Computer typesetting of technical journals on UNIX

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ABSTRACT

A UNIX-based system for typesetting technical papers for high-quality output was evaluated by measuring use of computer and economic resources. Five manuscripts submitted to *Physical Review Letters* were typeset at Bell Laboratories, after preparation of programs to handle the equations, tables, and layout problems of this journal.

Computerized typesetting is substantially cheaper than typewriter composition. The primary cost of page composition is keyboarding and the aids provided by UNIX to facilitate input of complex mathematical and tabular text reduce input time significantly. Typing and correcting articles on UNIX, with a single experienced typist, is between 1.5 and 3.3 times as fast as typewriter composition. Input on UNIX averaged 2.4 times as fast as conventional methods. The composition cost per camera-ready page using a full-scale UNIX-based system producing 200 finished pages per day would be about $10 per page as compared with typewriter composition costs of $30 per page.

INTRODUCTION

UNIX[1] is a general purpose time-sharing operating system for the PDP-11 family of minicomputers. It is used extensively for the preparation of technical documents, ranging from internal technical memoranda in diverse fields to patent applications and books. The basic tools that UNIX provides for this are:

(1) A file system for long-term storage of information on the computer.
(2) A text editor for input and modification of text.
(3) Formatting programs for producing output on standard ASCII terminals, line printers, or on a phototypesetter.
(4) Specialized programs for formatting mathematics and tables.
(5) Mechanical aids for proofreading and format checking.
(6) An especially convenient mechanism for connecting programs together to perform complex tasks.

The document preparation facilities of UNIX are used heavily on a daily basis by scientists, secretaries and typists, preparing material of all sorts, but with the emphasis on typesetting mathematics.

This paper describes an experiment performed to evaluate the cost and performance of UNIX as a production system for computerized typesetting of technical papers for a primary technical journal, *Physical Review Letters*. This project was done in cooperation with the American Physical Society (APS), which supplied the test materials.

TEXT FORMATTING LANGUAGE

The basic tool for document formatting is a general-purpose text formatting program called *troff*.[2] *troff* provides standard facilities for formatting text into lines, with justification, hyphenation, size and font control, and the like. In addition, it has a macro capability, text and arithmetic variables, numerical computation and testing, and conditional branching. In effect, *troff* is a programming language, albeit of an unconventional sort.

However, these programming operations are generally not used directly by typists. Instead, a higher level descriptive language is used in which the typist indicates the content of each section of the input, by typing commands such as ".TL" before the title, or ".AU" before the author name(s). *troff* programs are written to interpret these descriptive commands and generate appropriate low-level typesetter requests for each particular journal style (e.g., that of *Physical Review Letters*). The macro instructions in the layout program for each journal enforce the local style rules; for example, the title of an article in *Physical Review Letters* is centered and set in bold-face. Different journals may have different styles for this, but the article need not be retyped or even edited to print it in a different style; only the program used to interpret the commands is changed.

MATHEMATICS LANGUAGE

Within a document, mathematical expressions are written in a special language[3] which has been designed to be easy to learn and use by non-technical people like secretaries and typists. For example, in this language the display equation

$$\sum_{i=0}^{\infty} x_i \rightarrow \frac{\pi}{2}$$

is written as

```
.EQ
sum from i=0 to infinity x sub i -> pi over 2
.EN
```

The "formatting commands" .EQ and .EN signal the beginning and end of a displayed mathematical expression. In-line expressions like $\vec{x}$ are written as %x vec%, where the "%" is a user-chosen character.

Essentially all details of sizes, fonts, etc., are handled automatically by this system; handfiddling is hardly ever needed.

The mathematical parts of a document are interpreted by a separate program called *eqn*. *eqn* operates as a preprocessor which converts the mathematical parts into the rather complicated *troff* commands necessary to actually position and print the expressions properly. The non-mathematical parts of the document are passed through *eqn* untouched.

