Plankalkül: Not Just a Chess Playing Program

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Germany, 1935: an eclectic young man, aeronautic engineer and futurist painter, had set his mind on simplifying and speeding up calculations in airplane design systems. It was thus, in the humble living room of his Berlin house, that Konrad Zuse (1910-1995) devoted himself to the design and construction of a binary, programmable machine, the Z1, capable of processing data in a faster and more efficient way than had previously been known.

The young German engineer aimed to equip the machine with a number of formulas: ready-to-use patterns, which would allow it to limit operations to just those numbers involved in the operation, or to the incoming data. Zuse thought of a "universal superformula", a free scheme that was able to process any type of problem, just like the Universal Turing Machine proposed in the paper of 1936 – itself unfortunately not widely-diffused in pre-WWII Germany.

Using an extensively employed component from the world of telecommunications, the relay, he recognized not only the technical and practical advantages of the two-value system over decimal but also realized that all the operations of algebraic calculation could be made by using components in either of two states. In his "Einführung in die allgemeine Dyadik" (1938), he expressly drew inspiration from Leibniz and coined the term *Dyadik*. In this work, he proposed a "logistics math" that turned out to be equivalent to the propositional calculus and Boole's algebra, of which he was aware only later thanks to his math teacher.

The initial prototype was followed by other, more advanced versions featuring an improved arithmetic unit (the Z2) and relays (the Z3), culminating in the creation of an effective machine (the Z4) set up for the first time in Zurich in 1950, just a few months before the UNIVAC was released in the United States.

While building his machines, the German scientist also started to devise a conceptual and notational system for writing «programs» to execute applications much more complex than the basic arithmetic calculations hitherto used.

«For a year and a half, I devoted myself to the progressive study of formal logic. I found within it many of my own thoughts [...]. Now, I aim to finalize the process of the *plan calculus*[1]. To do this, I have to clarify a number of notions.»

Zuse was perfectly aware, as early as 1939, that it was possible to create a «calculus» based on predicate logic. Later on, while working on his PhD dissertation "*Ansätze einer Theorie des allgemeinen Rechnens unter besonderer Berücksichtigung des Aussagenkalküls und dessen Anwendung auf Relaisschaltungen*", he further developed the project to formal-

[1] Incidentally, *Plan* is German of 'program'. Thus when Zuse speaks of a *Plan*, he means what was later called a program. Zuse used *Kalkül* as it was used in *Assagenkalkül* and *Pradikatenkalkül*. Thus *Plankalkül* is an instrument for reasoning about programs – quite a modern point of view.

ize a programming language. Here the term "computation" (*Vorschrift*), the cornerstone of modern programming, occurs more than once along with a precise and rigorous definition: «computation means to start from certain data and produce new data following a specific rule».

Computing, in other words, allows one to generate an output by processing input data through an algorithm. Therefore it requires the formalization of a set of rules for representing these algorithms on machines designed to execute the desired operations in a «transparent» fashion. This, in turn, calls for «a purely formal description of each computation routine» which would grant anyone the ability to write an accurate and well structured "*Rechenplan*".

Driven by these motivations, Zuse devised the *Plankalkül* as a universal, algorithmic, high-level language, suited to the formal representation and solution of extremely complex problems, such as algorithmic chess-playing against himself.

The formalization of the chess game imposed the need to structure disordered thoughts with strict formulas. Controlling the game, i.e. making the match follow the rules, would have initially required operations starting from binary values to be fed into series of binary values, and then into long lists of binary pairs arising from these previous values. This would have led to increasingly complex arrays one would then have to structure in line with rules built from elementary data. Instead, Zuse started work on his Plankalkül.

The aim of the present study is to highlight the general purpose and technical specifics of this language, its historical and scientific background, and the philosophical inspiration leading Konrad Zuse to make use of Hilbert's predicate logic in the formalization of the "computation projects" for his machines.

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