Using Variational Design to Reinforce Dimensioning Concepts in Freshman Graphics

by Dennis Stevenson, P.E.
University of Wisconsin-Parkside

Introduction

Dimensioning has traditionally been one of the most difficult topics for most freshman graphics students. The concept issues are difficult, abstract, judgement-based and filled with interdependencies. At the same time, there is an increasingly limited amount of time that can be spent on such topics in order to make room for new materials. The instructor had tried to teach students a brief system of dimensioning rules for a number of years, with the hope that students would not embarrass themselves too badly when taking their drawings out to the shop.

Results have been marginal at best. The author suspects that the "forgetting curve" was rather steep for these rules, falling rapidly after the exam.

Project

Recently, it was decided that some additional topics should be added to a freshman graphics course for engineers. One of these was a general introduction to parametric and variational design. Since a basic component of variational design relies on dimensioning, the author decided to experiment with combining these topics. This paper reports on the implementation and results of the "experiment."

Variational Design Objectives

After some initial testing and reflection, it was decided that students should be able to add dimensions to control the shape of a given two-dimensional profile, and then adjust the dimensions to obtain a desired shape and size. At first, a commercial CAD program was used. However, it was abandoned for a special program, written just for this purpose, in order to ease demands on student's time.

Profile Shape but not Size

Students are given a part profile, figure 1, with a number of available dimensions for them to use to define that profile. This diagram shows the shape of the profile but not its size. The sized profile will be shown in be space underneath the profile as control dimensions are selected. The program has six such pre-defined profile exercises like this one. Since this is a simulator, it is not possible to define additional profiles.

State of Dimensions

Each dimension can have one of two states: control and reference. A control dimension fixes the size of the corresponding part feature, while a reference dimension reports the size of the feature. Control dimensions are the ones that normally appear on drawings, and are used in manufacturing to make and inspect the object. Reference dimensions, on the other hand, are shown less frequently on part prints. They are derived values that are based on current sizes of control dimensions. If a designer wishes to change a reference dimension, the appropriate control dimensions must be adjusted, or the dimension switched from a reference to a control state. In the given profiles, students determine whether each dimension will be a control or a reference dimension. Initially all dimensions are reference dimensions.

State of Definition

At any time, a profile must be in one of three possible states: undefined, over-defined or defined. An undefined profile does not have enough control dimensions to completely fix its size. An over-defined profile has too many control dimensions, such that some of them could potentially conflict with each other. A defined profile has just enough control dimensions to determine its size. There are many different combinations of control dimensions that could be used to establish a defined profile, choosing from the ones available in the profile diagram.

Students select control dimensions using the controls grouped in the upper right of the window. A diagram of the profile is drawn in the lower left, as much as the currently selected control dimensions will allow. In figure 2 dimensions A, B and C define the bottom, right and top of the part.

In figure 3, enough control dimensions have been added to completely define the profile. All control and reference dimension values are listed. These initial values can then be changed to suit the designer's purposes.

Vary Design

At this point, students can begin to change the values of control dimensions using "smaller" and "larger" buttons, while observing the results on the size of the profile. Values of reference dimensions may be seen here, also. Students are given as objectives a particular ratio of sizes, area constraints or other goals as mini-design problems. Often they must select a set of control dimensions that will cause a specific variation in the profile when one key dimension is changed. Interestingly, since there are so many possible permutations of control dimensions, the only way to grade student's result is by testing its behavior.

This process is the heart of variation design, where the designer makes selected changes, and the computer maintains predefined relationships among other parts of the design. In this example, predefined relationships include the circular radius tangent to left and right sides, horizontal and vertical features, etc. as well as the student-selected control dimensions.

It is possible to vary control dimensions to the point that the defined geometric relationships break down. At this point, be computer is no longer able to do its part in the variation design endeavor, the design becomes "inverted" and the process stops.

Examples and Conclusions

Figures 3 through 5 shows some possible outcomes for this profile. This variational design material was introduced prior to a discussion of dimensions. Afterwards, students did better than expected on dimension exam problems, at least so far as fundamental concepts are concerned.

Most major graphics texts in engineering emphasize a standard manner of applying dimensions to drawings, with ANSI Y14.5 and related material as the focus and model.[1,2,3] The approach reported here is somewhat different in that its initial concentration is on the relationships between changes in dimensions and the intended impact on the design. One model of such a relationship is the foundation of a varational CAD design package such as Autodesk Designer.[4]

Standards and conventional practices should not ignored, or course, but it appears to be helpful to provide the engineering students with a framework of logical relationships to deal with dimensioning concepts, in addition (and prior) to these standards.