TABLE LANGUAGE

Tables within a document are handled in a fashion quite analogous to mathematics: a special language,[4] again designed to be easy to learn and use, permits quite complicated tables to be entered by typists. The program does all the computations necessary for lining up columns, leaving space for the widest elements, drawing lines, etc. For example, in this language, the input

```
.TS
center, box;
c s
c c
l n.
Weight: English to Metric
Name (tab)  Grams
pound (tab)  453
ounce (tab)  28.349
grain (tab)     0.0648
.TE
```

will produce the output

Weight: English to Metric	
Name	Grams
pound	453
ounce	28.349
grain	0.0648

As with *eqn*, a program *tbl* interprets table specifications, generating appropriate *troff* commands. *tbl* is also a preprocessor. Tables may contain mathematics; in this case, *tbl* is run into *eqn*, and the output of *eqn* is passed in turn to *troff.*

PAGE LAYOUT

APS/AIP journals normally set all pages in double column, except for very wide equations and the text surrounding them, which are set full width, i.e., a single wide column. Figures and tables are placed only at the top or bottom of columns, and may be either narrow or wide depending on their content. Lines are not justified (ragged right margin) but all columns are the same length. Figure 1 shows one of the sample pages, as produced by our system. Figure 2 shows the same page taken from the published journal. Notice the order in which the material is read.

All material is typed in with the UNIX text editor, using ordinary ASCII terminals with no special characters. The typist inserts commands in the text as needed to specify different formatting actions. The major commands are those which delimit equations, tables and figures; the identification of the title, authors, authors' institutions, and abstract; the beginning of each paragraph; and the commands "begin double column" or "begin wide single column." Figures may be marked as either wide or narrow; captions and figure size are placed in the text at the point where the figure is referenced. Of course within tables and equations there are commands appropriate for those processes. Figure 3 shows the beginning of the input used to prepare the output of Figure 1.

There are four stages in the procedure that formats a document, although the user only types one command. The UNIX system permits different programs to be linked at command level by connecting the output of one program to the input of the next program; the program network constructed is called a "pipeline." This pipeline facility is used very heavily by the typesetting system, since we could not run as one program all of the pieces of our typesetting software. Running them separately not only avoids the space limitations of our system but minimizes the interaction between the authors of the different programs.

(1) The file is preprocessed to measure the length of the various one- and two-column sections of the paper. This information is needed by the layout programs to avoid extremely short double column sections. There are two ways of performing this step: we can use a procedure that goes through the internal steps of producing galleys for the entire paper, but instead of printing the galley proofs merely records the length of each section. Usually, however, we simply count the number of characters in each section and assume a standard number of input characters per column inch. This can be done much faster by the computer and is accurate enough for papers of the style of *Physical Review Letters*.

(2) The table processing program *tbl* comes next, if the paper contains any tables. It ignores most of the manuscript, but extracts tables and arranges their

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is

$$\langle \beta,b|H|\beta',b\rangle = \langle \beta,b|H_{\text{diag}}|\beta',b\rangle + \tfrac{1}{2}\sum_{\alpha}\left\{\frac{\langle \beta,b|H_{ba}|\alpha,a\rangle\langle \alpha,a|H_{ab}|\beta',b\rangle}{E_a(\alpha)-E_b(\beta)} + \frac{\langle \beta,b|H_{ba}|\alpha,a\rangle\langle \alpha,a|H_{ab}|\beta',b\rangle}{E_a(\alpha)-E_b(\beta')}\right\}, \quad (10)$$

where the labels β and α index the bonding ($|\beta,b\rangle$) and antibonding ($|\alpha,a\rangle$) eigenfunctions of H_{diag}. The valence and conduction bands are now decoupled to order $(V_1/V_2)^2$. In lowest approximation, $[E_a(\alpha)-E_b(\beta)] = 2|V_2|$ and the sum over intermediate states can immediately be evaluated. The total valence-electron energy (including magnetic-field-dependent terms) is the trace of Eq. (10) in the bonding representation. This expression contains both paramagnetic and diamagnetic terms. The former arise from the matrix elements of $H_{ab} + H_{ba}$; hence they depend upon bond angles and crystal coordination. The latter emerge from the H_{diag} term.

