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NEW ZEALAND CERTIFICATE IN STATISTICS

A memorandum from the Technicians Certification Authority of New Zealand, annotated by John Offenburger, Wellington Polytechnic.

The Technicians Certification Authority has recently approved a new course, New Zealand Certificate in Statistics, details of the course structure being :

Years I and II

* English * Mathematics I * Mathematics II

and four from the following list provided at least one Year II subject is included :

General Science	* Biology I	Geography II
* Physics I	* Biology II	* Commercial Practice
* Physics II	* Bookkeeping I	History I
* Chemistry I	* Bookkeeping II	History II
* Chemistry II	* Geography I	* Mechanics

* means subjects prescribed by the Authority. In other cases the subjects are as for the School Certificate examination (Stage I) or for the University Entrance examination (Stage II).

A 50% pass in the School Certificate examination or 30% in the University Entrance examination gives exemption from the corresponding T.C.A. subject at Year I. Similarly, a 40% score in the University Entrance examination, or accredited University Entrance provides exemption from the corresponding T.C.A. Year II subject, but there is no exemption at all from English.

Years III and IV

Year III (externally examined)	Mathematics III Elements of Statistics
Year IV (internally examined)	Applied Statistics I Numerical Analysis I

Plus any two subjects from the following lists, provided that the pre-requisite conditions as laid down for the corresponding subjects in the regulations for N.Z.C.X. are fulfilled.

Year III (externally examined)

Biology III
Chemistry III
Electronics I
General Economics
Geology I
Mechanics and Strength of Materials
Physics IIIA
Physics IIIB
Principles & Practice of Accounting I

Year IV (internally examined)

Biochemistry I
Mathematics IV
Mechanical Technology I
Microbiology I
Principles & Practice of Accounting II
or
Accounts of the Public Sector II
Public Economics
Soil Science

Year V

Applied Statistics II
Computer Methods
Numerical Analysis II

Method of Examination

There will be one three-hour paper in each of Elements of Statistics and Mathematics III, and in each subject of the 5th year. The paper in Computer Methods will contribute 60% of the mark, while the coursework should count for 40% of the total examination mark.

Minimum Hours of Study

Applied Statistics I	3 hours per week
Numerical Analysis I	3 " " "
Computer Methods	2½ " " "
Applied Statistics II	3 " " "
Numerical Analysis II	2½ " " "

Cross-Credits

Elements of Statistics will be accepted in place of Laboratory Mathematics in all science options. Elements of Statistics will replace Laboratory Mathematics from I969.

A cross-credit for Elements of Statistics will be given to students who have already passed Laboratory Mathematics.

Introduction of the Course

Years III and IV will be introduced in 1969, and Year V in 1970. The complete regulations will be published in the Handbooks of the T.C.A., who will also have stocks of Syllabus Prescriptions.

Further Possible Exemptions

Exemptions for one or possibly two Year III subjects can be obtained, e.g. Chemistry Stage I and Physics Stage I university-passes give exemption from Chemistry III and Physics III of T.C.A. It may be possible also to find exempting subjects for Elements of Statistics, but the universities differ in the courses and content they offer and the problems have not yet been resolved.

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THE SIMPLE ANALYSIS OF TIME-CORRELATED OBSERVATIONS

GEOFFREY H. JOWETT,
Department of Mathematics,
University of Otago

(Presented to the N.Z.S.A. Conference, July 1967)

1. Introduction

Many statistical applications involve data in the form of time series, such as weekly outputs, hourly temperature charts (or equivalently in the form of spatial series such as soil acidities, ore grades etc. along transects). These may be studied by examining means, differences between means, regression coefficients, or other linear functions of the observations and comparing them with their standard errors, or by some more sophisticated but essentially equivalent procedure. Books and articles in this field are usually fairly advanced from the mathematical point of view and therefore inaccessible to many statistical practioners. Nevertheless it is possible to isolate something simple and useful in the way of technique which saves us from having to close our eyes (often at the risk of serious error) to the time-correlated nature of our data, without plunging us into too much mathematical sophistication.

