



The Geometer's Sketchpad Version 2.0

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The *Geometer's Sketchpad* (Jackiw, 1991) is a new type of catalyst software, developed for the Macintosh computer, that supports an intuitive approach to geometry. The *Sketchpad* provides the user with a set of mouse-driven geometric construction tools (point, line, segment, ray, and circle tools) and menu-driven constructions such as a perpendicular line, given a selected point and straight object. The mouse interface permits the user to make continuous, dynamic transformations of geometric constructions simply by dragging part of the on-screen construction with the mouse pointer. All geometric relations embedded in the construction are maintained during these continuous transformations, thus providing the user with visual confirmation of what is and what is not invariant in these geometric constructions. Measurements of lengths, areas, angles and ratios can be obtained. These measurements are "active" in the sense that they automatically update as constructions are manipulated. Recording and play-back features built into the program provide the user with a written record of the constructions that can be saved and used to recreate the construction (on a new set of "givens") when needed (see Figure 2). This recording feature also provides teachers with a means for evaluating student work with these tools.

Upon its release in 1991, *The Geometer's Sketchpad* was heralded as a revolutionary development with powerful implications for learning (Devaney, 1992; Olive, 1991). At that time it did not seem reasonable or necessary to think about major improvements to this software. However, the new version of *Sketchpad* takes us into an even more dynamic dimension of learning, opening up avenues of exploration never imagined.

Version 2 of *Sketchpad* has the capability to define transformations based on constructed objects. A rotation of a figure based on a constructed angle can be changed dynamically by simply changing the angle. Similarly, a

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translation based on a segment or a dilation based on the ratio of two segments can be changed dynamically by simply altering the segments. Custom transformations can be built from combinations of transformations and used

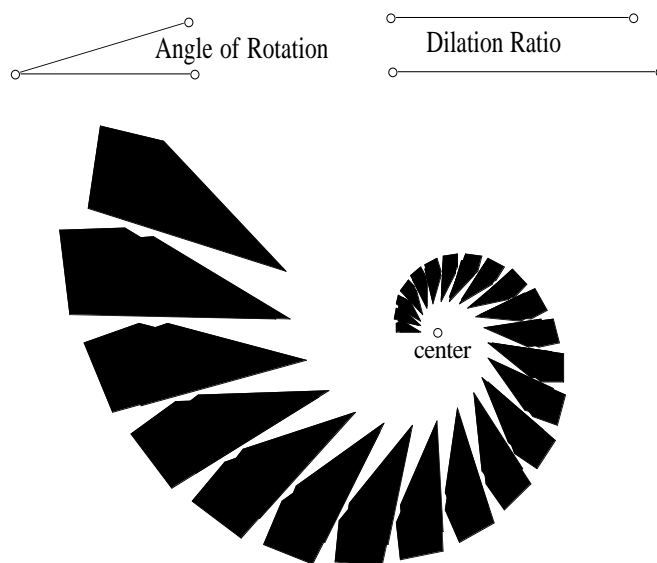


Figure 1: Iteration of a rotation and dilation of a quadrilateral.

iteratively on a construction. Figure 1 illustrates the result of a rotation followed by a dilation of the original figure about a center point, iterated many times. Changing the angle which defines the rotation will cause the whole structure to curl or uncurl. Moving the point which defines the ratio of the dilation will cause the shapes in the spiral to diminish or grow larger. Changing the original shape causes every figure in the spiral to change accordingly. All of these changes occur in real time as the user moves the mouse pointer.