To extend this procedure to next order in (V_1/V_2), we keep higher powers of T in Eq. (8), and expand the energy denominator of Eq. (10) about the "average" gap $E_g \equiv 2|V_2|$. The result is a series of commutators of the form $H_{ba}[H_{\text{diag}}, [H_{\text{diag}}..., [H_{\text{diag}}, H_{ab}]]]$ which again can be evaluated with trace methods. To order $(V_1/V_2)^2$,

$$\chi = \frac{-Ne^2}{4mc^2}\sum_{j=1}^{4}\left\{\langle r_\perp^2(j)\rangle_{\text{local}} + \langle r_\perp^2(j)\rangle_{\text{overlap}}\left[1-\frac{3}{4}\left(\frac{V_1}{V_2}\right)^2\right]\right\} + \frac{\tfrac{1}{2}N(e\hbar/mc)^2}{E_g}\left[1+\frac{1}{4}\left(\frac{V_1}{V_2}\right)^2\right]. \quad (11)$$

Since $(V_1/V_2) < 0.5$,[5] the second-order terms in Eq. (11) are small and may be ignored. Equation (11) was derived on the assumption of zero overlap between orbitals that form a bond. With overlap, the expression is modified as follows[10]:

$$\chi = \frac{-Ne^2}{4mc^2}\left(\frac{1}{1+S}\right)\sum_{j=1}^{4}\left[\langle r_\perp^2(j)\rangle_{\text{local}} + \langle r_\perp^2(j)\rangle_{\text{overlap}}\right] + \frac{N}{2}\left(\frac{e\hbar}{mc}\right)^2\left(\frac{1}{1-S^2}\right)\frac{1}{\tilde{E}_g}, \quad (12)$$

where $\tilde{E}_g$ is the energy gap modified for overlap. Equation (12) is our final result, which we compare with the HKF model. Their diamagnetic and paramagnetic terms can now be identified with well-defined, gauge-invariant quantities: the orbital area $\langle r_\perp^2(j)\rangle_{\text{local}}$, the overlap area $\langle r_\perp^2(j)\rangle_{\text{overlap}}$, the overlap integral S, and the energy gap $\tilde{E}_g$. $|M|^2$, which depends only on the geometrical arrangement of the bonds, is given by

$$|M|^2 = (1-S^2)^{-1}(e\hbar/mc)^2 N_0. \quad (13)$$

Here N_0 is Avogadro's number. This result implies that $|M|^2$ is constant for all covalent tetrahedrally bonded materials, as observed by HKF. With the value $S = 0.5$,[11] Eq. (13) gives $|M|^2 = 1.7\times10^{-4}$ eV cm^3/mole, in good agreement with the experimental values[1] 1.8 ± 0.6 (diamond), 1.8 ± 0.3 (Si), and 2.2 ± 0.2 (Ge) in units of 10^{-4} eV cm^3/mole.

To evaluate the diamagnetic terms in Eq. (12), we have used Herman-Skillman wave functions[12] to calculate $\langle r_\perp^2(j)\rangle_{\text{local}}$. It can be shown[10] that $\langle r_\perp^2(j)\rangle_{\text{overlap}} \lesssim (0.15)\langle r_\perp^2(j)\rangle_{\text{local}}$. Our results[13] for $r_\perp$ agree with experimental values[1] (indicated in parentheses): diamond 0.84 Å (1.04 ± 0.15 Å), Si 1.23 Å (1.32 ± 0.1 Å), Ge 1.25 Å (1.48 ± 0.06 Å).

In conclusion, we have derived a particularly simple expression for the susceptibility of tetrahedral semiconductors in terms of gauge-invariant quantities characterizing the chemical bonding and the spatial structure of the solid. Work is presently under way to extend our formalism to differently coordinated solids and to amorphous materials.

It is a pleasure to thank Professor M. Kastner and Dr. S. Hudgens for stimulating our interest in this problem, and for many helpful suggestions and discussions.