2. The Calculation of standard errors

Suppose we have six evenly spaced observations from a time series which we denote by X(1), X(2), X(3), X(4), X(5) and X(6). If these observations were weekly outputs following the installation of an incentive bonus scheme, for example, it is easy to imagine that we might be interested in the simple mean

$$\bar{X} = \frac{1}{6}(X(1) + X(2) + X(3) + X(4) + X(5) + X(6)) \qquad (1)$$

and might wish to estimate its standard error so that we would know how far to trust it. Or if X(1) and X(2) were capillary pressures of a patient on the two days before an eye operation, X(3) the pressure on the day of the operation, and X(4), X(5), X(6) the pressures on the three days following the operation, we might be interested in the difference between means

$$D = \bar{X}_{Before} - \bar{X}_{After} = \frac{1}{2}(X(1) + X(2)) - \frac{1}{3}(X(4)+X(5)+X(6)) \qquad (2)$$

and wish to test its significance by comparing it with its standard error. Again if X(1),...X(6) are successive sales figures, we may use the regression slope

$$b = \sum_{t=1}^{6} \left[(t - \bar{t})X(t)\right] / \Sigma(t - \bar{t})^2 \qquad (3)$$

as an estimator of trend slope for forecasting purposes, and require its standard error to help in assigning limits to our forecasts.

Closer examination of (1), (2) and (3) reveals that these expressions are all weighted sums of the six observations. Explicitly

$$\bar{X} = \frac{1}{6}X(1) + \frac{1}{6}X(2) + \frac{1}{6}X(3) + \frac{1}{6}X(4) + \frac{1}{6}X(5) + \frac{1}{6}X(6) \qquad (1')$$

$$D = \frac{1}{2}X(1) + \frac{1}{2}X(2) + 0X(3) - \frac{1}{3}X(4) - \frac{1}{3}X(5) - \frac{1}{3}X(6) \qquad (2')$$

$$b = -\frac{5}{35}X(1) - \frac{3}{35}X(2) - \frac{1}{35}X(3) + \frac{1}{35}X(4) + \frac{3}{35}X(5) + \frac{5}{35}X(6) \qquad (3')$$

and can be regarded as special cases of the weighted sum

$$W = W_1X(1) + W_2X(2) + W_3X(3) + W_4X(4) + W_5X(5) + W_6X(6) \qquad (4)$$

Hence if we have a general method for calculating the standard error of a weighted sum of the form of W, we may apply our method to cases such as (1), (2), (3) simply by expressing the formulae that arise as weighted sums.

The procedure for the calculation is simple, easy to remember, and readily programmed for computer if the data are much more numerous than six, since the operations required are matrix operations available as subroutines. Having grasped the idea of the procedure, one can more readily work out one's own computational short cuts in special cases than dig relevant formulae out of the literature.

The coefficients W_1, W_2, W_3, W_4, W_5, W_6 are written in the margins of a table, and serial correlation coefficients in the body of the table, as shown in Table I.

The serial correlation coefficients measure the extent to which observations at various separations in time tend to resemble one another; estimating them from data will be discussed as a separate problem below. The sampling variance of W is calculated by (i) multiplying each entry in the table by the product of the two coefficients opposite to it in the margins, (ii) adding all such products, and (iii) Using the resulting total as a multiplier for σ^2_E, the variance of the random component of the time series (also estimated as described below). In matrix notation

$$\sigma^2_W = \underline{W} \, \underline{\varrho} \, \underline{W}^1,$$

where $\underline{W}$ is the row vector of coefficients and $\underline{\varrho}$ the matrix of serial correlations (cf. Table I).

