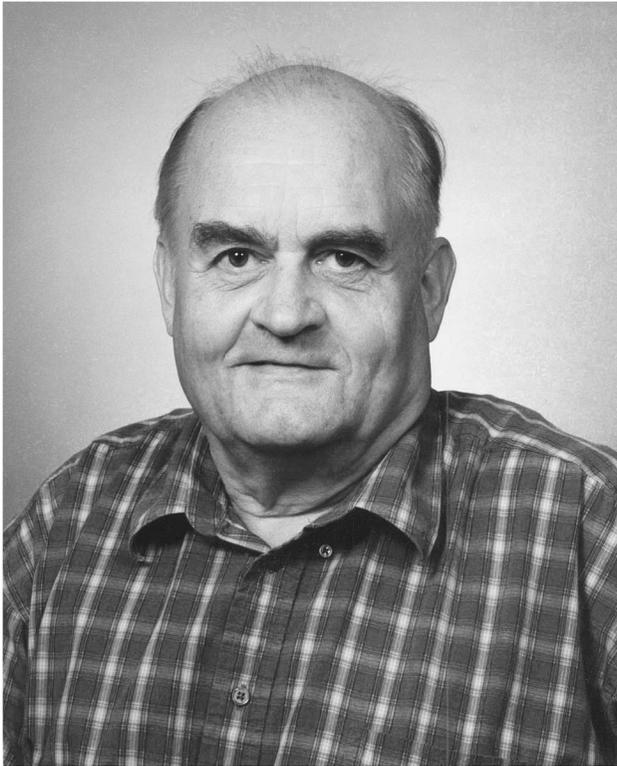


WOLFGANG HAKEN: A BIOGRAPHICAL SKETCH

ILYA KAPOVICH



Wolfgang Haken

Wolfgang Haken¹ was born in Berlin on June 21, 1928. His father was a physicist working for the German Patent Office and his mother was a housewife. His two younger brothers died in 1927 of scarlet fever, and Wolfgang

¹ Born as Wolfgang Rudolf Gunther Haken. He dropped his middle names “Rudolf Gunther” and changed his legal name to just “Wolfgang Haken” in 1976, when he became a U.S. citizen.

grew up as a single child. During his childhood in Berlin, Wolfgang developed an early interest in Mathematics. At the age of 4 he made what he thought was his first important mathematical discovery: that counting should start with 0 rather than with 1, and that 0 is the first natural number. He tried to convince his father to patent this fact but did not succeed at the time.

Wolfgang's mother died in August 1939, several days before the start of World War II, and the family remained in Berlin for most of the war. In 1944, at the age of 15, Wolfgang was drafted to serve in an anti-aircraft battery. He was soon transferred from Berlin to Dessau and from there to Soest, where he met the end of the war. After the war, Wolfgang first worked as a farm hand, and passed a high school GED exam in 1946. In the summer of 1946 he started his undergraduate studies at the University of Kiel. At the time Kiel had only two mathematics faculty members: a Professor of Mathematics and a Professor of Geometry, which were regarded as different subjects when the university was founded in 17th century. The Professor of Mathematics at Kiel was Karl-Heinrich Weise; most of Haken's mathematics classes were taught by Weise. In the Fall of 1947, while Haken was still an undergraduate student, he attended a topology course by Weise. In this course Weise stated several famous open problems in topology, including the Poincare Conjecture, the Four Colour Problem and the Unknot Problem. This experience marked the start of Haken's interest in topology. He received a pre-diploma (roughly equivalent to the Bachelor of Science in the western system) in physics and mathematics at Kiel in 1948. He then started his doctoral studies in Mathematics at Kiel, with Weise as his thesis advisor. Haken obtained his PhD from Kiel in 1953, with the dissertation entitled *Ein topologischer Satz über die Einbettung $(d - 1)$ -dimensionaler Mannigfaltigkeiten in d -dimensionale Mannigfaltigkeiten*. Haken met his future wife, Irmgard², at Kiel in 1950 where she was also studying mathematics as an undergraduate student. They got married in 1953. Later Irmgard also received a PhD in Mathematics, and also with Weise as the advisor, in 1959.

After getting his PhD, Haken obtained a job at Siemens in Munich as an electrical engineer, where he worked on designing microwave devices until 1962. The first three of six children of Wolfgang and Irmgard were born during this period: Armin in 1957, Dorothea in 1959, and Lippold in 1961.