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Figure 1

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order in T, is

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Figure 2

```
.ds VN 35
.ds NU 20
.nr dy 17
.nr mo 11
.nr yr 75
.sp 3.6i
.TL
Chemical-Bond Approach to the Magnetic Susceptibility of Tetrahedral Semiconductors*
.AU
V. P. Sukhatme† and P. A. Wolff
.AI
Center for Materials Science and Engineering and Department of Physics
Massachusetts Institute of Technology, Cambridge, Massachusetts 02139
.ps 9
.ft 1
(Received 22 May 1975)
.AB
A chemical-bond theory of the magnetic susceptibility of
tetrahedral semiconductors is presented. Starting from a
Hall-Weaire—type Hamiltonian, we derive an expression for
the susceptibility, whose diamagnetic and paramagnetic contributions
are written in terms of gauge-invariant physical quantities. Our
analysis confirms a recently postulated model for the susceptibility.
Theory and experiment are in good agreement.
.AE
.2C
.PP
In a recent Letter,$"" sup 1$ Hudgens, Kastner, and
Fritzsche (HKF) proposed a model susceptibility function for
tetrahedral semiconductors of the form
.EQ (1)
chi =~ {-N sub 0 e sup 2} over {6mc sup 2} ~ left [ sum from
roman core ^ langle r sup 2 rangle ~+~ sum from roman val ^ langle
r sup 2 rangle right ] ~+~ {|M| sup 2} over {E sub g} .
.EN
They ascribed the first two diamagnetic terms in this
formula, denoted by $chi sub c$ and $chi sub v$, to core
and valence electrons, respectively; the last term
$( chi sub p )$ is a Van Vleck paramagnetic susceptibility
arising from virtual interband transitions. HKF also
measured the susceptibility, and its temperature dependence,
for diamond, Si, Ge, GaAs, and GaP. From these data, they could
then
.ul
separately
determine $chi sub v$ and $chi sub p$. They find nearly complete
cancelation between $chi sub v$ and $chi sub p$, a constant
interband matrix element $(|M| sup 2 )$ despite wide variations in
$E sub g$, and values of $ langle r sup 2 rangle sub roman val sup half$
that scale with lattice spacing. These results support their
model, but leave several questions unanswered. In particular,
the meaning of the various terms $( langle r sup 2 rangle sub roman val$,
$|M| sup 2$, etc.) appearing in Eq. (1) remains unclear. It is
not obvious, moreover, that such quantities are gauge invariant.
The purpose of this Letter is to sketch a derivation of the HKF
model which resolves these difficulties. We will show that Eq. (1)
follows from a simple tight-binding picture, and we will present
```

Figure 3—Beginning of input for Figure 1

columns to be left-adjusted, right-adjusted, centered, or aligned by decimal points, as required. Headings as requested by the typist are placed over the columns. The typist need only specify the form of each column and type the data separated by tabs; other processing is automatic.

(3) The next procedure is *eqn*, which identifies equations and processes the input language into the typesetting (or line printer) language. Equations within tables are handled properly.

(4) The actual typesetting and layout by *troff* now follow. In the process of this stage the input material is handled three times.

(a) First, sections of double and single column text are collected. Material specified as too wide for double-column must of course be set full width, but the program will change narrow material to wide if setting as requested would cause an unattractive section of very short columns. Up to an entire page of text is gathered and processed at once. There is no backup: a limitation of our typesetting software prevents us from ever changing the initial decisions about line length, etc., used with a particular piece of text. Instead, the estimates of the lengths of each section of text produced by the first program in the sequence permit the layout routine to decide the proper format for each section. For example, there are two cases in which the program will change narrow text to wide: if it is too close to the bottom of a page, or if the next change to wide text follows very closely. As the text is gathered, figures and out-of-text tables are collected but temporarily set aside. The expected location of each figure is identified. By preference, figures are first placed at the top of the current page. If that space is no longer available, figures are placed at the bottom of the current page. If there is no space on this page, figures are placed at the top of the next page. The figures are not actually written out until the text for the page is processed, however, since (for example) it is not possible to place a half-width figure in full width text and on occasion the program is forced to widen a figure to full width in order to place it on the current page. It is possible, but rarely necessary, for the user to indicate where a particular figure is to be placed.

(b) Second, columns are formed by taking the double column pieces of text and dividing them into two columns. This may be difficult (for example, the expected breakpoint may be in the middle of a half-inch high equation) and thus the program tends to be conservative. It tries to put slightly less on each page than will actually fit; for *Physical Review Letters* the typography is sufficiently simple that one line of leeway is usually adequate, whereas for a very mathematical paper from *Physical Review D* three lines per page were left. The user can override this default for any paper and for any page, if it matters. While forming the columns the program counts the number of breaks between paragraphs and around equations in each column, and also measures the lengths of the columns.

(c) Third, the actual page is written out. The figures, and appropriate margin, and the columns of text are placed. To even up the columns, extra space is placed between paragraphs and equations. This is generally not noticeable, although it does mean that the lines in the two columns are not aligned. This conforms to APS/AIP practice. We do not have the capability of adjusting column lengths by changing the spacing between each line.