Table I: Basic Layout for Calculation of Standard Errors

W_1	W_2	W_3	W_4	W_5	W_6	
1	$\rho^{(1)}$	$\rho^{(2)}$	$\rho^{(3)}$	$\rho^{(4)}$	$\rho^{(5)}$	W_1
$\rho^{(1)}$	1	$\rho^{(1)}$	$\rho^{(2)}$	$\rho^{(3)}$	$\rho^{(4)}$	W_2
$\rho^{(2)}$	$\rho^{(1)}$	1	$\rho^{(1)}$	$\rho^{(2)}$	$\rho^{(3)}$	W_3
$\rho^{(3)}$	$\rho^{(2)}$	$\rho^{(1)}$	1	$\rho^{(1)}$	$\rho^{(2)}$	W_4
$\rho^{(4)}$	$\rho^{(3)}$	$\rho^{(2)}$	$\rho^{(1)}$	1	$\rho^{(1)}$	W_5
$\rho^{(5)}$	$\rho^{(4)}$	$\rho^{(3)}$	$\rho^{(2)}$	$\rho^{(1)}$	1	W_6

Table II: Basic Layout for Computation of σ_D^2

$\frac{1}{2}$	$\frac{1}{2}$	0	$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	
1	.593	.352	.209	.124	.073	$\frac{1}{2}$
.593	1	.593	.352	.209	.124	$\frac{1}{2}$
.352	.593	1	.593	.352	.209	0
.209	.352	.593	1	.593	.352	$-\frac{1}{3}$
.124	.209	.352	.593	1	.593	$-\frac{1}{3}$
.073	.124	.209	.352	.593	1	$-\frac{1}{3}$

Example 1. A time series (actually the thickness of hand-spun wool) has the following parameters:

$$\sigma_E^2 = 4.05, \quad \rho(1) = 0.593, \quad \rho(2) = 0.352, \quad \rho(3) = 0.209,$$
$$\rho(4) = 0.124, \quad \rho(5) = 0.073.$$

Calculate the standard error of the statistic D given by (2).

The numerical equivalent of Table I in this case is given in Table II.

It is obvious that economies can be effected in calculating the required sum of products, and thus

$$\sigma_D^2 = 4.05 \left[1 \times \frac{1}{2} \times \frac{1}{2} + .593 \times \frac{1}{2} \times \frac{1}{2} + .352 \times 0 \times \frac{1}{2} + \ldots. + 1 \times (-\frac{1}{3}) \times (-\frac{1}{3}) \right]$$

$$= 4.05 \left[\frac{1}{2} \times \frac{1}{2} \times (1 + 1 + 2 \times .593) + \frac{1}{3} \times \frac{1}{3} \times (1 + 1 + 1 + 4 \times .593) + 2 \times .352 - \frac{1}{2} \times \frac{1}{3} \times 2 \times (.209 + .124 + .073 + .352 + .209 + .124 + .593 + .352 + .209) \right]$$

$$= 3.47$$

Hence $\sigma_D = 1.86$ (5)

The economies are effected differently in the other two cases, but are once again obvious, and from similar calculations we find that $\sigma_{\bar{X}} = 1.37$, $\sigma_b = 0.5612$.

It is instructive - and also rather alarming - to note that if we had ignored the serial correlation (i.e. replaced the off-diagonal terms in Table II by zeros), we would have miscalculated $\sigma_{\bar{X}}$ as $\sqrt{4.05/6}$, i.e. as 0.821. This is less than two-thirds of the correct value, and would give apparent three-sigma limits which were narrower even than the correct two-sigma limits. Simple means are commonly affected in this direction, the effect on other statistics being sometimes in this, sometimes in the opposite, direction.