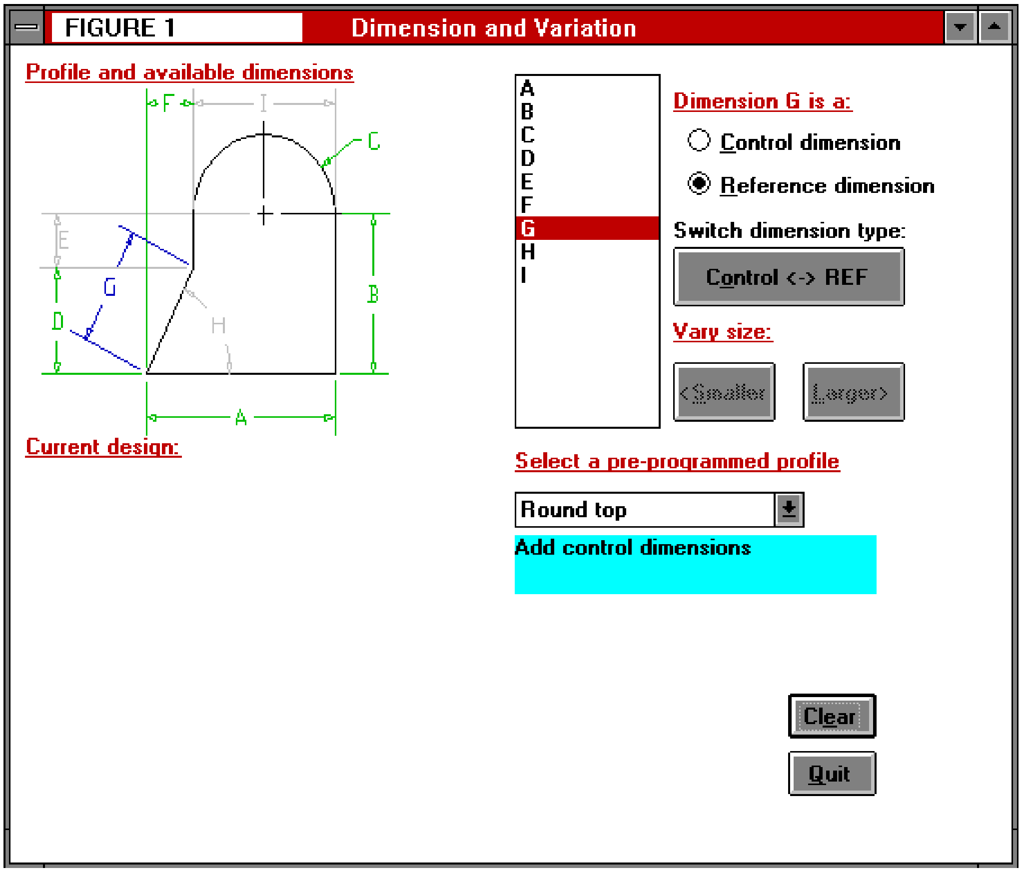
FIGURE 1
Dimension and Variation
Profile and available dimensions
F
I
C
E
G
D
H
B
A
Current design:
A
B
C
D
E
F
G
H
I
Dimension G is a:
Control dimension
Reference dimension
Switch dimension type:
Control <-> REF
Vary size:
<Smaller
Larger>
Select a pre-programmed profile
Round top
Add control dimensions
Clear
Quit

