Claude Shannon and "the" Differential Analyzer

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There is no doubt that Claude E. Shannon, after his graduation, moved to the MIT to work at Vanneva Bush's *Differential Analyzer*.

Many sources, not only in the internet, use pictures of the well-known purely mechanical Differential Analyzer that was programmed by using screw- and nutdrivers to open and fasten clutches; It has been described by V. Bush in his 1931 paper [Bush1931]; according to this source, there are nearly no relays used therein, at least no relay logic that could have inspired Shannon's master's thesis.

However, a machine nearly unknown even to experts in the area of analog computing was built from 1935 on for several years and kept completely secret until 1945, as it was apparently the most flexible and useful computer at that time. It is today called the *Rockefeller Differential Analyzer*, as the creation of this advanced machine was heavily sponsored by the Rockefeller Trust.

Instead of using shafts and torsion ampifiers, servo systems were used to couple the computation units, so that a new configuration could be established within minutes instead of several hours, and two or three small problems could be processed in parallel.

Very few photos seem to exist, and often the well-known pure mechanical Differential Analyzer is shown in this context. The MIT museum [1] provides photos about Vannevar Bush (although mostly without explanation), most of them showing the predecessors, but a few apparently the Rockwell Differential Analyzer, in particular `VB27i`, which is also used as Fig.1 in [Owens1986]. Beware that `VB18` is from the predecessor machine, the *continuous integrator* ([Owens1986], Fig.3, p.71), which is plausible, while Gleick ([Gleick2011], p. 173) shows it in the conext of the machine Shannon worked with, which is at least misleading.

The Rockefeller Differential Analyzer contained a large number of relays and tubes (thermionic valves and thyratrons) and finally a prototype of a telephone exchange crossbar switch from Bell Labs ([BushCaldwell1945], p.304). Owens reports *several thousand relays*, which is consistent with the text on p.304.

The connection matrix was established by reading punched tapes. A relay logic apparently transformed these commands of a few bits to the signals to set the connection matrix. This was probably Shannon's target, although no confirmation has been found so far, that has lead to his master thesis, probably well before the machine was operable.

The biography by J. Soni and R. Goodman ([SoniGoodman2017]) does spare the reader the technical details, nevertheless tells on page 33/34 that is was a new machine sponsored by the Rockefeller Foundation. It also tells that *A hundred relays … coordinated the Differential Analyzer*, but no source is provided.

Axel Roch's book ([Roch2009]) shows on page 32 the pure mechanical DA, but cites from an interview of Friedrich W. Hagemeyer with Shannon from 1977 via Hagemeyer's thesis ([Hagemeyer1979]):

> a very complex relay control system which was continuing in getting out of order and had to be repaired

Roch's citation suggests that the relays were unreliable; but it makes more sense that a complex relay circuit was unreliable because it was not designed systematically. Relays were established in telephone exchanges and fairly reliable.

For the cited number of 100 relays, no source is given. In the interview ([Hagemeyer1977]) such a number has not been detected, and Hagemeyer's thesis also does not give this numbers.

Wikipedia in both entries (German and English) gives specific numbers already in the initial versions, but no sources.

References

BushCaldwell1945:

V. Bush, S.H. Caldwell: *A new type of differential analyzer.*
In: Journal of the Franklin Institute, vol. 240 no. 4, 1945, pp. 16-32
DOI:10.1016/0016-0032(45)90453-4

Owens1986:

L. Owens: *Vannevar Bush and the Differential Analyzer.*
In: Technology and Culture, Vol. 27, No. 1 (1986), pp. 63-95
https://www.jstor.org/stable/3104945

Bush1931:

V. Bush: *The differential analyzer. A new machine for solving differential equations.*
In: Journal of the Franklin Institute, Vol. 212, Issue 4, 1931, pp. 447-488
DOI:10.1016/S0016-0032(31)90616-9
https://www.sciencedirect.com/science/article/pii/S0016003231906169

Hagemeyer1979:

F.-W. Hagemeyer: *Die Entstehung von Informationskonzepten in der Nachrichentechnik*. Dissertation, Berlin 1979.
http://weisses-rauschen.de/hero/hagemeyer/hagemeyer_dissertation.pdf

Hagemeyer1977:

F.-W. Hagemeyer, Oral interview with Claude Shannon in 1977.
Digitized Version: File `16_Shannon.mp3`
http://weisses-rauschen.de/hagemeyer/

SoniGoodman2017:

J. Joni, R. Goodman: *A Mind At Play*.
Simon & Schuster, New York, 2017
ISBN 978-1476766683

Gleick2011:

J. Gleick: *The Information. A History, a Theory, a Flood.*
Fourth Estate, London, 2011
ISBN 978-0-375-42372-7

Roch2009:

A. Roch: *Claude E. Shannon. Spielzeug, Leben und die geheime Geschichte seiner Theorie der Information.*
gegenstalt Verlag, Berlin, 2009
ISBN 9783981315608

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[1] https://webmuseum.mit.edu/detail.php?module=people&type=popular&kv=6887