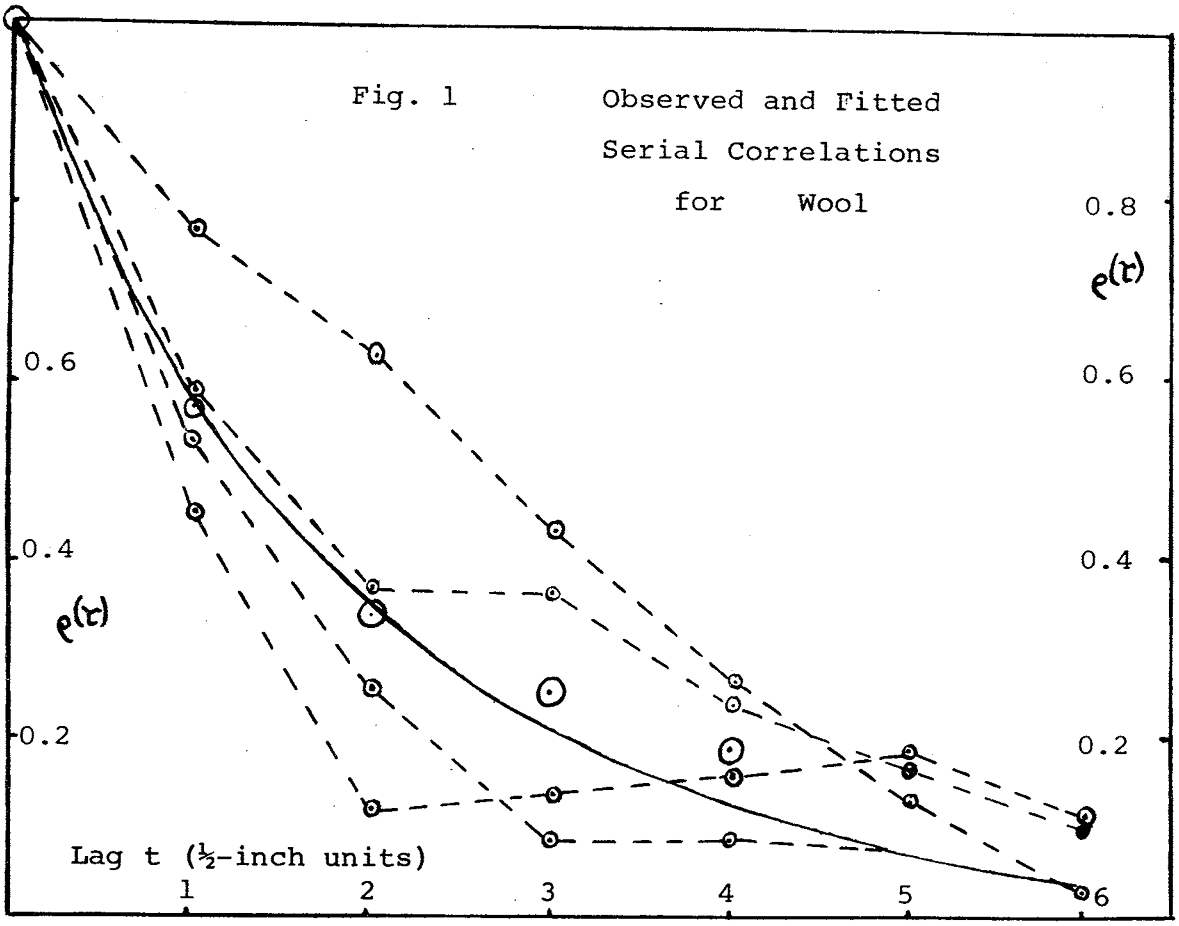
3. Estimation of population parameters

To apply these formulae in practice, we need estimates of σ_E^2, the population variance of the random component of the series, and the serial correlations $\rho(\tau)$ for different values of τ as required in the equivalent of Table I. Estimates of $\rho(\tau)$ must be smoothed intelligently before use, since sampling fluctuations between estimates at neighbouring lags do not tend to cancel each other out when subtracted, as population values would do, and at large lags are apt to be very erratic. It is often necessary to pool evidence from various sources to obtain reliable estimates; there is no neat small sample procedure which makes allowance for the errors of both mean and estimated standard error simultaneously, as do such tests as the t-test for random data. Also the smoothing must often be allowed to be strongly influenced by a reasonable assumption about the form of $\rho(\tau)$, a common assumption being that its graph resembles a decreasing exponential curve.

