the edges of the crab. The line around the crab interspersed with vector points in the screen capture below shows the result.
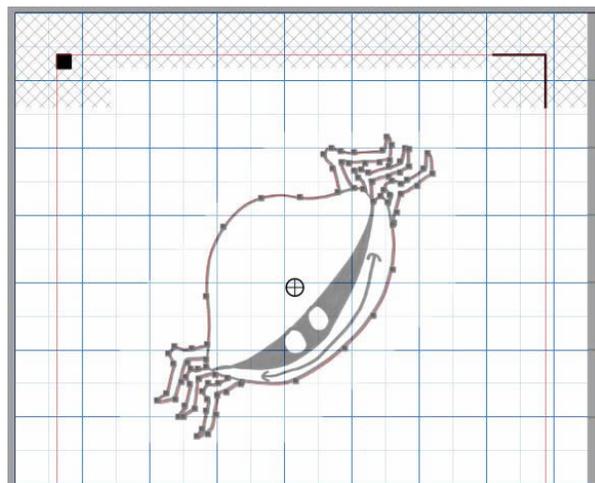

Figure 6. An Autotraced Vector Outline

The crab was then cut out of a sheet of red card stock using the digital die cutter. The computer application guided the blade of the die cutter from one point on the cut line to the next. As the illustration below demonstrates, this resulted in a figure with smooth edges.

Figure 7. Crab Printed and Cut out of Cardstock with a Die Cutter

In the example below, there was not sufficient contrast between the giraffe and its background to use the autotrace function effectively. Therefore, the designer used a vector drawing tool to place each of the points around the outline of the giraffe.
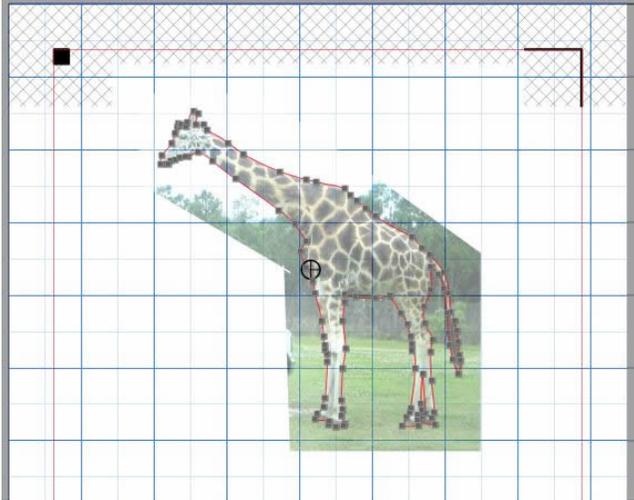
Figure 8. A Manually-Constructed Vector Outline

These vector points (as they are termed) guided the blade of the die cutter to cut out the giraffe shown in the illustration below.

Figure 9. Giraffe Cut out of Cardstock with a Die Cutter

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A different kind of mind set that might be termed *digital thinking* is useful for digital design. Most digital design programs offer a choice of vector types: line or curve. As noted above, two pieces of information are needed to specify a line: (1) direction and (2) magnitude. Additional information is needed to specify a curve. The magnitude and direction are needed, but information about the shape of the arc that constitutes the curve is also needed. In the menu below, the *Polygon* tool would be used to enclose a shape primarily comprised of lines. The *Curve Shape* tool (to the right of the Polygon tool) would be used to select points enclosing a curved shape.
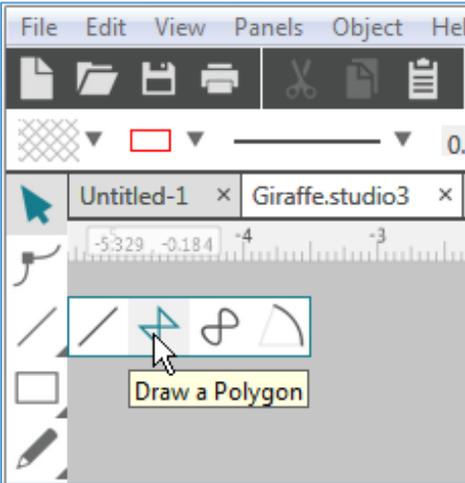
Figure 10. The Polygon Drawing Tool

These considerations do not arise when a figure is drawn with a pencil, but in the digital world, an understanding of the underlying representation can be helpful. A *Point Editor* can later be used to change individual points to refine the design.