In 1956 Haken sustained a near fatal accident while mountain climbing in the German Alps. He fell over 30 feet and remained in a coma for several days. The accident significantly damaged Wolfgang's foot but did not dampen his enthusiasm for the outdoors.

While at Munich, Haken continued doing mathematical research in combinatorial topology. He solved the long-standing Unknot Problem by producing an algorithm for deciding whether a knot diagram represents the unknot.

² Born Anna-Irmgard von Bredow, she goes primarily by Irmgard.

Haken's solution, at over 100 pages long, was eventually published in "Acta Mathematica" in 1961 in a paper titled *Theorie der Normalflächen* [9]. The paper started Haken's work on developing the theory of "normal surfaces", which came to play crucial role in 3-manifold topology. The solution of the Unknot Problem got Haken's work noticed by several mathematicians in the United States. Ralph Fox, a topologist at Princeton, had his graduate students go over Haken's proof in detail, and, somewhat to Fox's surprise, they found the proof to be correct. Bill Boone, a group theorist at UIUC, also became intrigued by Haken's paper. At the time Boone was working on topics related to the unsolvability of the word problem for finitely presented groups and he understood that there were close connections between algorithmic problems in group theory and algorithmic problems in low-dimensional topology. Since by then it was known that the word problem for finitely presented groups is, in general, undecidable, Boone expected the Unknot Problem to be undecidable as well. Therefore Haken's proof came as a considerable surprise to him. Just 6 weeks after the publication of Haken's paper in Acta, Boone invited Haken to come for a year to UIUC. Haken came to Urbana-Champaign with his family in 1962 and spent the 1962-63 academic year at UIUC as a Visiting Professor. Mahlon Day, who was the Math Department Head at UIUC then, suggested to Haken that, when preparing for the visit to Illinois, Haken obtain a U.S. immigrant visa (which was relatively simple to do at the time). Haken followed this advice, which made it easier for him to settle permanently in the U.S. later. During his year at Illinois, Haken applied for and obtained a temporary membership at the Institute for Advanced Study at Princeton. He spent two years, 1963-1965, at Princeton. In 1965 Haken joined the faculty at the Department of Mathematics at UIUC as a tenured Professor. The last three children of Wolfgang and Irmgard were born in the U.S.: Agnes in 1964, Rudolf in 1965 and Armgard in 1968.

Haken's 1961 paper on the Unknot problem explored in detail the properties of incompressible surfaces in a 3-manifold and introduced the notion of what came to be called a *Haken 3-manifold*, defined as a compact prime and \mathbb{P}^2 -irreducible 3-manifold which contains a two-sided incompressible surface. The notion of a Haken manifold became central in the development of 3-manifold topology over the next 50 years, particularly in Thurston's geometrization program. In a 1962 paper Haken proved that Haken manifolds admit a "hierarchy", that is, they can be cut into 3-balls along incompressible surfaces [10]. Haken published several more papers on the topology of 3-manifolds in the 1960s and 1970s [11], [12], [13], [14], [8], [15], [16], [17], and his work in this area remains widely influential. Motivated by Haken's work, in 1968 Waldhausen formulated a question which came to be known as the "Virtual Haken Conjecture" [18]. The conjecture states that every compact, orientable, irreducible 3-manifold with infinite fundamental group

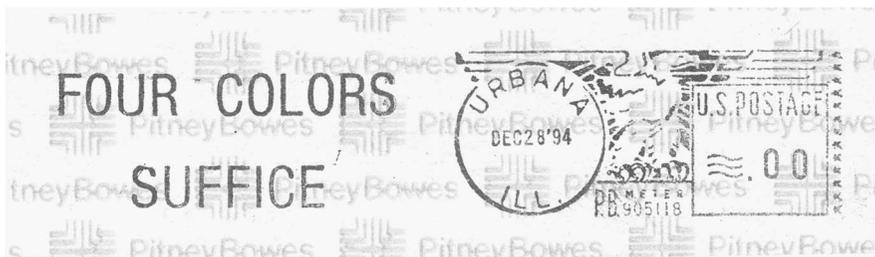


FIGURE 1. The “Four Colors Suffice” postmark used by the UIUC Department of Mathematics after the Appel-Haken proof.

admits a finite cover which is a Haken manifold. The Virtual Haken Conjecture informed much of the subsequent development of 3-manifold topology and geometric group theory. The conjecture was recently proved by Agol [1], with a substantial portion of the proof relying on the work of Wise, and of Kahn and Marković.