There are other powerful additions to version 2 of *Sketchpad*. The scripting feature is now truly recursive, providing an option to "loop back" through the construction at any point in the generation of the script. This powerful option opens up new ways to create and investigate fractals through the simple construction of a fractured segment, or the construction of one branch of a "fractal tree." Figure 2 shows an edge of the Koch Snowflake fractal at three levels of recursion, created by playing the following script on any two points:

Given:

1. Point [A]
2. Point [B]

Steps:

1. Let [j] = Segment between Point [B] and Point [A].
2. Construct Point [C] by scaling Point [A] 33.33% about center Point [B].
3. Construct Point [D] by scaling Point [A] 66.67% about center Point [B].
4. Construct Point [E] by rotating Point [C] 60.000° around Point [D].
5. Let [k] = Segment between Point [D] and Point [A].
6. Let [m] = Segment between Point [E] and Point [D].
7. Let [n] = Segment between Point [C] and Point [E].
8. Let [p] = Segment between Point [B] and Point [C].
9. Recurse on [A], and Point [D].
10. Recurse on [D], and Point [E].
11. Recurse on [E], and Point [C].
12. Recurse on [C], and Point [B].

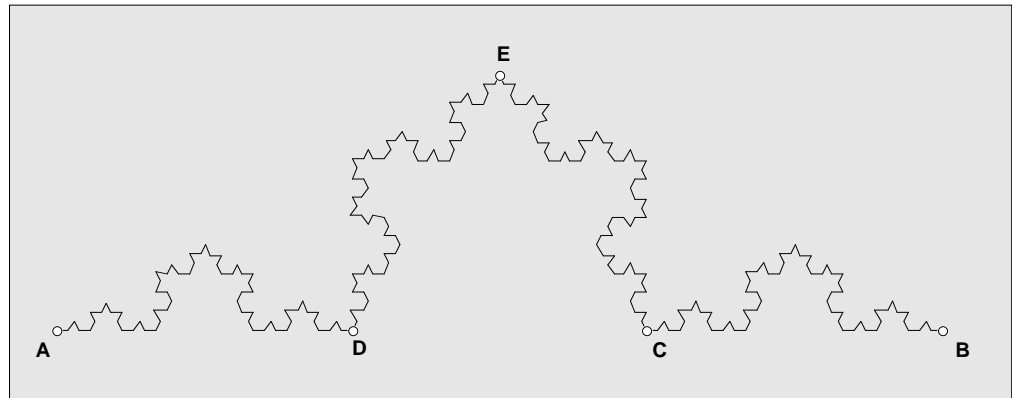


Figure 2: "Koch Edge" from *The Geometer's Sketchpad*.

The measurement features of *Sketchpad* have been enhanced by the addition of a Table option which allows the user to create a table of data based on any measurements. The tabled data can be exported to a spreadsheet for analysis and graphing. Trigonometric ratios, natural logarithm, square root, round and truncate functions have also been added to the *Sketchpad* calculator.

Although *Sketchpad* was not designed for such, with a little ingenuity (and a lot of patience!) graphing of alge-

braic relationships among constructed objects can be dynamically achieved within *Sketchpad* itself. Two graduate students at the University of Georgia have created a series of *Sketchpad* environments for investigating functional relations dynamically (see Lin & Hsieh, this issue). Students' understanding of the notion of variable can be greatly enhanced when the student can physically move a point representing the x-value and immediately see the effect on the object constructed according to some function $f(x)$. The use of the dynamic dilation feature makes the construction of algebraic polynomial functions fairly simple; Lin and Hsieh, however, have found ways to construct and graph trigonometric, exponential and logarithmic functions geometrically using the *Sketchpad*.

Another new feature of version 2 which has greatly enhanced the *Sketchpad's* animation capabilities is the action buttons. A button can be defined by the user to start an animation rather than having to go through the object selection and path-match sequence each time the animation is activated as in version 1. The path objects may also

be hidden. Action buttons can be sequenced and activated by a sequence button. A movement button can be used in sequence to define movement on any set of points, thus animation is no longer restricted to segments or circles. I have used this feature to investigate the influence of non-linear geometric transformations (such as inversion in a circle) on different polygons. This feature could provide a powerful new way of visualizing complex transformations in analytic geometry. Figure 3 illustrates an airfoil shape generated through the Jaworski transformation of a circle.

