The Demise of the Slide Rule
(and the advent of its successors)

Every text on slide rules describes in a last paragraph, sadly, that the demise of the slide rule was caused by the advent of the electronic pocket calculator.
But what happened exactly at this turning point in the history of calculating instruments, and does the slide rule "aficionado" have a real cause for sadness over these events?
For an adequate treatment of such questions, it is useful to consider in more detail some aspects like the actual usage of the slide rule, the performance of calculating instruments and the evolution of electronic calculators.

Usage of Slide Rules

During the first half of the 20^{th} century, both slide rules and mechanical calculators were commercially available, mass-produced and at a reasonable price.
The slide rule was very portable ("palmtop" in current speak, but without the batteries), could do transcendental functions like sine and logarithms (besides the basic multiplication and division), but required a certain understanding by the user. Ordinary people did not know how to use it straight away. The owner therefore derived from his knowledge a certain status, to be shown with a quick "what-if" calculation, out of his shirt pocket. The mechanical calculator, on the other hand, was large and heavy ("desktop" format), and had addition and subtraction as basic functions. Also multiplication and division were possible, in most cases as repeated addition or subtraction, although there were models (like the Millionaire) that could execute multiplications directly.
For mechanical calculators there was no real equivalent of the profession-specific slide rule (e.g. for concrete or hydraulic calculations): the mechanical calculator had to be supported by specific tables for such applications.

The Performance of Calculators

Speed was not a characteristic of the slide rule, nor of the mechanical calculator: the slide rule required effort and time for setting and reading values on a scale, but the mechanical calculator spent much time in repeated additions and subtractions. In the computer era, the unit "FLOPS" (FLoating point OPerations per Seconds) is used to express the arithmetical performance: on the slide rule an experienced user can achieve a speed of 1 FLOPS while a classic PC runs around one MegaFLOPS = 10^6 FLOPS (a contemporary supercomputer-cluster may run between 1 and 1000 GigaFLOPS = 10^9 FLOPS). The speed of -for example- an electro-mechanical Monroe CSA-8 may drop for some divisions way under 0.1 FLOPS.
The accuracy, in number of decimals, was an important differentiator between slide rules and mechanical calculators: a 25 cm slide rule will not exceed an accuracy of 3 decimals, where for example an Ohdner ("sewing machine") could achieve at least 3 times as much. It is clear that for these reasons the slide rule could not be used in financial / accounting offices, or for executing more complex computing models. The slide rule was for the first rough approximation “anytime – anywhere”, and the mechanical calculator for the consolidation of a numerical model, in the “back-office”.

Computers

How were these aspects changed by the introduction of electronics in computing machines? Let us first differentiate between the early computers and the later electronic calculators.
The “general-purpose” digital computers became commercially available after the second world war, but during the first years they were a hundredfold more expensive, more complex and more massive, compared with the mechanical calculators of that time.

Only during the 60's the technology, miniaturisation and price of digital electronics had improved such, that an electronic version of the calculator became feasible.

A separate class of electronic computers should be mentioned: the analogue computer. These machines made use of the "analogue" value of an electrical voltage to represent a numerical value; in this aspect they operated more like the slide rule, which uses the analogue value of "distance" on a scale. Analogue computers were not very accurate, just like slide rules, but they worked in real-time, with the advantage that they could differentate and integrate over time. As it turned out, these machines were only used in control applications (military and process-technology), before they were made redundant by the much faster advances in digital technology.
There has never been a commercially available electronic calculator based on analogue principles.

In the timeline between mechanical and electronic calculators, there has been a brief period of electrical "relay-based" calculators. Relay switches (switched "solenoids", operating one or more electrical contacts) had been used already before 1900 in automatic telephone exchanges, to switch telephone calls based on received dial-pulses.
These switching elements have been used in the first experimental computer models (Stiglitz, Bell Labs, Zuse, in the late 30's), and in the first commercial relay desktop calculators (Casio 14-A Relay Calculator, 1957).

Timeline of Electronic Calculators

Some highlights in the development of electronic calculator were:

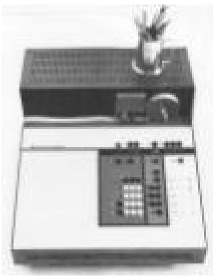
1960

First electronic 4-function tabletop calculator ANITA MkVII. Its successor, the MkVIII, was the first successful commercial version. This (30 pounds) product of the British firm Sumlock Comptometer and Bell Punch, used 177 gas-filled thyratron tubes as switching elements. Internally however, this calculator operated still on a decimal basis, not digital. The keyboard still looked like a "Comptometer".
The name ANITA meant: “A New Inspiration To Arithmetic”.
It is notable that not only computer makers, but also the producers of mechanical calculators (who saw the looming threat of electronics) were active in the field of the new electronic calculators.
Around this time Faber Castell releases its well-known Novo-Duplex 2/83 slide rule.