If long series of observations are available in which the systematic component may be estimated accurately and subtracted, estimates of σ_E^2 and $\rho(\tau)$ may be calculated directly. The appropriate formulae are

$$\text{Est. } \sigma_E^2 = \text{Av } \left[E(t)\right]^2, \tag{6}$$

$$\text{Est. } \rho(\tau) = \text{Av } \left[E(t)E(t+\tau)\right]/\text{Est } \sigma_E^2, \tag{7}$$



<u>Table III: Estimates of Parameters for Hand-Spun Wool</u>

	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Mean	Smoothed
σ_E^2	2.74	5.85	2.39	5.21	4.05	4.05
$\rho(1)$	.456	.769	.590	.468	.570	0.593
$\rho(2)$	.117	.629	.356	.251	.338	0.352
$\rho(3)$	.135	.436	.360	.082	.253	0.209
$\rho(4)$	.157	.265	.238	.090	.188	0.124
$\rho(5)$	.186	.128	.167	.071	.138	0.073
$\rho(6)$	.113	.025	.105	.028	.068	0.043

where E(t) is the residual after subtraction of the systematic component and Av denotes the operation of simple averaging over available data.

Example 2.

Measurements of thickness were taken on four lengths of hand-spun wool, each 100 in. long, at a spacing of 0.5 in.* The mean thickness of a specimen was regarded as a sufficiently accurate estimate of the systematic component of the measurements taken in it, and subtracted as described above, giving values which could be regarded as values of E(t) for purposes of application of equations (6) and (7). The resulting estimates are given in Table III, the correlations being illustrated in Fig. 1 for lags up to $\tau = 6$ half-inch units.

At the time serial correlations were calculated for greater lags also, but are not reproduced here. Estimates for separate specimens were averaged to give the estimates in the sixth column of the table, and then "smoothed intelligently" by a graphical procedure which resulted in taking $\rho(\tau) = \rho^{\tau}$ for $\rho = 0.593$. This appeared to give an acceptable smoothing; mathematical fitting would be more objective and rigorous, of course, but it is far from being such a simple and straight forward task, as (e.g.), sketching a plausible straight line on a semi-logarithmic plot. The plots for the separate specimens in Fig. 1 illustrate the treacherous swings of sample correlation graphs.

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* This was a practical exercise for students taking a statistics course.

In many applications the systematic component may not be satisfactorily estimated - it may be too complicated in structure or the specimens of series may be too short - and it is necessary to use indirect methods. These make use of the following simple principles:

(i) if two observations have the same value for their systematic component, it will cancel out when they are subtracted,

(ii) the variance of differences of observations for which the systematic component does not cancel out, as in (i), but gives a constant difference, is an appropriate substitute for their mean square as an estimator.

The formula required is

$$\text{Est } \sigma_E^2(1 - \rho(\tau)) = \frac{1}{2} \text{ var} \left[X(t) - X(t') \right] \qquad (8)$$

where var$[X(t) - X(t')]$ is the variance of differences $X(t) - X(t')$, calculated from pairs t, t' for which the systematic components of $X(t)$, $X(t')$ differ by a constant. This variance may be replaced by the unadjusted mean square if (i) applies, i.e. if the constant is zero. This does not (9)
give separate estimates of σ_E^2 and $\rho(\tau)$, but these may not be necessary. If we leave σ_E^2 as an algebraic symbol in the calculation of standard errors, in some cases it cancels out (i.e. when the total of the coefficients w is zero; this is the case for the statistics b and D for example). If the cancelling does not take place, we may sometimes obtain a satisfactory estimate of σ_E^2 by averaging estimates obtained by (8) for values of τ which are so large that $\rho(\tau)$ may be assumed negligible.

Example 3.

