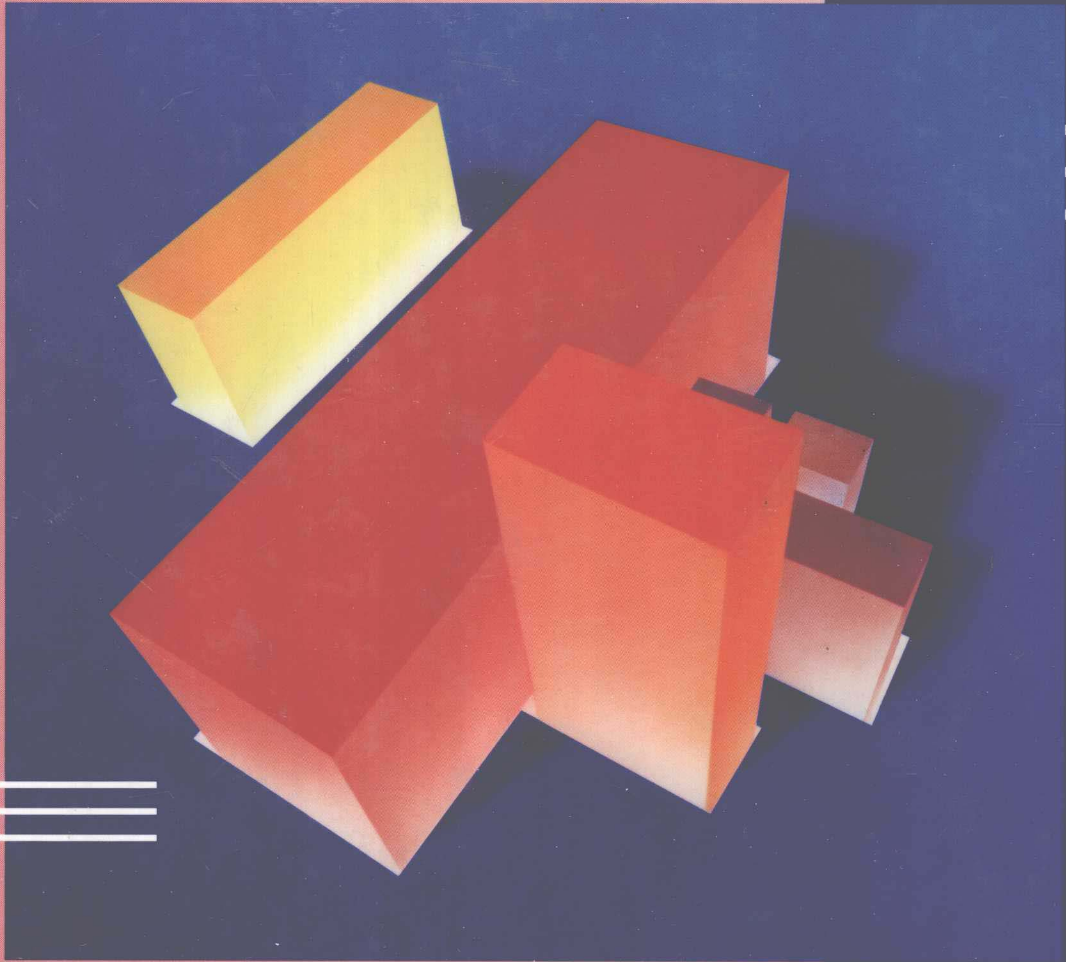
CONCEPTS OF TECHNICAL GRAPHICS

JON M. DUFF



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Jon M. Duff
Purdue University

PWS-KENT Publishing Company
Boston

PWS-KENT
Publishing Company

PWS-KENT Publishing Company is a division of Wadsworth, Inc.

Library of Congress Cataloging-in-Publication Data

Duff, Jon M., 1948–
Concepts of technical graphics / Jon M. Duff.
p. cm.
ISBN 0-534-91860-3
1. Engineering graphics. I. Title.
T353.D84 1990
604.2—dc20 89-39278
CIP

Printed in the United States of America

1 2 3 4 5 6 7 8 9 — 94 93 92 91 90

Sponsoring editor: Jonathan Plant
Production editor: Pamela Rockwell
Manufacturing coordinator: Marcia Locke
Production services: PC&F, Inc.
Interior design: PC&F, Inc.
Cover design: Julia Gecha
Cover art: James E. O'Neal
Interior art: Jon M. Duff
Typesetting: PC&F, Inc.
Cover printing: Arcata Graphics/Halliday
Printing and binding: Arcata Graphics/Halliday

Concepts of Technical Graphics

PWS-KENT Series in Engineering

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Preface

The field of technical graphics enjoys a long and rich heritage in the textbooks that have been used in the training of engineers, technologists, and technicians. Many educators have spent their entire professional lives perfecting and documenting their approaches to teaching technical graphics. Why, then, would yet another decide to enter the field by writing a new technical graphics text?

