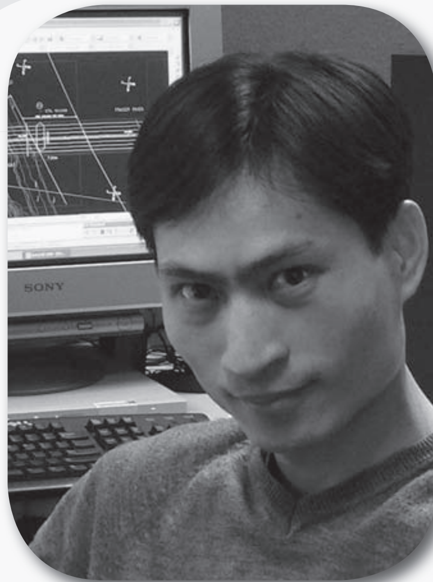
4

Beyond Words

Lam Loc



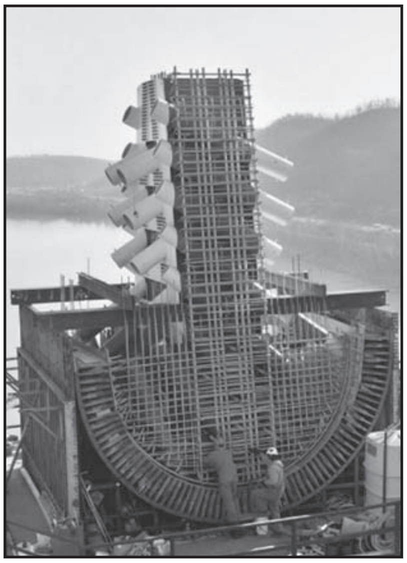
Courtesy of Lam Loc

Key Concepts
from Previous Chapters

2 Engineering Design Process
2 Communicating the Solution

Imagine using only words to describe your design for a bridge to your construction team. It's not easy! Sure, you may get across a general idea of the design, but how long would you have to talk? You'd probably be talking for a long, long time to convey all the necessary design details, such as the thickness of each steel beam, the angle of each cable, or the size of each nut or bolt. It's often said that a picture is worth a thousand words. In engineering, a picture may be worth hundreds of thousands of words—and a lot of time!

I should know. I spend my days creating drawings that help engineers communicate their ideas more effectively. My name is Lam Loc. I am a Computer-Aided Design (CAD) technician at HNTB, a firm based in Kansas City with offices all over the country.



Courtesy of Lam Loc

The company designs transportation systems, bridges, airport systems, sports stadiums, and even plans for cities. These massive construction projects require hundreds and thousands of design details.

I always saw myself working in architecture or graphic arts. Growing up in Guangdong, a province next to Hong Kong, China, I loved looking at structures and trying to understand what kinds of decisions went into their design. I even started an art club in my high school. The club members would get together to study drawing, painting, or anything to do with art. I didn't know any architects or engineers while growing up and didn't really have a clear sense of how I might become an architect myself. But I knew that if I worked hard and applied myself, I'd find a way.

After high school, I came to the United States to live with my brother, who had moved here several years earlier. I felt that I'd have more opportunities to pursue my dreams in the United States than I would have in China. When I arrived in America, I knew very little English, so I worked in restaurants and took English as a Second Language (ESL) classes at night. Over time my English improved and I began looking for an opportunity to learn about design or architecture.

I found out about a year-long CAD program being offered at the school I attended. CAD, or Computer-Aided Design, refers to computer programs that allow engineers to create precise drawings of their design ideas. I realized that learning CAD might be a good way to start working in the field of engineering. Just about every engineering and design company needs CAD technicians, people who have specialized training in using CAD systems.

In my first class, I learned techniques for drawing by hand. Our instructor would bring an object to class—say, a birdhouse or a hair dryer—and we would create precise sketches of the object. To draw an object by hand, I had to examine it very closely. In a sense, I had to learn how to look at an object in a new way, by noticing how all of its surfaces and details were oriented in space. After learning the basic principles of hand-drawing, I began studying how to create drawings using computers.

After I earned my certificate, I was hired as a draftsman-in-training by a large engineering company in Boston. I trained for a year before becoming a draftsman. After working at the same company for the next couple years, I found my job at HNTB. I love my job, even though it can get stressful at times. I sometimes work late in the evenings or on weekends to finish my work on time, but I don't mind spending my extra time drawing. Even when I'm not working, I often spend my free time designing my own website or other working design projects.