Digital software designers make use of algorithms that enable the computer to repeat a series of operations. A similar mindset can also be advantageous in CAD design.
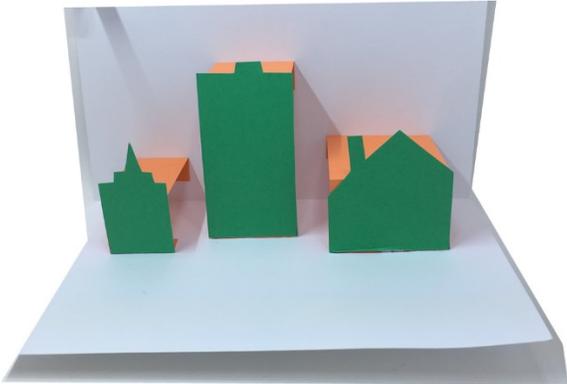

Figure 11. A Pop-up Card

The pop-up card in the illustration above displays a set of three buildings that pop up when the card is opened. Each of the buildings is connected to the card with an orange tab. The designer worked out the technique for one building and then replicated the method for the other two buildings.

A two dimensional pattern that is cut out of a material can be folded up and combined in an almost infinite number of ways to create three-dimensional objects. A fold that is creased to create a valley is called a *valley fold* while a fold that is creased to create a peak is called a *mountain fold*. The beak of the bird in the pop-up card in Figure 12 exhibits both valley folds (at the edges of the beak) and a mountain fold (in the center line of the beak).
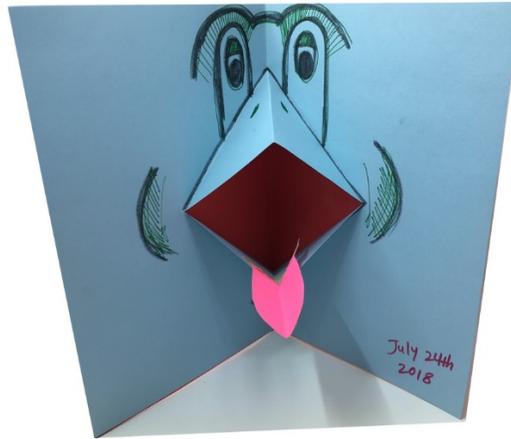

Figure 12. Mountain and Valley Folds

The Silhouette Studio design program can specify whether the die cutter should score a line to create a fold line, or cut completely through the card stock or vinyl. This allows designers to incorporate fold lines as well as cut lines in a pattern.

This ability to create score lines used to fold and bend materials facilitates creation of three-dimensional objects. The pattern is cut out of a flat sheet of material, and then transformed into a three-dimensional object using the fold lines in the design.

Figure 13. A Digitally-designed House

This can even extend to design of three-dimensional objects that move. The bevel gear in the illustration below was created from a flat sheet of card stock and folded to construct the gears.
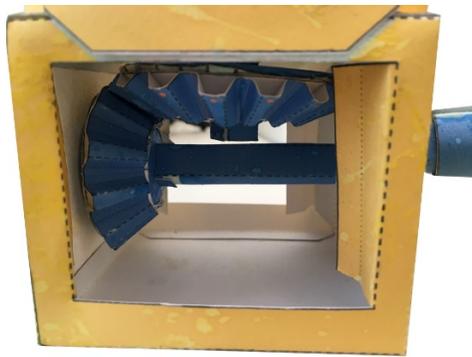
Figure 14. A Bevel Gear

Rob Ives is a teacher in England who has used this capability to good advantage. After ten years in the classroom, he has now transitioned to a full-time role as a designer, posting patterns for animated designs that move on his web site at https://www.flying-pig.co.uk.

Figure 15. Animated Die-Cut Figures

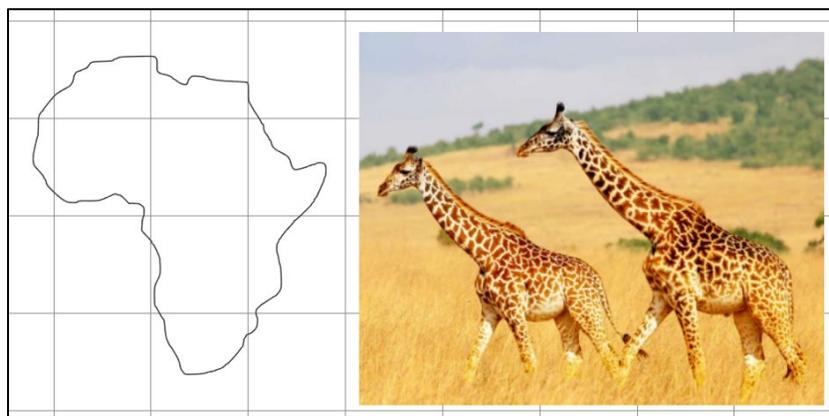Sometimes combining two graphics is useful. For example, in the illustration below, the outline of the African continent might be combined with a scene from a safari.