The past twenty years have seen major changes in the manner in which technical graphics is produced, stored, retrieved, transmitted, and evaluated. Each major revolution in the graphics technology renders obsolete the texts that were based on the previous technology. But the part of those texts that does *not* become obsolete is the *theory* of technical graphics, which is independent of the current technology used for displaying, storing, retrieving, transmitting, and evaluating the graphic image.

Beyond that, I have found that while technical graphics is being *used* by more and more individuals in our technical society, it is actually being *produced* by fewer and fewer. This text is aimed at helping the reader understand the fundamental theory of technical graphics. It is not intended to replace existing texts used to train drafting technicians and technologists. Instead, *Concepts of Technical Graphics* is intended for those who will receive but one course in the subject and for whom drafting skill is not an appropriate or desirable goal.

The focus of *Concepts* is the body of graphics knowledge that is independent of paper and pencil. Why is it important to present the subject matter in this way? Because we have seen drafting technology change dramatically in the past ten—even five—years. Equipment available today wasn't even dreamed of a year ago and will probably change again in the next twelve months. As educators, we must teach our students to think about graphics in a way that doesn't confuse its techniques with its concepts.

Some might say that graphics *is* technology dependent and so must be linked to the state of the art. This view rejects the idea that a body of knowledge called technical graphics exists just as certainly as a body of knowledge called chemistry or mathematics or physics. Each of these subjects exists independent of laboratory technology because its body of knowledge is so well defined that even major technological changes do little to alter it. I suggest to you that the same is true of technical graphics. (Many graphics teachers have acknowledged this for years, even though their texts have not reflected it.) For that reason, you will not find passages in *Concepts* covering equipment, supplies, drafting methods, or procedures. Manual drawing will not be covered, nor will computer drawing. The fact of the matter is that it is unimportant how or on what equipment graphics are produced. What is important to learn is that the part of graphics that is technology-independent—transportable in any situation, with any equipment.

To accommodate a variety of teaching methods, *Concepts* is coordinated with three parallel workbooks. For a freehand drawing approach, the text may be used with *Freehand Exercises in Technical Graphics.* This workbook is especially effective for engineers who will move on to a CADD course. Drafting technologists may prefer to use *Mechanical Exercises in Technical Graphics.* This workbook develops mechanical board drafting skills coordinated with methods outlined in *Concepts.* Finally, *CADD Exercises in Technical Graphics* is ideal for those students who will take only one computer graphics course. This workbook features problems that can be used with *any* computer graphics system.

If you are taking a course in manual drawing, you should find that *Concepts* covers the topics normally presented in lecture and provides a solid foundation for subsequently *applying* the knowledge on a drafting board. If you teach a freehand approach to graphics, *Concepts* contains the core without the baggage. If your school has replaced manual graphics with computer graphics as the basic course, *Concepts* presents the theory behind the graphics you'll find on *your* computer system. You can also *teach* technical graphics using this text and the workbooks together with the support documentation provided with your computer graphics equipment. Finally, if you teach a course in computer graphics to students who haven't all taken a previous course in technical graphics, you may find that some are unable to understand or appreciate what they are seeing on the screen. For these individuals, *Concepts* is the perfect complement to the computer instruction.

The knowledge of technical graphics does not depend on the particular "drafting standards" that are current at any given time. Standards are important in the *practice* of technical graphics, but the theory of technical graphics is independent of the particular standards in use. Drafting standards are being updated monthly, with major changes taking place every several years. Some companies adopt one set of standards; others embrace something quite different. Two of the fastest-changing topics are dimensioning and tolerancing.[1] Yet the *concepts* of dimensioning and tolerancing do not depend on which standard is in effect at a given time. For this reason, students should study the *theory* of dimensioning and tolerancing before they learn their *applications* to a particular standard. The same can be said concerning the argument about which system of measurement should be adopted – SI or English Standard. *Concepts* takes the position that it is unimportant what units are assigned to the graphics, that the graphics exist independently of the particular units assigned to an image. This is all the more true for automated systems, where scaling a model is the very last step before it is sent to a printer or plotter. It has been my experience that students, especially college freshmen, have difficulty not with fractions, decimals, or the metric system but with the *concept* of measuring and scaling. The concept and its resident problems exist independent of the English Standard or the metric systems.

