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CS 1501

05 June 2020

W Paper 3 – W Paper 1 Revision

Donald Ervin Knuth is an American mathematician, computer scientist, and revered professor at Stanford University. He is the 1974 recipient of the Alan M. (A.M.) Turing Award, the Association for Computing Machinery's most prestigious technical award that is widely regarded as the "Nobel Prize of computing" and given to those who have made major contributions to the field of computer science ("A.M. Turing Award"). This essay aims to detail the life of Donald Knuth and his contributions to the field of computer science that have deemed him deserving of the A.M. Turing Award, as well as his continuing influence on modern computing.

Knuth was born on January 10, 1938 in Milwaukee, Wisconsin. His father was a teacher at a Lutheran high school and also played as a church organist on Sundays ("A.M. Turing Award"). Since an early age, Knuth demonstrated academic acuity and an aptitude for solving complex problems. He inherited his father's appreciation for music and language, possessing particular interest in the structure of English grammar. He edited for his school paper and created crossword puzzles in during the seventh and eighth grade. Knuth was so savvy with words during that period that he won a television set and candy for his peers from a word-building contest sponsored by a candy manufacturer, where contestants competed to form as many words as possible from the phrase "Ziegler's Giant Bar." He managed to form 4,500 legal words out of the phrase, despite the judges having only 2,500 words on their master list.

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Additionally, Knuth won the Westinghouse Science Talent Search (now the Intel Science Talent Search) after proposing the Porterzbie system of weights and measures, a metric system using the thickness of issue #26 of *Mad Magazine* for length, calling a group of 48 things a "MAD," and naming the basic unit of power a "whatmeworry (Shasha and Lazere 90)."

Although Knuth excelled in his academics, he found mathematics and physics uninspiring and planned to pursue a career in music after graduation. However, his plans changed after the Case Institute of Technology (now Case Western University) offered him a full scholarship to study physics (Raskin 61). While he completed his undergraduate degree, his instructor introduced him to one of the earliest computational mainframes, the IBM 650, of which he expressed immense interest in and read its manual from front to back. He learned to program using the IBM 650, creating trivial programs such as one that could factor numbers into primes and another that taught a computer how to play tic tac toe, as well as developing a faster assembler and compiler code for the IBM 650 (Shasha and Lazere 91).

Knuth soon switched his major to mathematics, and by the time he would have earned his B.S., his work was so prominent that his university awarded him his M.S. at the time of his undergraduate graduation in 1960. One exhibit in his collegiate portfolio includes a system that analyzed the value of a basketball player, which the coach of his university's basketball team used to help the team win a league championship (Koshy 244).

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After receiving his M.S., Knuth continued his education to pursue a PhD in mathematics at the California Institute of Technology. In his second year of the doctorate program in 1962, he signed a contract with publisher Addison-Wesley to write a book on compilers consisting of twelve chapters. Knuth produced his first draft of the book totaling 3,000 pages in 1965, emphasizing organization, aesthetics, and the presentation of reliable information on the field after noticing a trend of spotty information in many technical publications at the time. Addison-Wesley decided to reorganize the draft into seven volumes instead of twelve chapters under the title *The Art of Computer Programming* (TAOCP). By 1973, they published TAOCP's first three volumes, which focused on basic concepts of computing and data structures, random numbers and arithmetic, and sorting and searching algorithms ("A.M. Turing Award").

The earlier volumes made a monumental impact on the field of computer science through its organized and visually pleasant presentational format and by encouraging other people of the field to restructure curricula on the subjects of the publications and expand on his work. As a result of this impact, Knuth was awarded the A.M. Turing Award in 1974, accompanied by a citation reading from Bernard A. Galler,

> The 1974 A.M. Turing Award was presented to Professor Donald E. Knuth of Stanford University for a number of major contributions to analysis of algorithms and the design of programming languages, and in particular for his most significant contributions to the "art of computer programming" through his series

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> of well-known books. The collections of technique, algorithms, and relevant theory in these books have served as a focal point for developing curricula and as an organizing influence on computer science. (Knuth 667)

Before he received the A.M. Turing Award for his work on TAOCP in 1974, Knuth published a fascinating mathematical novelette called *Surreal Numbers* during a weeklong relaxation in Oslo, Norway in 1973. The novelette serves as an entertaining introduction to method of constructing numbers created by John Horton Conway of the University of Cambridge, where two ex-student characters explore and build up to Conway's number system through a four-act dialogue (Knuth). On his Stanford faculty webpage covering the novelette, Knuth explains, "I wanted to give a reasonably faithful portrayal of the important principles, techniques, joys, passions, and philosophy of mathematics," as he researched in order to simulate understanding Conway's system as a surreal experience (Knuth).