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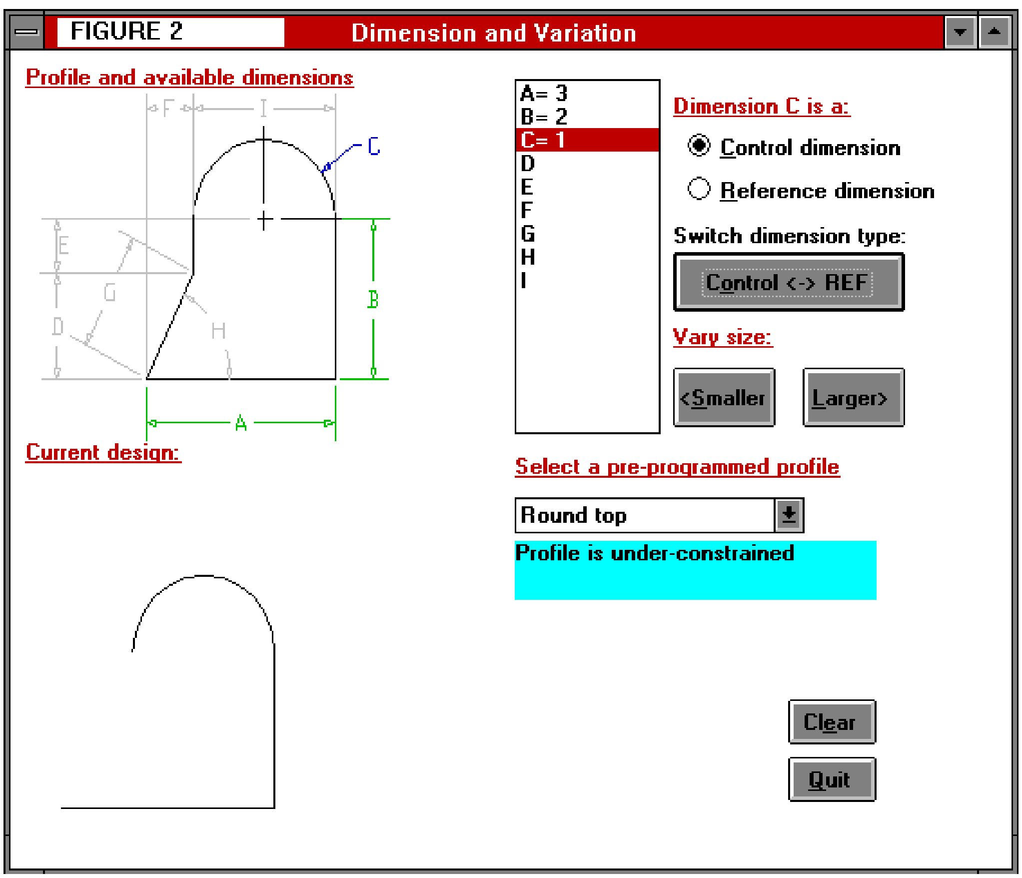
FIGURE 2
Dimension and Variation
Profile and available dimensions
F
I
C
E
G
D
H
B
A
Current design:
A= 3
B= 2
C= 1
D
E
F
G
H
I
Dimension C is a:
Control dimension
Reference dimension
Switch dimension type:
Control <-> REF
Vary size:
<Smaller
Larger>
Select a pre-programmed profile
Round top
Profile is under-constrained
Clear
Quit

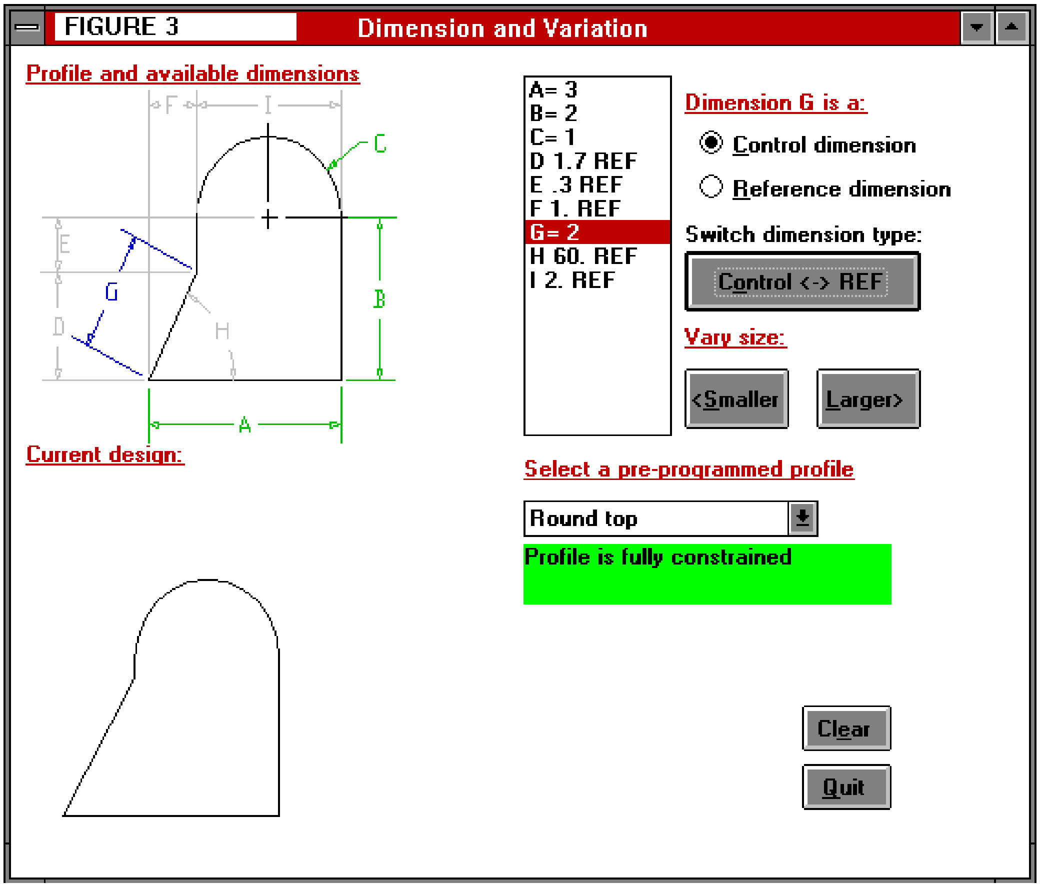
FIGURE 3
Dimension and Variation
Profile and available dimensions
F
I
C
E
G
D
H
B
A
Current design:
A= 3
B= 2
C= 1
D 1.7 REF
E .3 REF
F 1. REF
G= 2
H 60. REF
I 2. REF
Dimension G is a:
Control dimension
Reference dimension
Switch dimension type:
Control <-> REF
Vary size:
<Smaller
Larger>
Select a pre-programmed profile
Round top
Profile is fully constrained
Clear
Quit