The *Concepts* approach to text organization is slightly different from that of other graphics texts. Each chapter has an overview of the chapter topic that is intended for general reading. It introduces each concept, establishes definitions, and gives examples. It does not present the technical aspects of the subject. Rather than having to read text, flip to figures for explanation, and then turn back to text again, the reader will find the teaching part of the book in the figures and their captions. After reading the general chapter text, the student is advised to seek out those figures that present the graphics topic of particular interest. The accompanying caption discusses that and only that topic.

Concepts of Technical Graphics is not intended to be a reference book on engineering drawing. Many fine reference texts are available to all students studying the subject. There are also vendor-supplied catalogues and brochures that are collected and distributed as reference books. All of these present the *technology-dependent* aspects of technical graphics and should be used along with *Concepts.* These references are frequently updated by the vendors. Some subjects not found in this book might be considered glaring omissions, namely, dimensioning, tolerancing, and manufacturing procedures. But these topics are not graphics topics in the same sense as the graphics discussed in this book. Rather they are the domain of what is *done with* the concepts of technical graphics; they are best handled in applications courses.

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[1]These two areas are not technical graphics topics and are better covered in textbooks on manufacturing.

What I have concentrated on in *Concepts* is teaching the body of knowledge of technical graphics. To that end, I have assembled presentations used by some of the most successful graphics teachers in the country. I hope they are as helpful to you as they have been to others.

For the most part, *Concepts* should seem familiar to you, yet it represents a fundamental change in the way the core of technical graphics is taught. As I tell my students, "I'm not interested in whether five years from now you will remember the proportions of an arrowhead, or specific line weights, or drafting standards, or conventional drafting symbols. You will learn these as the need arises. What I intend to do is alter forever the fundamental way you *think* about technical images. This new way of thinking about technical graphics will give you the conceptual tools to adapt to any change in the technology and grow with it."

Jon M. Duff
Purdue University

Acknowledgments

The author is grateful to the following reviewers for their helpful suggestions:

Eric Haffner
Western New England College

William C. Koffke
Villanova University

John Jensen
Marquette University

Francis Mosillo
University of Illinois at Chicago

Introduction

What Is Graphics?

The making of visual images to communicate ideas, feelings, information, or history is a solely human activity. Long before the human race developed written language, visual images were used to communicate ideas. Today, written language has become the primary tool for communicating thoughts and ideas. But using words to describe the visual world is inefficient. Writing is essential for discussing concepts, meanings, or feelings—things that generally do not have form. But for things that do have form, a *visual image* can capture the necessary information and present that information in a form more naturally associated with the subject. So we talk about things that may have no form, and we create images of things that do have form. Rather than talk about color, we show color. Rather than talk about form or texture, we create a pictorial representation of texture and form.

Just as a person must be literate in order to understand written language, a person must be taught to understand information presented in graphic form. Visual literacy is one subject children should study in an organized fashion from a very early age, but because our world depends so heavily on written language, the development of visual literacy is pretty much left to chance. This neglect is not crucial for most people, but for those whose lives and professions require skill in the creation and analysis of visual information, visual literacy is a necessity. This book is intended to help the student learn to "read" our visual world.

What Is Technical Graphics?

If there is a thing as technical graphics, there must be a nontechnical graphics with which to compare it. Nontechnical graphics includes those graphic arts that concern themselves with the decorative and philosophical aspects of the visual world. They reflect the skill and subjective feelings of the visual artist and are very difficult to analyze and evaluate. The human race has long used this form of visual imagery to express joy, sorrow, political and religious beliefs, and to stretch its perception of its own humanity. These are all valuable human activities and will continue to be an important part of our visual history. Technical graphics, however, is a different class of visual expression. The people who create technical graphics do not express joy, sorrow, or personal beliefs. Instead, they are setting down, in the form of visual images, to the best of their ability and using the tools available, the most accurate descriptions and representations of existing or imagined physical objects. The ability to set these down in a unambiguous form assures that their geometric representations will be clearly understood by others of similar background and training.