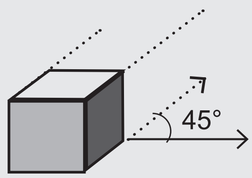
Drawing and the Design Process

Every company and probably every engineer approaches the design process a little bit differently. In large companies like HNTB, the design process is slightly different than the process described in earlier chapters. At HNTB, the design process begins when a prospective client needs to design a structure or some other system. The client may be a government agency that is planning to build a new section of highway, or perhaps a corporation that wants to construct a recreation facility for its employees. Typically, a client contacts several firms like HNTB and asks each firm to submit a proposal.

Our engineers and architects thoroughly research the client's design problem and then develop some possible solutions. They often make sketches of their possible solutions to share their design ideas with one another. Each company offers a proposal to the client, who chooses the proposal that best meets their design requirements.

That's where I come in. Instead of building a prototype, I create several three-dimensional (3-D) design drawings. These drawings are created to give the client a sense of what our design would look like and how it would function once constructed. Engineering firms used to make 3-D models of their proposed design, but building models is as expensive as it is time consuming. Using CAD software, we can create realistic drawings that illustrate a design with less cost. Design changes are less expensive, too! We simply edit the drawing on our CAD systems. We can get a revised proposal to a client quickly using CAD technology.

In an ***oblique drawing,*** the front side of the object appears flat in the picture plane and the sides and top of the object are at a 45-degree angle to the horizontal lines of the front side.



Oblique

A Matter of Perspective

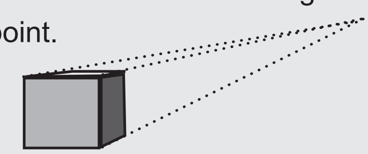
Humans have not always been able to represent 3-D objects very convincingly. In fact, before the Italian Renaissance, which started in the 1400s, artistic drawings were hardly realistic.

In an ***oblique drawing,*** the front side of the object appears flat in the picture plane and the sides and top of the object are at a 45-degree angle to the horizontal lines of the front side. These angled lines are half as long as the lines of the actual object, which creates a sense of depth. However, oblique drawings do not look very realistic.

In the early 15th century, the Italian architect and engineer Filippo Brunelleschi developed a mathematical theory for creating 3-D drawings that resulted in much more realistic depictions. Brunelleschi studied the way people viewed objects in space. A number of artists had experimented with ways to improve representations of 3-D objects, but Brunelleschi was the first to find a scientific explanation for how humans see in 3-D.

He observed that when we look at an object, the object's parallel lines appear to converge on an imaginary point on the horizon. This imaginary point is called the ***vanishing point.*** To draw an object that looks realistic, the front face of the object can be drawn as a flat, two-dimensional (2-D) shape, but parallel lines moving away from the viewer must be drawn so they seem to converge at a vanishing point in the distance. All of Brunelleschi's original drawings and paintings have been lost, but his system, called ***perspective drawing,*** has been used and further developed by many other artists.

In a ***perspective drawing,*** the lines of the object that move away from the viewer converge on an imaginary point called the vanishing point.



Perspective

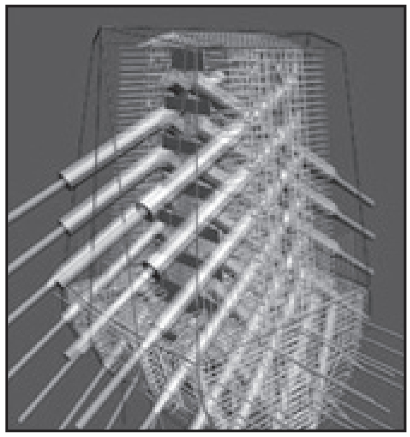
Courtesy of Wikipedia

"Marriage at Cana" by Giotto (1267–1337). This painting was made prior to the use of perspective drawing.

Courtesy of Wikipedia

"Christ Handing the Keys to St. Peter" by Pietro Perugino (1446–1524). This painting uses perspective drawing.

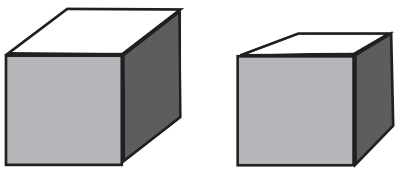
Using CAD software, I can create nice-looking 3-D images that have multiple vanishing points. Look at this perspective drawing of the top of a tower that HNTB designed for a bridge in Ohio last year. It actually has two vanishing points, which gives the impression that the viewer is looking at the object from one of its edges.



Courtesy of Lam Loc

Now, perspective drawings are a wonderful way to showcase a design to a client because they look so exciting and dynamic. But for engineers, perspective drawings have some drawbacks—the big disadvantage is that it is impossible to know the dimensions of an object by measuring a perspective drawing. That's because the sides of an object are drawn the way the viewer sees them, not at their true lengths.