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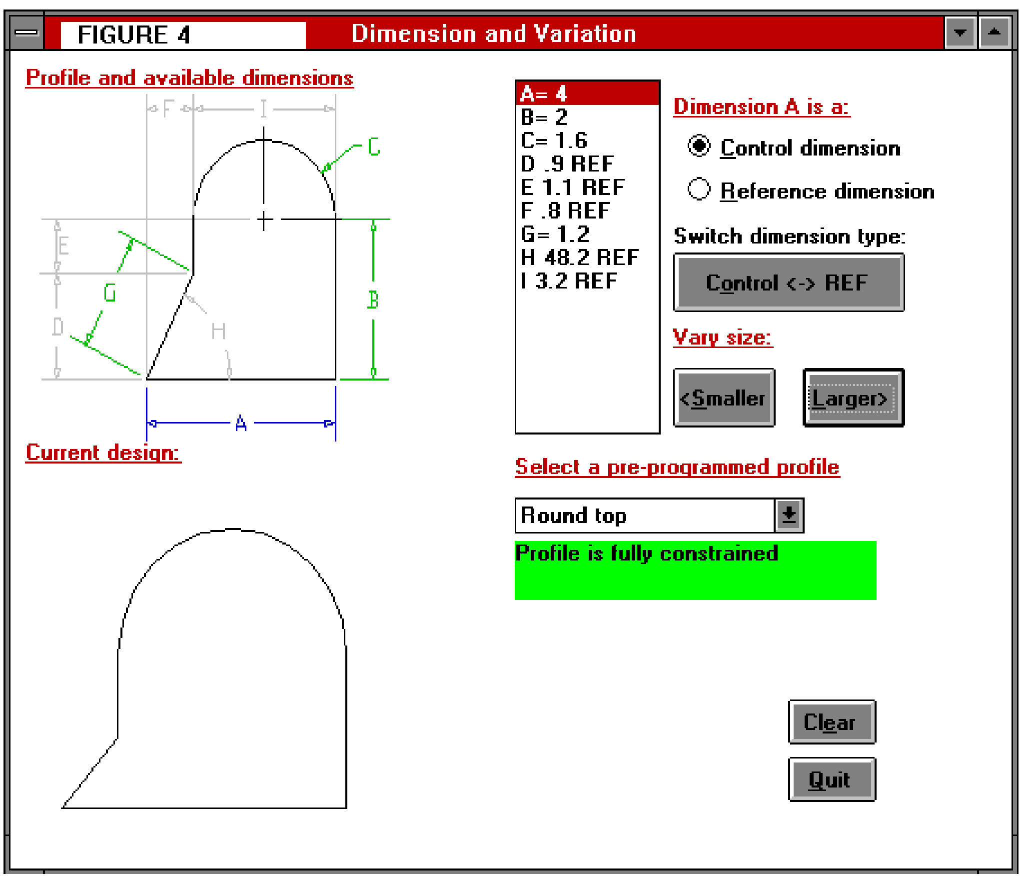
FIGURE 4
Dimension and Variation
Profile and available dimensions
F
I
C
E
G
D
H
B
A
Current design:
A= 4
B= 2
C= 1.6
D .9 REF
E 1.1 REF
F .8 REF
G= 1.2
H 48.2 REF
I 3.2 REF
Dimension A is a:
Control dimension
Reference dimension
Switch dimension type:
Control <-> REF
Vary size:
<Smaller
Larger>
Select a pre-programmed profile
Round top
Profile is fully constrained
Clear
Quit