The concepts of technical graphics have existed almost unchanged for over two thousand years. For this reason there exists a *body of knowledge* unique to technical graphics that can be taught and learned. Essentially, this body of knowledge is composed of three parts, the first of which is the subject of this text:

1. The representation of shape (visual geometry).
2. The representation of size and attributes.
3. The representation of operations.

The Representation of Shape

Most of this text is devoted to the theory of shape description. Technical graphics represents the world as it actually exists. Visual art encourages interpretation. A good example of this is in the use of perspective. We spend our lives viewing the world in perspective. Visual artists document this view with perspective images that might show, for example, a building off in the distance that is *smaller* than one much nearer the viewer. Of course, we know that buildings of the same height remain the same height (they don't actually shrink!) no matter how near or far away they might be.

Description of Size and Attributes

Technical graphics is even further removed from nontechnical graphics in the manner in which size and attributes of objects are shown. Because the images are to be used for some practical purpose—design, manufacturing, construction, bidding, service, or maintenance—there can be no debate as to their dimensions or their materials. Visual art allows many interpretations. Technical graphics allows only one.

The Representation of Operations

Because technical graphics must communicate not only shape and size but also how to change material from one size to another and from one surface finish to another, these functions must be communicated either graphically or verbally. Combining shape, size, and operational description makes technical graphics the powerful communications tool that it is.

Why Do We Make Technical Graphics?

We have already established that technical and nontechnical graphics evolved for entirely different reasons. For what, then, do we use technical graphics? It is used for three basic purposes:

1. Design
2. Documentation
3. Persuasion

Design

Technical graphics is used to design solutions to technical problems. It is used in far more areas than just engineering, architecture, and technology. It is used in medicine, science, law, and theology. Technical graphics, used as a design tool, allows a designer to "get down on paper" ideas that are difficult to explain in words. Very loose or unstructured concepts can be structured and clarified. A designer might have an idea for a certain shape to be used to connect two other shapes. But until that shape is put down, looked at, and compared to the original conception, little can be said about the merits of the design. In the early stages of design, the technical graphics are rough and fast; sometimes the rougher and faster, the better, because the most profitable time the designer spends in the early stages of design is on exploration rather than on refinement. So get it out! Scribble and sketch out one idea after another, allowing your pencil to literally be the output device for your brain.

But of course you'll have to stop this idea-flushing at some point and start comparing alternatives. You'll will have to stop comparing and analyzing and put your most promising solution to work. At this point it might be said that the design activity basically stops and the engineering activity begins. In general, the design activity follows these steps:

1. Free exploration of possibilities without an overriding concern for feasibility.

2. Comparison of alternative solutions, based on identified criteria.
3. Choosing the most promising possibility and executing the engineering to make it work.

Documentation

Most technical graphics that an engineer, technologist, architect, or manager sees are *documents.* How do these differ from design graphics?

Documents are not constantly changing. They may be revised or updated, but only under a very controlled set of rules. Where design graphics is often very personal and unstructured, document graphics is just the opposite. A typical goal would be to put 50 different people to work on a project and, when it was done, be unable to tell the work of one person from that of another.

Many graphics teachers and practitioners have proposed that technical graphics is a *visual language,* and that it must follow strict rules of grammar, syntax, composition, and spelling similar to those of written language. Unless the language of technical documents were rigorously standardised, they would be as indecipherable as something written by an author who had created his own rules of spelling and syntax. If you have ever read something written by a very young person or by a foreigner who knows little standard English, you know what I mean. Another example of a structured language is computer programming language. A language interpreter or compiler is most unforgiving when it comes to demanding an exact and predictable form of communication. Technical graphics has not arrived at that point yet, although it is approaching that level of precision in its use of scanning and optical character recognition. As long as humans make and interpret technical graphics, however, there will be both the chance for human error *and* the possibility for better human communication.

Persuasion

This last purpose goes beyond mere communication. It influences what is to be done with and to the subject of the technical graphics. A document might communicate *how* to assemble parts in a certain order. Persuasive images attempt to show *why* those parts should be assembled in a given order. Persuasive graphics are generally not engineering documents, which are generally used for communication and control. Persuasive graphics are used to present the design for approval, present data or information for decision-making, or to influence the purchasing, use, servicing, disposal, or acceptance of a product or concept. There are very few rules for this kind of graphics, though technical documents are often used to persuade.

This text deals with technical graphics. It does not deal with design and marketing. The technical graphics techniques presented in this text are used for design and marketing, but those subjects are better left to their own texts.