Knuth is also responsible for creating TeX and Metafont, a digital typesetting designed to replace the erroneous phototypesetting that often placed limitations on printing mathematical formulas and code snippets and caused a decline in quality for the printing of TAOCP (Knuth 5). Amidst TeX's development, Knuth created a new programming methodology that he called "literate programming," which emphasized writing programs in such a way that allowed the code read like works of literature. In his

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article, “Literate Programming,” Knuth explains, “Let us change our traditional attitude to the construction of programs: Instead of imagining that our main task is to instruct a computer what to do, let us concentrate rather on explaining to human beings what we want a computer to do (Knuth 1).”

In addition to this new methodology, Knuth introduced his WEB system, which, “produces a document that describes the program clearly and that facilitates program maintenance…[and] produces a machine-executable program. The program and its documentation are both generated from the same source, so they are consistent with each other (Knuth 2).” This system served as a foundation for programming documentation standards that other contributors to the field would build on to be compatible for other programming languages.

Knuth continues to exert his influence within the field of computer science and mathematics in the context of more recent years. He is an active contributor for *Numberphile*, an educational channel and website featuring videos and discussions that explore topics from a variety of fields of mathematics. He also occasionally appears in videos on *Computerphile*, the sister channel to *Numberphile* that covers topics from a variety of fields of computer science in a similar fashion. Such videos that Knuth takes part in include “Surreal Numbers (writing the first book) - Numberphile," in which Knuth discusses his inspiration for writing *Surreal Numbers*, his interactions with Conway on

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his number construction system, and the main idea of the number system – where two numbers can have infinitely many numbers in between – as a surreal concept (Numberphile 00:00:00 - 00:04:41). In another video, "Why Don Knuth Doesn't Use Email - Computerphile," Knuth explains why he has not used email since 1990, effectively describing the service as an unwelcome distraction with little reciprocation that interfered with his work and his personal life (Computerphile 00:00:00 - 00:02:10).

Knuth is an accomplished pioneer of the field of computer science and mathematics that has shown excellence since an early age. His contributions to the field, of the likes of TAOCP and the WEB system, have made a lasting impact on how people understand and present information on computing, the analysis of algorithms, and the design and methodology of programming languages. He continues to participate in the mathematics and computer science communities, and many programmers and computer scientists still use his writings as a focal point for their studies and teachings and continue to expand upon his work to this day, making him a worthy recipient of the A.M. Turing Award.

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Works Cited

"A.M. Turing Award." A.M. Turing Award, Association for Computing Machinery, 2019, amturing.acm.org/. Accessed 03 June 2020.

Computerphile. "Why Don Knuth Doesn't Use Email - Computerphile." *YouTube*, discussion with Donald Knuth, 21 August 2015, https://youtu.be/QS8qwMna8_o. Accessed 19 July 2020.

Knuth, Donald E. "Computer Programming as an Art." *ACM Turing Award Lectures*, doi:10.1145/1283920.1283929. Accessed 04 June 2020.

Knuth, Donald E. "Literate Programming." *The Computer Journal*, 1983. Accessed June 05 2020.

Knuth, Donald E. "Literate Programming" (PDF), 1984. Accessed June 04, 2020.

Knuth, Donald. "Surreal Numbers." *Knuth: Surreal Numbers*, Stanford University, www-cs-faculty.stanford.edu/~knuth/sn.html. n.d. Accessed July 19, 2020.

Koshy, Thomas. *Discrete Mathematics with Applications*. Elsevier, 2004.

Numberphile. "Surreal Numbers (writing the first book) - Numberphile." *YouTube*, discussion

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with Donald Knuth, 27 June 2016, https://youtu.be/mPn2AdMH7UQ. Accessed 19 July 2020.

Raskin, Molly Knight. *No Better Time: the Brief, Remarkable Life of Danny Lewin, the Genius Who Transformed the Internet*. Da Capo Press, 2013.

Shasha, Dennis Elliott, and Cathy A. Lazere. *Out of Their Minds: the Lives and Discoveries of 15 Great Computer Scientists*. Copernicus, 1998.