It is also possible for students and teachers using the *Sketchpad* to demonstrate and share their work with each other via a local area network. This non-hierarchical networking makes collaboration possible in real time among students working on different machines and also provides a means for the teacher to

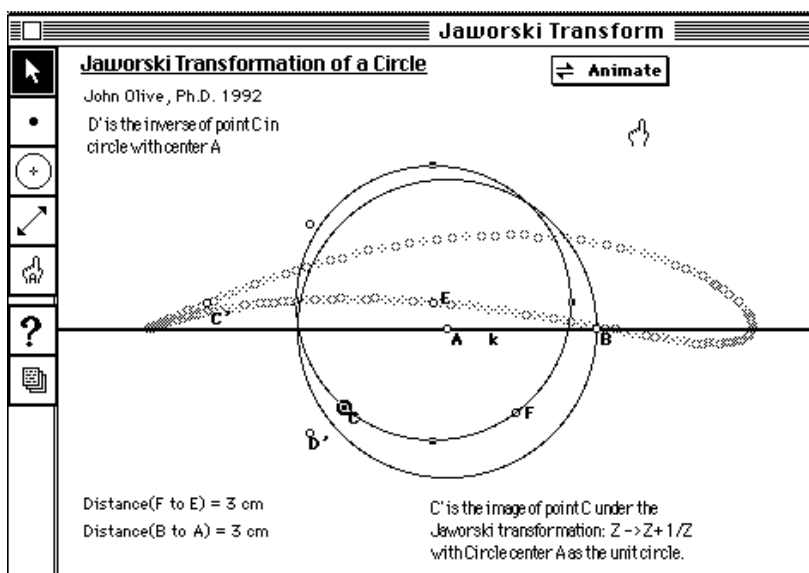


Figure 3: Jaworski Transformation from *The Geometer's Sketchpad*.

monitor the work of all the students in a lab situation from one monitor or display device. Multiple demonstrations could also be shown simultaneously on the same classroom display screen.

Devaney (1992) predicts that computer tools like the *Sketchpad* will radically change the way students learn geometry and will also change the content of the geometry studied. The *Sketchpad's* influence on mathematics, I believe, will not be confined to geometry; in the hands of creative users it will be used to connect geometry with other areas of mathematics and to areas of physics and mechanics. I also predict that such connections will be

made more transparent for the rest of us when version 3 of *The Geometer's Sketchpad* becomes a reality!

References

- Devaney, R. L. (1992, May). The Geometer's Sketchpad. *UME Trends*, 4(2), 2.
- Jackiw, N. (1991). *The Geometer's Sketchpad*. [Computer program]. Berkeley, CA: Key Curriculum Press.
- Olive, J. (1991). Learning geometry intuitively with the aid of a new computer tool: The Geometer's Sketchpad. *The Mathematics Educator*, 2, 26-29.



EndNote Plus Version 1.2.1

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Ease of use and transparency of features make *EndNote Plus 1.2.1* (Niles and Associates, 1991) easy to learn for anyone who has previously used a data base in Macintosh or IBM formats. Its purpose is clear; it provides the facility for both novice and professional writers to build, maintain, and modify a variety of personalized libraries in order to create alphabetically assembled and correctly formatted bibliographies. *EndNote* is accessible through a variety of word processing programs. This review is based on the version that works with Microsoft Word 5.0. As a graduate student, I have found *EndNote* to be extremely useful because of its capacity to perform the tedious task of selecting any entries referenced from a bibliography and attaching them to an already written paper. I hope to illustrate both strengths and weaknesses of the software with the proviso that I am a confirmed user who does not always take full advantage of all of its features.

An *EndNote* library can be built by either keying in entries or importing data from other sources. Conveniently, *EndNote* provides protocols for the importation of data stored in the Pro-Cite or Refer formats. Also, with an additional piece of software called EndLink, it is possible to import from existing databases with different formats, including Silver Platter and SciSearch.