The Tools of Technical Graphics

Because this text is intended to be *technology independent,* specific tools and techniques will not be discussed. Whatever the technology, there are certain general classes of tools and techniques that are characteristic of all technical graphics technologies. These general classes of tools are used for:

1. Creation
2. Review
3. Editing
4. Storage
5. Retrieval
6. Transmission

Whether we are talking about manual graphics drawn on paper or computer graphics created on a screen, these six classes hold true.

Image Creation

Somehow the concept must be given form. By far the best way to do this is to have the image already available in the form of:

- a drawing.
- an underlay you can trace over.
- a template you can trace inside.

If none of these are available, original graphics must be created using:

- a repertoire of geometric primitives, such as lines, points, circles, arcs, curves, and so on.

You can see that the closer the primitives are to the final image, the more efficient the process will be. From already having the image on the top end to having to create each piece of geometry on the bottom end–this is the range of image-making, whatever the level of available technology. It would be worse only if you had to actually make the equipment necessary to make the graphics. Manually, this would involve making your own pencils, scales, triangles, and templates. Electronically, this would mean writing your own computer programs to make lines, arcs, curves, and so on.

Image Review

After a graphic has been made, it often needs to be compared to other images for compatibility or sent to be reviewed by other individuals. This means that the graphic needs to be:

- put in a form that protects the original.
- copied into a medium that allows underlays/overlays.
- enlarged or reduced as needed.

There are several reasons for protecting the original. First, since there is an investment in time—and that means money—the original is valuable. It also becomes the *base* for subsequent versions and must not be lost. Besides, each time it is copied, there is a certain amount of degradation. Changes that are made must be noted and controlled. A change may change the identification scheme of the graphic—its name or title, identification number, file name, extension, or version.

Image Editing

After review, changes are often called for. These changes can take the form of:

- changes in the original.
- changes in a copy of the original.
- adding to the graphic.
- deleting from the graphic.
- merging existing graphics with the image.

When you edit, you alter the image. You can take out linework or text by erasing or deleting; you can add graphics by overdrawing or merging. Manual merging can be done with scissors and tape. Electronic graphics merges one *drawing file* with another. Once changes have been completed, the new graphic is reviewed and, if passed, entered into the archival storage system.

Image Storage

A graphic that is "in the system" can be accessed by referring to the unique identification number/name associated with that design. If a drawing is not in the system, it is of limited use. The greater the accessibility of the graphics, the more powerful the system. Storage systems usually have these characteristics:

- a deep archive, usually removed from the workplace
- a working file, easily accessed by everyone
- methods of copying from the file
- procedures for, but controls on, replacement in the system

Not only is it important for each graphic unit to be locatable within the system, it is important that it have a logical and meaningful identification associated with it. It would be advantageous, for instance, to be able to get to all technical images related to one another by any of several critieria, such as product, material, date of design, cost, and so on. In order for this to work efficiently, an overall plan or structure must be in place so that all entries are archived according to these criteria.

Image Retrieval

If the graphic is in the system but you can't find it, or if once you do find it you can't get a copy of it, the system isn't working very well. The components of image retrieval are:

- identifying the graphic you want.
- finding that graphic.
- getting a copy of that graphic.

It is often difficult to find the image you want, especially if the system has several million entries. This is where a well-defined title and identification scheme really helps. It may be advisable to keep a log or possibly a book of reduced copies for quick reference. Finding what you need should not be difficult *if* the archive system is well maintained. It is not uncommon for material to be missing because individuals have borrowed and not returned originals, microfiche, diskettes, or tapes. Remember, when you get data from a system, you get a *copy* of the information and not the original.

Drawing Transmission

Getting graphics from one place to another is an important aspect of using technical imagery. It may be as simple as showing your fellow worker or your boss your design, or it may be as complicated as sending critical data by satellite to a remote drilling site in an undeveloped part of the world. Of course, a *copy* of the graphics is sent, not the original. The quality of the images depends largely on the equipment used. It does no good to send substandard images just to save time or money. A copy of a technical document must still be able to communicate its technical information or it's useless. In transmitting technical graphics, take the following into consideration:

- the need for the technical graphics
- the ramifications of getting/not getting them on time
- the cost of transmission compared with the cost or importance of the project.
- the form of the transmitted document in terms of readability, scale, and reproducibility

If you study the concepts presented above, you will be able to apply them to any job, whatever the level of sophistication of the technology available for making, editing, storing, retrieving, or transmitting an image. And that will make you a flexible and productive employee.