(5) The output medium is now chosen: the page may be written either on the typesetter, on a scope (for checking layout) or on a terminal for proofreading. In any case, the input typed by a typist is completely independent of the output device ultimately used.

If the pages produced are not acceptable, the user can make adjustments in the document in several ways. Material may be changed from narrow to wide format; in fact, the program will diagnose any equation which is too big for its intended appearance. Figures may be moved around in the text or enlarged, and more white space can be added to pages. For *Physical Review Letters* such methods are not usually necessary; they were only resorted to for trivial changes in the five papers of the experiment. Specifically, in two papers one line of white space was dropped from a page; and in one paper a figure was moved.

Finally, multiple papers may be run back to back and any individual paper may be placed at any vertical position on a page. These facilities are necessary to produce an entire issue of a journal, although irrelevant to the cost measurements in this experiment.

THE MAIN EXPERIMENT

Five copy-edited manuscripts (i.e., papers as given to typists at APS) were obtained from the editorial offices of *Physical Review Letters* through the courtesy of APS. Before looking at these manuscripts, eleven papers from the published journal were typed and typeset for practice and program debugging. Then the manuscripts were typed and typeset.

The experiment was done working entirely from manuscript; the published versions of the papers were not looked at until afterwards, and then only to supply one table omitted from one of the manuscripts and the date and initial page positions and volume numbers.

The sequence of operations performed by the typist for a paper is essentially this:

(a) original input of the paper (including a limited amount of "on-the-fly" correction of errors);
(b) rudimentary check of spelling, legality of equations and formatting commands (done by machine);
(c) fix any errors found;
(d) print a draft version on the typesetter;
(e) proofread draft;

(f) cycle through (c), (d) and (e) until the paper is in a satisfactory state.

Obviously some of these operations, particularly printing a draft, are normally overlapped with other activities, so the human time involved will not include (d) if there is enough typesetter capacity to keep typists busy.

The table below shows the data collected for the five papers, and the corresponding totals for each category. Each paper is characterized by its size in characters of raw input (including all mathematics, formatting information, etc.), the number and size of display equations like

$$S=\sum_{i=0}^{\infty} x_i$$

and the number and size of in-line mathematical expressions like π_i. The data on equations and in-line expressions give a rough measure of the complexity of the paper. Figure captions and tables are entered as normal input; their content is included in the size information. All times are in minutes.

Statistics on Five Sample Papers

	Browman	Lee	Keiser	Wolff	Tidman	Total
raw input (characters)	11236	15160	13366	15197	14004	68963
in-line expressions	154	130	118	113	134	649
(characters)	1256	1291	2913	1872	2083	9415
display equations	5	0	3	20	17	45
(characters)	318	0	385	3314	3058	7075
figures, tables	4, 1	3, 0	1, 1	0, 0	3, 0	11, 2
raw input time	56	63	66	77	84	346
subsequent editing time	14	21	22	20	21	98
total typing time	70	84	88	97	105	444
output pages	3	3.5	3	3	3	15.5
time per page	23	24	29	32	35	29

The average typing time per *final* page is thus 29 minutes. The statistics with regard to typing time do not take into account the unquantifiable fact that the typist, Ms. Carmela Scrocca, is extraordinarily fast and competent. For comparison, however, the total times recorded by APS for their typing and correction of the same papers are presented below.

Comparison of Typing Times

	Browman	Lee	Keiser	Wolff	Tidman	Total
APS	230	240	135	300	170	1075
UNIX	70	84	88	97	105	444
APS/UNIX	3.3	2.9	1.5	3.1	1.6	2.4

Although the total UNIX performance is 2.4 times faster, this does represent a spectrum of typists. The fairest comparison is probably with the papers by Keiser and Tidman, which were typed by the best typists at APS. If we assume that Ms. Scrocca and these typists are of comparable skill, then the UNIX system is 1.5 times as fast as typewriter composition. (A further experiment with a longer and more mathematical paper again showed a ratio of 2.4 to 1.)

There are two other significant costs for which we have some data—proofreading and page composition. According to APS, page composition takes approximately 15 minutes per paper on the average. Much of this effort can be eliminated by the automatic layout operations described above; it seems reasonable to believe that the computer system could reduce this to five minutes per paper of human time.