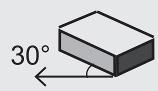
Look at the two images of a simple cube below. On the left you see an oblique drawing of a perfect cube with sides that are two feet long and two feet wide. (Remember: All sides of a cube are of equal length and width.)

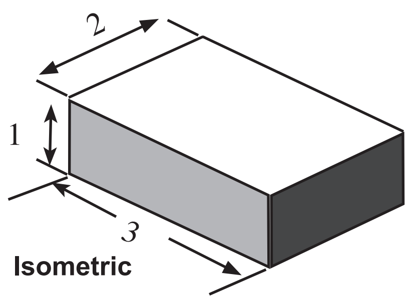


On the right you see a perspective drawing of the same cube. Do all the sides of the drawn cube appear to be the same length and width? If you used a ruler to measure the length of each side of the drawing, you'd find that they are not equal in length. In fact, if I hadn't told you that this shape was a cube, you could not have known that from looking at these two drawings.

This is why engineers depend on a different drawing method to convey information about the size and shape of an object. Engineers use an ***isometric drawing*** to represent a 3-D shape in two dimensions. All vertical lines are drawn vertically, but all horizontal lines are drawn at 30 degrees to the horizontal. The sides are not shortened as in an oblique or perspective drawing. As a result, isometric drawings of objects look a bit distorted to the viewer. Regardless of how they look, isometric drawings convey more meaningful information to the engineer than other 3-D drawings do.

In an ***isometric drawing,*** all vertical lines are drawn vertically, but all horizontal lines are drawn at 30° to the horizontal. Engineers can communicate the measurements of an object through an isometric drawing.



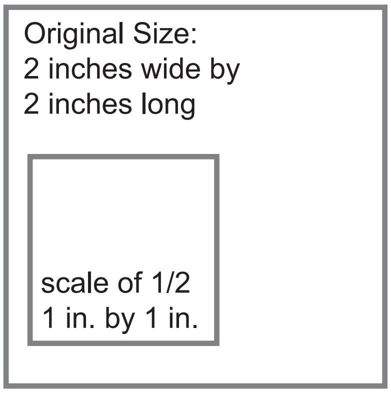


> ***Scale*** refers to the ratio of an object in a drawing to the size of the true object. The scale factor is the ratio of the size of a drawn object to its real size.

Scaling

A full-size drawing of a skyscraper or a bridge would be too big, so, I make my drawings much smaller than the true size of the object—sometimes as much as 10,000 times smaller. How do you convey the true measurements of an object when the representation is so much smaller than the object? I draw the object to scale.

Scale refers to the ratio of the size of an object in a drawing to the size of the object in real life. The ***scale factor*** is the ratio of the size of drawing and the size of the object. Suppose I want to make a scale drawing of a cube that is 82 inches on a side. If I draw the cube using a scale factor of one to ten (1:10), then each side would be 8.2 inches. If I use a scale factor of 1:20, then the each side of the drawn cube would be 4.1 inches.



To determine the length of any line I draw, I use the simple equation $x = sl$, where x is the length of a line in my drawing, s is the scale factor, and l is the length of the real object. (In equations, x is often used to represent an unknown number, while two factors written next to each other indicate multiplication.) For example:

$$x = sl$$

If $s = 1/10$

$$x = sl = 1/10 \times 82 \text{ inches} = 8.2 \text{ inches}$$

If $s = 1/20$

$$x = sl = 1/20 \times 82 \text{ inches} = 4.1 \text{ inches}$$

> The ***metric system*** is a system of measurements in which all of the units are based on multiples of ten.

Metric System Prefixes

Giga-	G	10^9
Mega-	M	10^6
kilo-	k	10^3
hecto-	h	10^2
deka-	da	10
deci-	d	10^{-1}
centi-	c	10^{-2}
milli-	m	10^{-3}
micro-	μ	10^{-6}
nano-	n	10^{-9}

For Good Measure

Our company recently got a job building a bridge in India. Determining the dimensions for the drawings of that bridge will be a little more complex. That's because people in India use the ***metric system*** for measuring lengths. The metric system is a system of measurements in which the standard unit for length is one meter. Just about every country in the world except for the United States and Great Britain uses the metric system exclusively.

In the United States, we use the British system of inches, feet, and miles for measuring—but not always. As more and more American companies and organizations work in other countries, the metric system is becoming more widely used. In fact, many scientists in the United States now use the metric system for making measurements. Engineers still use the British system, but they do use the metric system occasionally. So they need to know how to convert between the British and metric systems. At the end of this book, you'll find a conversion chart that lists various metric units and their British equivalents.