1963

First transistorised tabletop calculator, Friden EC-130 (over $ 2000.-). This machine had for that time a futurist design, remindful of the film "2001 - A Space Odyssey". It was a binary machine (but with a special BCD coding), and had an acoustical delay-line for memory. The display was a real CRT screen, showing the 4 registers of a stack memory. This was the first calculator where the priority of operations was determined by the “Reverse Polish Notation” (RPN), see also the later HP calculators.

1964



First programmable tabletop calculator, Mathatron ($ 5000,-).
There were also machines which could be programmed via punched cards, like the Wyle WS-02 (1964) or the Wang LOCI-2 (1965).

Around this time Nestler introduced for its slide rules the new plastic material Astralon, amongst others for the Polymath-Duplex.

1968

First programmable scientific tabletop calculator, HP9100A (Hewlett-Packard, $ 4900,-), which used RPN input, like the Friden EC-130 before. Until the high 90's RPN has been the only standard for for HP calculators.

1970

One of the first portable 4-function calculators, de Sharp EL-8. This machine is recognisable by its combined " ´ ÷" key. The 8-segment (not 7!) display had a lower-case "0" (like a "6" without its tail), so that at first sight every EL-8 display looks defective. These first calculators did not yet have leading zero suppression.

So this was the start of the electronic pocket calculator age, although the EL-8 still was rather bulky for a pocket, and needed lots of batteries too.
Then the development of the pocket calculator went fast, the volume of the box shrank, and the price dropped from more than 1000 Dutch Guilders to some 100 Guilders around 1972 (today the battery or solar cell may cost already more than the rest).
The price battle took its toll on the quality of the calculators, especially the material and design of the encasement.
In general, pocket calculators were esthetically too horrible to look at.

1972

First pocketable scientific calculator, HP 35 Classic ($ 395,-). As the story goes, Bill Hewlett of HP called his developers and said, pointing at his HP 9100: "design a calculator with the same functions, but fitting my shirtpocket". And that was what happened. The success of the HP 35 was overwhelming, due to its compact dimensions, flashy design and extensive functions, and this very machine made the general public aware that the slide rule indeed was rendered obsolete by this successor. The HP 35 gave the engineers, just like the good old slide rule, again a special status, not only because of its high price and flashy design, but especially because ordinary people could not work straightaway with RPN: in RPN notation the calculation 5 * (3 + 2) had to be entered as:
5 ENTER 3 ENTER 2 + *.

The "scientific" functions were the goniometric en logarithmic operators. In principle this can be calculated from tables in memory, or by series expansion. But HP has chosen for the CORDIC method (COordinate Rotation for Digital Computers). By this algorithm a sine, for example, is calculated by representing the given angle as a complex value, and reducing the angle to zero by successive rotations where every next step decreases the angle change by a factor 2 ("binary search"); in a digital "processing unit" the factor-2 iteration can be implemented with elementary shift and add operations.
The electronics were packed in only 5 IC's (Integrated Circuits): one for the arithmetical registers and calculations, one for "control & timing", and three ROM's for microprograms, like the CORDIC algorithm.
Ironically, 1972 was the year in which the production of the Curta ("coffee grinder") was terminated.
In that same year, Faber-Castell tried to prolong the life of the slide rule by releasing a combination product consisting of a slide rule with an electronic calculator in verso (Type TR1).

1974

First programmable scientific pocket calculator HP 65, with register and program memory on magnetic strips ($ 795,-).
In the following years most slide rule manufacturers decided to stop production.

Further Evolution of Calculators

After these first successful products, many other scientific calculators were released, both from HP (some 100 different type numbers until 2001, when HP announced termination of its pocket calculator line) and from competitors. Especially TI (Texas Instruments) was running a close race with HP: TI countered the HP 35 with its own SR-50, and the HP 65 with the SR-52. Mostly HP was ahead, and sometimes TI. But HP always had a better quality and a higher price than TI. The HP-adepts still speak about TI as "The Dark Side". Yet TI had been the first firm in the 60's to design dedicated IC's for calculator applications (in project “Cal-Tech”, 1965), but only in 1972 they released their own first 4-function pocket calculator, the TI-2500 Datamath.
These calculators from HP, TI and others have become the darlings of a new type of collector:

the collector of electronic calculators.