Proofreading times are of course much less objective. A careful proofreading by a technical reader took 94 minutes for the entire set of five papers, or about six minutes per page; this appears to be a fairly stable estimate, and is in reasonable agreement with values supplied by APS.

HARDWARE

The computer system used for these experiments is a PDP-11/45 running the UNIX operating system. The hardware for typesetting is a Graphic Systems C/A/T typesetter (not the current model) with four fonts and a range of point sizes selected by lens turret motion. The time required to set a page (8.5×11 inches) with this device ranges from about three minutes for pages with no point size changes to 15 minutes for the most complex material observed in *Physical Review Letters*. The articles from this experiment required on the average from eight to fifteen minutes per page depending on the amount of mathematics.

The actual computer time used for production of the papers is broken down as follows. First, initial input using the UNIX text editor proceeds at about 500 characters per CPU second; this accounts for about 140 seconds for the entire experiment. A similar amount would more than cover the subsequent editing and checking operations. Editing is certainly not the limiting cost.

CPU time required for typesetting is much larger, as shown in the next table.

	Browman	Lee	Keiser	Wolff	Tidman	Total
CPU time (seconds)	143	157	206	287	331	1124
pages	3	3.5	3	3	3	15.5

The cost per page then is about 74 seconds of CPU time. This is not the time per finished page. In this experiment, there were two complete drafts done before final copy, so in effect each page was done three times. It is our belief that with more careful proofreading of the first draft, this could probably be reduced to something much closer to two printings per page on the average.

The effort described above brought the papers into agreement with the APS copyediting instructions. Since we did not have access to an APS style guide a small amount of extra effort was expended to bring the manuscripts into exact conformance with APS rules by hunting around the library to find articles with similar features. The extra time involved in these changes is *not* included in the measurements.

COSTS

Although our typesetter averages about 12 minutes per page, it is an old model. The currently available Graphic Systems C/A/T (as timed at another Bell Labs computer installation) is twice as fast, using about six minutes per page. In a two shift day it could produce 160 pages of drafts. An extra 25 pages per day could be produced during an unattended third shift. At 2.5 to 3 tries per page, the finished page output rate would be 60–70 per day. Since a typist can comfortably sustain ten finished pages per day, six typists could keep one typesetter busy. The figure of five hours per day is deliberately conservative to allow for the Hawthorne effect, different typing skill levels, uneven workload, and non-typing time.

The cost of the basic computer hardware, exclusive of typesetting equipment, is about $150,000; this configuration could support (if there were no other demands on it) three or four typesetters at $15,000 each plus the twenty typists needed to keep the typesetters running. Realistically, two operators and a programmer would also be required. Amortizing the hardware (including three typesetters) over four years and 21 days per month makes a cost per day of $200 for equipment. The maintenance contract for the computer equipment costs about $60 per day. The Western Electric Company charges a one-time software license fee of $22,000 for the UNIX software, including typesetting programs; amortized over four years, this amounts to about $20 per day. Personnel costs are of course highly variable. The following table shows estimated monthly salaries per person, multiplied by a factor of 1.5 to allow for overhead and divided on the basis of 21 working days per month.

Item	Cost/day
Computer hardware	$200
Computer maintenance	60
Computer software	20
20 typists ($850/mo)	1200
2 operators ($800/mo)	110
1 programmer ($2000/mo)	140
4 proofreaders ($1100/mo)	300
Supplies, etc.	50
Total per day	$2080

Since this arrangement produces about 200 finished pages per day, the cost per camera-ready page is about $10. This does not include copy-editing or the handling of figures. If overhead costs were taken as equal to basic salary, so that a factor of 2.0 replaced 1.5 in the calculations for the table, the cost per page would come out at $14 instead of $10.

Quoted costs of conventional operations vary widely. In all the figures below the date is given after the price; the UNIX costs, of course, are 1976 prices. APS itself quotes $40 per page for monotype (1970) and $29 per page for typewriter composition (1972) including illustrations.[5] Other quotes are $32 per 1000-word page for AIP (1973) and $28 per 1000-word page for ASCE (1973) for similar typewriter composition methods; some of the differences in costs are explained by the fact that AIP expects text to cost $25 per 1000 words while mathematics costs $65 per 1000 words, and the various journals differ in mathematical content.[6] The IEEE also reports a *difference* of $18 per page between mathematical and nonmathematical journals (1973).[7] A large survey reported "editorial" costs of $29 and $26 per page (1975) for two groups of 20 journals publishing about 40,000 pages per year, but exactly what is covered by this is unclear, especially as one group reported 20 percent of its costs as "remainder" while the other reported 5 percent.[8] A very low cost quote was given by SAE at $10.50 per page composed (1973) although this is not for a complete journal but rather for individual article publication. They itemize editing and proofreading separately at another $1.50 per page.[9]