In 1970 Haken began to work on the Four Color Problem, which fascinated him ever since the 1947 topology course by Weise and a subsequent 1948 lecture at Kiel by Heinrich Heesch. In 1976 Haken and Ken Appel (who was also a professor at UIUC then) solved the Four Color Problem. Their proof included a substantial computer-aided component and marked the first time that a major mathematical result of this level of importance was solved with the help of a computer. Appel and Haken published an announcement of their proof in the *Bulletin of the AMS* in 1976 [2]. The proof itself was published in a series of papers in the *Illinois Journal of Mathematics* in 1977 [3], [4], [5], [6]. Inevitably, the proof generated much discussion and controversy in the mathematical community and was to a large extent responsible for the birth of Computational and Experimental Mathematics as significant directions in modern mathematical research. Appel and Haken published an extended version of their proof, addressing some of the questions and criticisms that were raised in the meantime, as a 700+ page book in 1989 [7]. Shortly after Appel and Haken announced their proof in 1976, the UIUC Department of Mathematics put the phrase “Four Colors Suffice” on its official postmark, which remained in use until mid-1990s, see Figure 1.

Wolfgang Haken delivered an invited address at the International Congress of Mathematicians in Helsinki in 1978. In 1979, Haken and Appel shared the Fulkerson Prize from the American Mathematical Society for their solution of the Four Color Problem.

Haken remained a professor of the UIUC Department of Mathematics until his retirement in 1998. He was also a member of the University of Illinois Center for Advanced Study from 1993 to 1998. While at UIUC, Haken was a

thesis advisor for 7 PhD students: Richard Rempel (1973), Thomas Osgood (1973), Mark Dugopolski (1977), Howard Burkom (1978), Robert Fry (1979), and Scott Brown (1995).

The “Saturday hike” is a delightful UIUC tradition going back to 1909 and having a long association with the mathematics department; the hike was for many years led by the late Joseph Leo Doob. From 1960s and through the present day, Wolfgang Haken has been a constant participant of the Saturday hike, as have been many other members of the Haken clan. Wolfgang’s wife Irmgard was an informal leader of the hike from 1993 to 2005, and continued to come to the hike in subsequent years, while her health allowed. Sadly, Irmgard passed away on April 4, 2017, while this article was in production.

During a winter hike some 14 years ago, a group of hikers, including Wolfgang and this author, walked for several miles along a creek, crossed an old bridge and walked on the other side of the creek back to the point right across the creek from our base-camp. While the rest of us looked at the camp and contemplated an arduous walk back, Wolfgang said “Well, we’ll just have to wade through”, then slowly but surely moved into waist-deep freezing water and crossed to the other side. Thus we saw how a *Virtual Haken* dealt with this real life problem, and we followed him.

Much of Wolfgang’s current scientific interests concern thinking about fundamental problems in cosmology.

Three of Wolfgang Haken’s six children live in the Urbana-Champaign area. Rudolf Haken, a renowned musician and a composer, is a professor of viola in the University of Illinois School of Music. Lippold Haken designs electronic musical instruments and equipment and owns a company manufacturing a unique “Continuum Fingerboard”. He is also a Lecturer at the Department of ECE at the University of Illinois, and conducts research related to sound. Armgard Haken received B.S. and M.S. in biology from UIUC, and is currently a program manager at the Beckman Institute, managing activities and grants related to cancer research.

Haken’s eldest son, Armin, obtained a PhD in Mathematics from UIUC in 1994, specializing in complexity theory and problems related to theoretical computer science. He is currently a software engineer in San Francisco. Dorothea Blostein, nee Haken, received a PhD in computer science from UIUC in 1987 and is currently a Professor in the School of Computing at Queen’s University in Kingston, Ontario. Agnes Debrunner, nee Haken, received a B. Sc. in Animal Science from UIUC. She is a leader in the U.S. underwater hockey community and lives near Denver, Colorado.

As of this date, Wolfgang and Irmgard have 13 grandchildren.

In 2014, in honor of Haken’s research contributions, the UIUC Department of Mathematics established a graduate student award called the Wolfgang Haken Prize in Geometry and Topology.



FIGURE 2. Wolfgang Haken and Ian Agol in Altgeld Hall 314 in May 2014.

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