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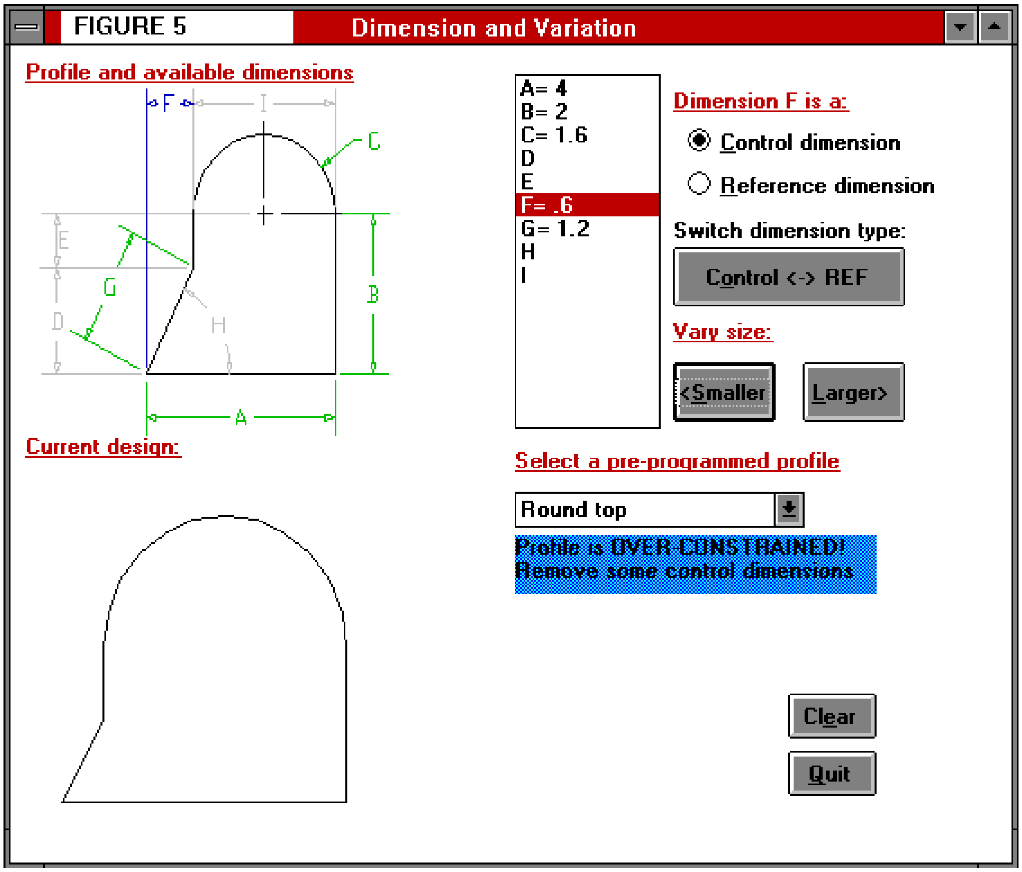

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1. Bertoline, Gary, et al, *Engineering Graphics Communication*, 1995, McGraw-Hill
2. Earle, James H., *Graphics for Engineers*, 1996, Addison-Wesley
3. Lamit, Louis Gary, et al, *Engineering Graphics and Design*, 1997, West
4. Howell, Steven K., *Introduction to Autocad Designer 1.1*, 1996, PWS

Dennis R. Stevenson, P.E, is Associate Professor of Computer Science and Engineering at the University of Wisconsin-Parkside. He teaches engineering graphics, design, CAD and engineering economics, and is the author of *Fundamentals of Design Graphics*, which includes the subject software.