In the case of the eye operation described above, the systematic effect takes the form of different levels before and after the operation. The variance of D as calculated by the procedure associated with Table II would be a null-hypothesis value with which the observed value of the variance of D over individual patients might be compared to test whether or not the effect of the operation varied from patient to patient. For estimates of $\sigma_E^2(1 - \rho(1))$ we have $\frac{1}{2}\text{Av } (X(1) - X(2))^2$, $\frac{1}{2}\text{Av } (X(4) - X(5))^2$, $\frac{1}{2}\text{Av } (X(5) - X(6))^2$, where the averages are taken over patients; these may be pooled. For an estimate of $\sigma_E^2(1 - \rho(2))$ we have $\frac{1}{2}\text{Av } (X(4) - X(6))^2$. For an estimate of $\sigma_E^2(1 - \rho(5))$ we have $\frac{1}{2}\text{var } (X(1) - X(6))^2$, the variance being used instead of the average square because the difference X(1) - X(6) involves the effect of the operation; and so on for other lags. These estimates, with appropriate smoothing, suffice for the calculation of the null hypothesis variance of D, with which the observed variance may be compared by means of an approximate large-sample F test with ν_2 nominally taken as infinity. The cancelling-out of σ_E^2 in the working takes place in this instance, as the reader may verify for himself by making up some figures to substitute.

This elementary account glosses over difficulties which arise when the fitting procedure is considered critically, but it may be argued that an estimation procedure based on appropriate assumptions, even if calculated in a partially subjective way, may well be much better than one which is mathematically impeccable but based on wholly inappropriate ones.

Further Reading

Jowett, G.H. (1955) The Comparison of Means of Industrial Time Series. Applied Statistics, 4, 32 - 46.

Jowett, G.H. & Wright, W.M. (1959) Jump Analysis Biometrika, 46, 386 - 399

(and references given in these papers)

Question

If a monkey were given a typewriter and four months to use it, what is the probability, not of his producing the complete works of Shakespeare as is so often contemplated, but of his producing enough copy suitable for the next issue of the NZ Statistician ?

Editor's Answer

100%, judging from the present supply of copy.

(regretably unsponsored advertisements)

(1) The Brain Drain Again

A letter from the Department of External Affairs to the Secretary of the N.Z. Statistical Association. (I0 October, I968)

Dear Mr Arnold,

In confirmation ... I attach a copy of a United Nations Technical Assistance Recruitment Service "job description" calling for a statistical adviser for Western Samoa.

I should be grateful if you would publicise this vacancy ... Any member who is interested in overseas assignments under International Technical Assistance organisations are also invited to lodge a general application through this Department. Draft notices are attached in accordance with your request.

Yours etc.

United Nations Technical Assistance Recruitment Service

Job Vacancy : WES-252-A : Statistical Adviser, Western Samoa.

A statistician, preferably but not necessarily with experience in agricultural census in a developing country and in the conduct of a cost of living survey, is required.

The expert will advise the Government on Statistics in population, health, education, agriculture, foreign trade, prices, employment, etc., The duration of the assignment will be one year with a possibility of extension.

Applications should be addressed to the Secretary, Department of External Affairs.

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International Technical Assistance Assignments

Statisticians with at least five years experience of statistical work are called for from time to time by the International Labour Organisation, and the United Nations Technical Assistance Recruitments Service. Appointments may be for short terms of a few months duration or for longer terms of one or two years. Suitably qualified statisticians are invited to register their interest in such appointments, through the Secretary, Department of External Affairs, Wellington.

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(2) Work made easy

Small electronic desk calculators are now entering the New Zealand market in a variety of makes and models. Each machine has some specialty which appeals to certain sections of the user community, e.g. commercial offices, scientific laboratories, engineering applications. In order to assist members to choose the machine most suitable for their needs we would ask those of our readers who have had experience with any machine to send in their comments for publication.

To start the ball rolling we print below a few basic comments about a number of machines, already sent forward by members, relating mainly to scientific applications. At present we can only suggest to possible commercial users that they contact the agents for the various machines, as we have had no comments from the commercial field.
We do not propose to publish prices as these may be changed without notice.

To the best of our knowledge these comments are accurate. If you spot an error, please let us know immediately.