Figure 16. Outline of Africa (left) and Image of Giraffes (right)

The outline of the continent would first be placed over the desired area of the background image.
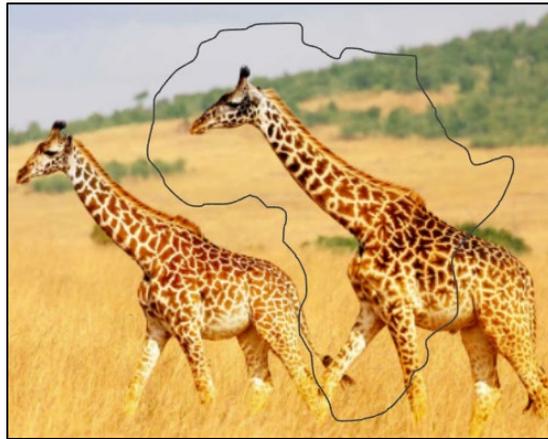

Figure 16. Outline of Africa Placed over an Image of Two Giraffes

The portions of the two images that overlap would then be combined using an *Intersect* command. Inside the memory of the computer, the design program checks each pixel of the background and the foreground images to see if they overlap. Pixels that overlap are combined, while images that do not overlap are deleted. The combined result is an image like the illustration below, creating an outline that can be printed and cut out using the digital die cutter.
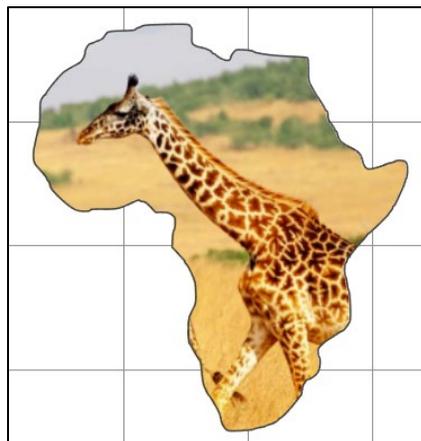

Figure 17. Outline of Africa Combined with an Image of a Giraffe

In other cases, it may be useful to combine two shapes. For example, it might be useful to combine two or more letters such as the ones shown below.
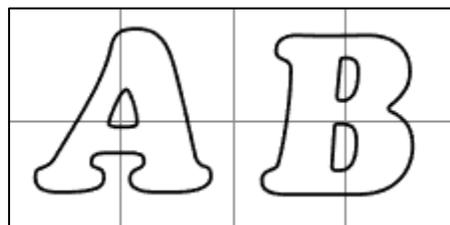

Figure 18. Outline of Two Letters

To accomplish this, the letters first must be shifted so that they touch at some point.
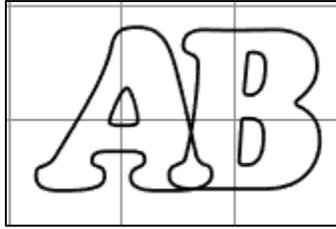

Figure 19. Overlapping Letters

The two shapes can then be combined into a single outline using a *weld* command. This makes it possible to cut them out as a single unit using the die cutter.
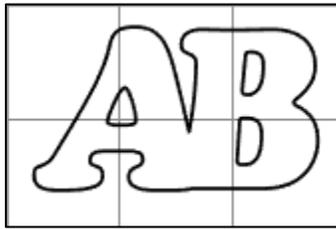

Figure 20. Merged Letters

The logic for this operation is different from the logic followed in the previous example. In this case, pixels are included in the combined result if they are present in either Image 1 *or* Image 2.

The result of one operation can then be used in a second operation. For example, in the illustration below, the letters of the word "Giraffe" have been welded together to form a combined shape.
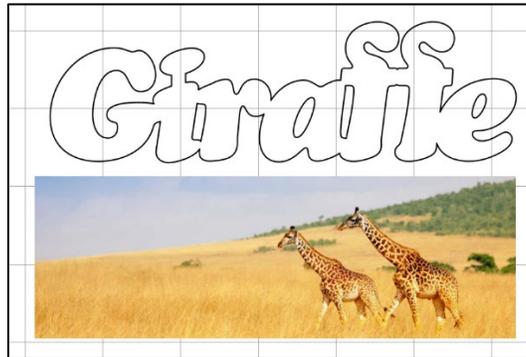

Figure 21. The Word "Giraffe" (top) and an Image of a Giraffe (bottom)

The letters of this shape can then be combined with a background image and then cut out using a digital die cutter.
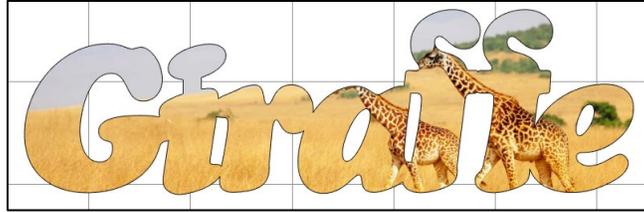
Figure 22. Merging the Word "Giraffe" with an Image

Understanding the concepts that underlie these operations can be helpful, allowing effective use of the program to achieve desired outcomes.