Perhaps the most useful summary is to note that many sources agree that a typist can be expected to produce about 1000 pages per year or four pages per day with conventional typewriter composition.[10,11] Our typist, at half an hour per page, could easily do 2500 pages per year, which exceeds even the best typists working with conventional equipment.

The small scale of the UNIX system makes it very adaptable. An operation with fewer typists and pages than the one we have sketched, for example, would not have proportionally higher costs, since the majority of the costs are manual and not tied to the computer installation. A half-size (or ten-typist) shop would still operate at about $12 per page or so. Furthermore, the UNIX system is general-purpose, and a use might well be found for the surplus computer capacity. (The American Physical Society is currently installing a UNIX system which will be used for both typesetting and editorial management functions.) In this case even a two or three typist operation would be reasonable, as only the typesetter costs would have to be covered in full by the printing operation.

On the other hand, costs cannot be significantly reduced by enlarging the computer system. Most of the cost is in typists' salaries, and even a 50 percent reduction in the hardware costs would provide at most a 5 percent saving per page. In addition, a larger typesetter would involve substantial (perhaps a person-year) software costs to revise the formatter. Further development, instead, should emphasize additional aids to the input typists. In particular, we have no way on our hardware of handling drawings or figure contents.

CONCLUSIONS

Computerized typesetting of technical material is faster than typewriter composition, because it mechanizes those parts of the typing job which most slow down the typist. In particular, the effort to lay out complicated equations and tables is essentially eliminated, as is the need for inserting and removing keys for special characters.

If the experiment were to be continued, some of our operations could be improved. In particular, inadequate communication with APS before the experiment caused some confusion on our part about their copy-editing conventions and format rules; this in turn led to extra editing time. Additional training of our typist in the use of our text editor would have been desirable; the process of making changes was not as efficient as that of initial typing. Similarly, we are not equipped or staffed for large scale proofreading operations, and a production shop would undoubtedly have proofread more accurately with fewer delays than we did. Finally, the layout of figures still requires occasional manual intervention; these programs could be further improved. In particular, the program works well on text with relatively few figures or very wide equations. More than four figures per page, in fact, cannot be done with APS style rules obeyed, and the program is likely to produce unattractive results in this case.

The present system, however, has many advantages. In addition to the basic demonstration of feasibility and economic attractiveness, there are obvious side benefits of computerized composition. The text is available in machine-readable form for secondary services like indexing, information banks, or later publication via computer-generated microfilm. Additional uses of a machine-readable file will certainly appear.

The UNIX system also contains several examples of computer aids not found in ordinary printing operations. Two different spelling error checking programs are available; one operates by letter patterns and one by reference to a dictionary. The syntax of the commands to lay out equations and pages can be checked automatically. To determine the number of column inches required for each article we had a special layout program which went through the steps required for setting galleys, although no printing was actually done. Many other programs for text handling are also available: for example, it is easy to scan multiple files for occurrences of particular words.

The quality of the output is higher than with typewriter composition. The copy is camera-ready, except for figures. Pages rather than galleys are produced, including complete header and footer lines. The output is attractive, with more fonts than are economic with a typewriter. Right-justified margins are available if desired. Recently many scientific journals have lowered their typographical standards to reduce costs; computers may make this unnecessary.

Copy-editing costs should also be reduced by a computer-based system. Changes are easier to make; presently copy-editors tend to mark repetitive changes at each point in a manuscript whereas computer editors can easily change all instances at once. It is also easy to number footnotes and equations automatically if desired. Finally, as computer editing systems spread, and more and more authors are able to provide the original manuscript in machine-readable form if desired, copy-editing can be done entirely by the use of a computer editor.

We conclude, finally, that a UNIX-based system would be an appropriate way now for a small scientific journal, using a reasonably simple typographic style, to compose its papers. It would also leave a publishing company in an excellent position to take advantage of future improvements in computing systems.

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