B U R R O U G H S C 3 3 5 0

Register : 16 digits

Read out : Nixie

Weight : 7 Kg

Dimensions : 4½"x12½"x16½"

Automatic Decimal : Two systems (a) compute - 4 and 6 places
and (b) memory - 0,2,4,6,8 places

Automatic Square Root : Two button pushes; accuracy to 8 places.

Multiplication : 8 digits x 8 digits maximum

Powers : 1 button push for each power

Constant Multiplier & Constant Divisor : One button push - these can be held in the two memories simultaneously.

Constant Dividend : Three button pushes.

Continued multiplication : Two button pushes.

Sums of Squares : 3 button pushes for each number.

Display : Good

Operating Lights : Good

Overflow : Display locks, but keys do not.

Hardware : Logic contained on three printed circuit cards lying flat. Replacement of a card, although not difficult is somewhat involved. Reed switches and Nixie type display should be very reliable. Logic is a mixture of Integrated Circuits and discrete components. Adequate servicing arrangements with properly trained staff.

B U S I C O M 1 6 2

Register: 16 digits

Dimensions : 6" x 13" x 13½"

Read out: Nixie

Weight : 7.4 Kg

Automatic Decimal: Positions 0, 1, 2, 3, 6, 9.

Square roots : Two button pushes. Fixed to 7 digits.

Multiplication: Maximum - 8 digits by 8 digits.

Powers : One button push for each power.

Constant Multiplier & Constant Divisor One button push for constant multiplication, three button pushes for constant divisor.

Constant Dividend: Three button pushes.

Continued Multiplication: Two button pushes.

Sums of Squares: Three button pushes for each number.

Shift Key: Removes digits one at a time from display - this is an addition to clearing key.

Mistake: Square root of 16 ones = 540,925 = square root of 15 ones (both wrong).

Display: Good

Operating Lights: Good

Overflow: Neither display nor keys lock.

Hardware: Logic is contained on 10 easily accessible printed circuit cards. A mix of integrated circuits and discrete components is used with core memory planes pluggable. Power supply protected from over-current conditions. Some untidyness in wiring, but in general machine appears easy to maintain. Maintenance contracts should be obtainable from Armstrong and Spring-Hall Ltd.

CANON-CANOLA 163

Register: 16 digits   Dimensions: 5½" x 12" x 15"

Read out: Nixie   Weight: 6.4 Kg

Automatic Square Root: one button.

Multiplication : 8 numbers by 8 numbers to left of decimal point. The rounding-off mechanism, however, allows multiplication of up to 15 decimals by 15 decimals with one integer, or 14x14 decimals with 2 integers and so on.

Powers: One button push for each power.

Constant Multiplier & Constant Divisor: One button push

Constant Dividend : Three button pushes.

Continued Multiplication: Two button pushes.

Sums of Squares: Two button pushes for each number.

RV Key: Exchanges divisor and dividend.

Shift Key: Removes digits one at a time from display - this is in addition to the clearing key.

Count switch: Counts the number of calculations.

Overflow: Display locks, but not keys.

Display: Good.

Operating Lights: Previously poor, now improved (possibly good).

Hardware: Logic is contained mainly on 9 printed circuit boards, comprising mixed integrated circuits and discrete components with integrated circuits predominating. Keyboard is Reed switches. Quality of printed circuit boards not as high as might be expected - some areas of copper are unprotected by tinning or lacquer. P-c boards easily removed and servicing should be simple. Service arrangements involve sending faulty machine to Auckland for repair, but a replacement is provided over repair-period.

FRIDEN 132

Register: 13 digits
2 registers (4 registers in machine, but the N.Z. agents had temporarily removed two.)

Read out: Cathode Ray Tube

Weight: 20 Kg

Dimensions 10" x 16" x 24"

Automatic decimal:
Floating decimal:
Automatic square root: } Machine has these facilities

Multiplication: Accurate to 25 digits.