As you can imagine, it would take a long time to calculate all of the dimensions of a complex object such as a bridge or a highway. Fortunately, the CAD software does most of these calculations for me. All I need to do is enter the design dimensions, choose the scale, and select the British or metric system. Of course, this saves a lot of time, and the calculations are very accurate. Still, I need to understand how to scale a drawing or convert from feet to meters. That way, if the CAD software generates an image that is not a correct representation of a design, I can figure out why and correct the problem.

> ***Orthographic*** drawings are 2-D, or flat, drawings of each side of an object. They are very useful to engineers for communicating the dimensions of a design.

Back to Two Dimensions

While isometric drawings are very useful for communicating the dimensions of a design, they can only represent three sides of any object at a time. To view all sides of an object, draftsmen use orthographic drawings. An ***orthographic drawing*** is a two-dimensional (2-D), or flat, representation of a 3-D object using views of each side of the object. An orthographic drawing of a house is shown here.

To get a sense of how an orthographic drawing is created, imagine a house inside a glass box (1). Next, imagine standing directly in front of each side of the box and tracing the sides, top, and bottom of the house directly onto the glass (2). You now have a drawing of each view of the house drawn on the glass (3). Finally, imagine unfolding the glass box so that it lays flat (4) to give you an orthographic drawing of the entire house.

Of course, many orthographic drawings are much more complex than this one. To the bottom right is a front drawing of the same bridge in Ohio. As you can see, I put a lot of information into each drawing. In this view, I've labeled all of the dimensions of the structure. I can even use color coding to distinguish one material from another.

It's always satisfying when a construction crew successfully uses my drawings to build a structure. My drawings were the major source of information for building a tower head in Ohio. The drawings allowed the HNTB engineers to communicate easily with all the different construction contractors. Knowing that my contribution helps gives me a lot of satisfaction and makes all my hard work and late nights worth it!

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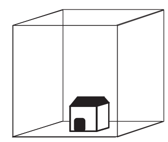

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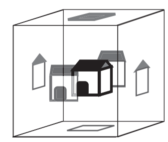

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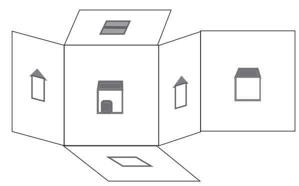

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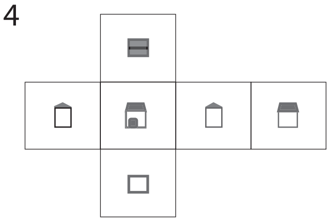

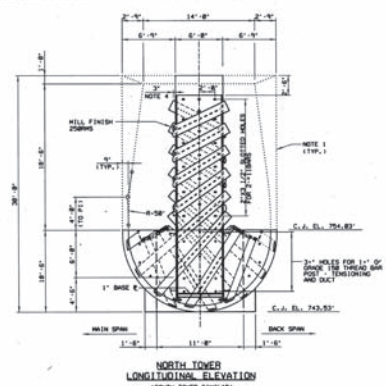

Courtesy of Lam Loc

What's the Story?

1. According to Lam, what's the purpose of engineering drawing?
2. What do oblique and isometric drawings have in common?
3. Why was Brunelleschi's contribution to drawing important? (In your answer, describe his contribution.)

Designing with Math and Science

4. On a piece of isometric graph paper, draw an isometric drawing of one of your books using a scale factor of 1:4. Be sure to list the book's measurements, and show all of the calculations you did to determine the measurements of the drawing.
5. Using quad-ruled graph paper, create an orthographic drawing of the same book using the same scale factor.
6. Use the conversion chart in the back of this book to determine how many centimeters long a football field is.

Connecting the Dots

7. How does the design process at HNTB differ from the one that Shawn and Jamy used?

What Do You Think?

8. Lam discusses how drawing helps his firm communicate design ideas to clients and construction teams. We all use drawings to communicate at some time or another. Describe a time when you used a drawing to communicate a message, an idea, or even an emotion.

Types of Drawing

Oblique

The front side of the object appears flat in the picture plane, and the sides and top of the object are at a 45° angle to the horizontal lines of the front side.

Perspective

A system for creating 3-D drawings that look realistic. In a perspective drawing, the lines of the object that move away from the viewer converge on an imaginary point called the vanishing point.

Isometric

All vertical lines are drawn vertically, but all horizontal lines are drawn at 30° to the horizontal. Engineers can communicate the measurements of an object through an isometric drawing.

Orthographic

2-D, or flat, drawings of each side of an object. They are very useful to engineers for communicating the dimensions of a design.