In subsequent releases of scientific calculators, numerous new features were introduced, like "continuous memory" (contents not lost at switch-off), financial "present value" calculations, statistics, conversions, complex numbers, matrices, alternate number systems (binary, octal, hexadecimal, sexagesimal), and the use of alfa-numerical symbols for names of variables, program labels and messages.
The slide rule could hardly compete with this, although some of the mentioned features can be found in slide rules. The slide rule was strong in conversions with a constant factor: for this purpose gauge points were added to the scales so that by a single position of the slide, any conversion could be read without even touching the slide rule ("hands-free" in current speak).
For conversions between polar and rectangular coordinates the sine, tangent and P-scale could be of assistance, but direct conversion was not possible on the slide rule.
Specialised slide rules have existed for financial applications like compound interest (e.g. the Faber Castell Disponent), or for calculations on statistical distributions (e.g. the Pickett 6-T).

After the introduction of programming by storing a series of key depressions, HP improved problem solving on its calculators with the "Solver", which allowed solving an implicit function of more than one variable for any one of the variables, given the values of the others.
As example the "free fall" equation: $y = v_o t - \frac{1}{2} G t^2$.
When this equation has been entered symbolically in the Solver, 4 variables are visible (distance y, zero speed v_o, acceleration of gravity G, and time t); any three variables can be allocated a value, after which the fourth variable is calculated.
The fields of expertise, for which specialised slide rules had been designed in the past, were now served by specialised calculator program modules for every area of professional knowledge.
All of these improvements gave the calculator an ever increasing advantage over the classical slide rule, which had drawn to the end of its own development cycle.

Further calculator improvements consisted of new display technologies, especially the low-power LCD (Liquid Crystal Display). LCD's brought display technology from light-emitting back to light-reflecting, the method that the slide rule had already used for 400 years!
Also memory size improved continuously, for storage of registers (variables) and programs.
The slide rule, on the other hand, knew only two types of register: the position of the slide and the position of the cursor. Of course there were extended register forms for slide rules, like the "Poly-Slide Rule" (e.g. the dual-slide Excise "Proof" rules), or the additional cursor to store intermediate results (e.g. the Hemmi type 154).

A new type of pocket calculator was introduced in the early 90's, the “graphical calculator”. This type has a somewhat larger screen display, to show not only calculation results, but also graphics of mathematical functions. The HP 48 was one of the first graphical calculators, but competing products were released by TI, Sharp, Casio and others.
These calculators were used primarily at schools (and sometimes loathed by teachers) because they supported the typical problems of elementary mathematical analysis.
Their popularity grew when newer types also provided the possibility to reduce and solve symbolically any equations, integrals and even differential equations.
This type of applications stands far apart from the slide rule. There have been slide rules with sliding lines and nomograms, but never on the same level as the graphical calculator.
A symbolical slide rule has been designed at one time, the Keuffel & Esser Analon (1975), which could "calculate" relations between dimensions in the MKSC system of physical units.

In parallel to the development of electronic calculators, the general computer evolved significantly too. During the 60's, the large and expensive digital computers of that time were perfect "calculators", thanks to computer languages like FORTRAN, ALGOL and COBOL.
In the 70’s J. Kemeny designed a simplified computer language, BASIC (Beginner’s All Purpose Symbolic Instruction Code), allowing anyone to learn calculating and programming on general purpose computers.
End 70's pocket computers with “BASIC-in-ROM” became available on the market (Casio, Sharp, TI, HP), which could compete with pocket calculators, but adding the easy flexibility of BASIC programming.

Then in 1981, the PC (Personal Computer), originally designed by IBM, started its victorious journey. A countless number of applications has been designed for the PC, among which the family of "calculus programs" which evolved like the pocket calculator: calculations, equations, programming, graphics and symbolic manipulations. But the performance of the PC in speed and memory overtook the graphical pocket calculator with giant strides. Today the PC, especially the laptop, is still shrinking in size, while graphical calculators are getting ever larger.
The many calculator programs for the PC vary from the freeware (gratis) CC4/Xplore for DOS or GraphCalc for Windows, and the cheap Derive, through the expensive, luxury and powerful programs like MathCad, MAPLE and Wolfram Mathematica.

See left figure for a 3D “tubeplot” in MAPLE:

```
> f:= [(t-5*Pi)*sin(t)/3, (t-5*Pi)*cos(t)/3, (t-5*Pi)*.9, t=0 ..
5*Pi]:
> tubeplot(f, radius = (t-5*Pi)*.2,
tubepoints = 25, style=PATCH
lightmodel=light3, shading=zhue, orientation = [-75,90]);
```

Conclusion

The demise of the slide rule is caused by the advent of the cheap, fast and versatile electronic pocket calculator. The special status which the owner used to derive from his slide rule, was happily replaced by the equally special status of the flashy HP-35.
In exchange for the classical slide rule, we obtained the gigantic advantages of the scientific, programmable, graphical and symbolical pocket calculator, and the even more powerful PC calculator software.
So what did we lose?
In fact: nothing. Because the loss of the nostalgic slide rule as calculating tool, has opened up the new and fantastic interesting field of the nostalgic slide rule as "collector's item".

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