Powers: Two button pushes for each power

Constant Multiplier:
Constant Divisor:
Constant Dividend: Two button pushes each (also 2 constant multipliers possible.)

Continued multiplication: One button push.

Sums of squares: Five button pushes for each power.
(Agent reports that model 132Σ gives sums of squares with only one button push.)

Display: Very Good

Operating Lights: Negative and overflow stand out very well.

Overflow: Keys lock.

General: Noisy Keyboard.

Hardware: Logic contained on 4 double-layer boards easily removable for servicing. CRT display derived from solid state character generator and driven by high voltage (ca 80 volt) transistor circuits. Acceleration voltage power supply also solid state. Keyboard is Reed switches. Warm-up time for CRT is quite short. All transistorised - no integrated circuits.

S A N Y O   1 C C - 1 6 1

Register: 16 digits   Dimensions: 5" x 11½" x 14½"

Read out: Mosaic   Weight: 7.1 Kg

Floating decimal:
Automatic decimal:) Machine has these facilities

Automatic square root: Not provided

Multiplication: Machine ceases multiplying as soon as the digit-register is full. Maximum is 8 digits by 8 digits.

Powers: Two button pushes for each power

Constant multiplier: Has to be recalled each time - three button pushes.

Continued multiplication: Two button pushes.

Sums of Squares: Three button pushes for each number.

Mistakes: $10^{12}/10^{-5}$ gives 10, and doesn't set overflow.

Display: Poor.

Operating Lights: Overflow, negative, etc. very difficult to see.

Hardware: Integrated circuits with some discrete components mounted on 9 pluggable circuit boards. Access to boards reasonable for replacement but not for testing. Mosaic in line digital display hard to read in high ambient illumination and lamps which will burn out are difficult to replace. A test button is available to test the lamps, but invalid readings could occur between checks.

SHARP COMPET 32

Register:	16 digits	Dimensions:	4" x 12" x 16"
Read out:	Nixie	Weight:	6.8 Kg

Automatic Decimal:	0,2,4,6,8 places
Square Root:	Two button pushes.
Multiplication:	8 digits by 8 digits maximum.
Powers:	One button push for each power
Constant Multiplier & Constant Divisor:	) One button push.
Constant Dividend:	Three button pushes.
Continued multiplication:	Two button pushes.
Sums of squares:	Four button pushes for each number.
Overflow:	Display locks but keyboard does not.
Display:	Not very good.
Operating Lights:	Good.
Hardware:	Logic contained on three printed circuit cards lying flat. Replacement of a card, although not difficult, is somewhat involved. Reed Switches and Nixie display should be very reliable. Logic is a mixture of integrated circuits and discrete components. Adequate servicing arrangements with trained staff.

TOSHIBA-TOSCAL BC 1621

Register: 16 digits

Dimensions: $7\frac{1}{2}$" x 13" x 17"

Read out: Nixie

Weight: 13.2 Kg

Automatic decimal: Machine has this facility.

Floating decimal: Does not always automatically align, but needs an extra button push.

Automatic square root: Giving maximum accuracy only.

Multiplication: 8 digits by 8 digits maximum.

Powers: One button push for each power.

Constant Multiplier & Constant Divisor:) One button push.

Percentage Multiplier and Divider: Automatically moves decimal point two places to the right.

Continued Multiplication: Two button pushes.

Sums of Squares: Three button pushes.

Mistake: Square root of 2 x 10^{14} - decimal point shows up to left of all digits and doesn't set overflow.

Exchange Key: Will change divisor to dividend but not with constant key depressed.

Display: Good.

Operating Lights: Negative, overflow, and memory lights are difficult to see.

Hardware: Electronic composed of 9 printed circuit boards containing transistorised circuitry. Very high packaging density would make servicing difficult. Quantity of logic on each board probably means that holding a complete set of spares would be necessary, and very expensive. Nixie read-out tubes should be reliable and last nearly the life of the machine. No integrated circuits, but this should not limit accuracy or reliability.

The New Zealand Statistician;

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