When it comes to accessing a new library or reference list, menu items are clear, sufficient guides because they are consistent with those of Microsoft Word. The "point-and-shoot" feature of Macintosh technology is fully supported in that the user need only point the mouse to the file

of interest, then click to select or double click to open an item.

When the user selects a set of references from an already established reference list (Figure 1), each reference entry can be opened in an individual window (Figure 2). If the user then selects one of the windows, entering and editing data in the fields is a simple word processing task.

A primary advantage of using *EndNote* is that it saves time. *EndNote* has a feature that allows a journal name or abbreviation to be held internally and to be dumped to any location on demand. This feature minimizes errors and saves time by requiring information to be typed correctly only once.

Merging or deleting libraries is just a Macintosh "cut and paste" away. This feature is particularly helpful for collaborative work. Users should be warned, however, that after the merge, any differences in the quality of the libraries will be clearly visible. Incomplete and poorly proofed entries from one library contaminate the other.

Searching and sorting the library for duplicate entries or required references is easily accomplished. *EndNote's* search feature allows for any or all fields to be searched under several logical conditions. If the options displayed in the REFERENCE-FIND window are not sufficient, additional characteristics can be added at the touch of an INSERT ITEM button. Becoming proficient with the SEARCH feature requires practice with logical conjunctions for more complicated searches. A secondary search option that has value is FIND DUPLICATES. It will select only those library entries which have the same author, title, and year. A third search tool is SORT LIBRARY, a tool with the capability to sort on a five-level criterion list. This SEARCH feature seems to be quite sufficient as few sorts require more than three levels.

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My favorite option within *EndNote* is OPEN PAPER, which generates a bibliography for a paper. While writing, I identify citations within specified markers such as []'s. Then, *EndNote* can open the completed paper from within any word processor, match each marked citation with its corresponding reference in the library, create a bibliography of the cited references, and append the alphabetized, formatted bibliography to the end of the paper. The matching of citations to library entries is monitored, and the user is notified of entries not matched. The newly created bibliography can then be altered with a word processing program.

EndNote provides a number of bibliographic styles, including APA, Author-Date, Chicago, JACS, MLA, MLA Note, Nature, Numbered, Science, and Vancouver. Any one of the styles can be modified easily or new formats can be created. To illustrate how easily abstracts can be added to a bibliography, consider the *EndNote* version of the APA format of a journal reference, shown below:

Author	Year	Title
Shulman	1985	On teaching problem solving and solu
Shumway	1982	Problem-solving research: a concept
Silver	1982	Knowledge organization and mathem
Silver	1985	Research on teaching mathematical p
Sinclair	1990	Learning: The interactive recreation

Figure 1: Excerpt from a sample reference list.

Author (Year). Title. Journal, Volume (Issue), Pages|.

The vertical bars are conditional tests, if the library field has an entry it will be printed, if not, the variable and corresponding punctuation are left out. To obtain annotated references, only a slight change of format is needed:

Author (Year). Title. Journal, Volume (Issue), Pages|.

Abstract

This modification communicates to *EndNote* that a blank line should be left after the reference and the contents of the Abstract field should be printed.

Some of *EndNote*'s limitations are noted in the manual. For example, it cannot properly rearrange fields when no author is listed; it cannot automatically change "Ed." to "Eds." for works with more than one editor; in text citations, it cannot automatically remove the author name when more than one work by the same author is cited. The lack of a spell check feature is somewhat of an inconvenience. However, I have found that the many advantages of using *EndNote* far outweigh its limitations. In my opinion, *EndNote* is an easily understood writer's tool that can enhance the presentation of written material.

Reference

Niles and Associates. (1991). *EndNote Plus 1.2.1* [Computer program]. Berkeley, CA: Author.

Reference Type	Book Section
Author	Shumway, R.
Year	1982
Title	Problem-solving research: a concept learning perspective
Editor	Lester, F. Garofalo, J.
Book Title	Mathematical problem solving issues in research
City	Philadelphia, PA
Publisher	The Franklin Institute

Figure 2: Sample window for entering and editing data.