Context and Driving Forces in the Development of the Early Computer Game Nimbi

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The Danish computer company Regnecentralen developed a computer version of Piet Hein's game Nimbi, a variant of the ancient game Nim, in 1962 and 1963. Piet Hein envisioned computers playing against humans, while Regnecentralen hoped Nimbi would illustrate the potential of computers to the public. Although technologically successful, Nimbi never fulfilled its promise due to hardware constraints and a lack of organizational follow-up.

People have been enthused with game playing for centuries, from smallish board games to strategy and live role-playing games. To provide thrills beyond the mere game playing, game developers have invented intriguing games and devised shrewd variants of existing games. Researchers have noted, "A cardinal theme in the theory of combinatorial games is how to generate new games from a given game or from a restricted class of games."[1] Gamers with a mathematical slant have analyzed games trying to uncover their secrets. Likewise, mankind has been thrilled by building game-playing machines and machines that compete against humans.

The merging of games and computers yielded an extremely powerful combination for both classic board games and videogames. Indeed, the past few decades have witnessed a flurry of novel videogames and genres—from Tetris to World of Warcraft. As game researcher Jesper Juul noted, "video games are a comparatively new cultural form, intimately linked to the appearance of computers, postdating literature, cinema, and television."[2] He continued: "There appears to be a basic affinity between games and computers: Like the printing press and cinema have historically promoted and enabled new kinds of storytelling, computers work as enablers of games, letting us play old games in new ways, and allowing for new types of games."

Regardless of age or type, all games share one central feature: rules. Because rules are explicit and formalizable, games lend themselves to computer implementation. This congruence has led to game-playing machines, machines that compete against human game players, and the use of games to illustrate the potential of computers. All these influences were at play in the development of the game *Nimbi* (a variant of the simple, ancient game Nim and developed by the Danish poet and game designer Piet Hein in 1945) at the Danish computing company Regnecentralen in 1962 and 1963. Regnecentralen management strongly supported the Nimbi development partly because it hoped the games would provide an opportunity to educate the general public about the potential of computers. Nimbi's development was successful, but due to a blend of hardware constraints and Regnecentralen's lack of follow-up and promotion, the game never fulfilled its promise.

Games and computers around 1960

In the 1950s and 1960s, efforts at the intersection of games and computing flourished, specifically game implementations and research centered on games. Board games were among the first noncalculation tasks implemented on computers in the 1950s.[3] For example, the British computer scientist Christopher Strachey developed a checkers program in 1951,[4] the PhD student A.S. Douglas developed the game OXO (or tic-tac-toe) on the EDSAC in 1951 to illustrate his thesis,[5] and a Nim program was developed for Silliac, the first Australian computer, in 1956.[6] Novel games also emerged that utilized the computer's unique capabilities, such *Tennis for Two*, developed

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by physicist William Higinbotham in 1958 at the US's Brookhaven National Laboratory (p. 50).[5] These develop-ments accelerated around 1960 when computers became smaller, cheaper, and more accessible as transistors replaced vacuum tubes. Many computers were installed in university labs where students and staff implemented games. A prominent example is *Spacewar*, often referred to as the first real computer game.[2,7,8]

These early developments were driven by individuals and organizations' publicity concerns. For example, the Silliac Nim program was specifically developed for Silliac's inauguration, and the program was demonstrated after the machine was started by John Northcott, administrator of the Commonwealth of Australia. Pamphlets titled "SILLIAC challenges YOU to play 'NIM' at a Public Demonstration" were printed for the public. The pamphlet even suggested that readers "practise at home because SILLIAC will be hard, but not impossible to beat" (p. 32).[6] Similarly, *Tennis for Two* was intended to generate more public interest in Brookhaven National Laboratory. Although it was "a very basic game [that] ran on analogue equipment, an oscilloscope," it succeeded in terms of publicity because "accounts of the time agree that the game was a huge success among the lab visitors" (p. 50).[5]

MIT also tried to generate public interest in computers using *Spacewar* because "guests at MIT's annual visitor day were less than impressed by the low hum of mainframes." MIT enlisted three employees "to create demonstration programs that would capture the minds of visitors." They created *Spacewar* on the new DEC PDP-1 computer with interactive capabilities. "The game was a runaway success.... a single, simple game that had an enormous influence on early programmers" (pp. 50–51)[5] partly because DEC decided to bundle the game with the PDP-1 computer as a debugging tool (p. 20).[7]

In the same way, embryonic research involving games and computing helped lay the groundwork for the artificial intelligence and cognitive science fields. Influential IBM computer scientist Arthur Samuel used games, especially checkers, as a vehicle to study learning.[9] Other researchers such as Claude Shannon, Allen Newell, and Nobel laureate Herbert Simon used chess—traditionally considered the epitome of intellectual skill—in their work on machine intelligence and human intelligence while developing theories of problem solving and human information processing.[10] Newell, Shaw, and Simon wrote a chess-playing program called NSS that ran on Johnniac to illustrate the idea of satisficing, one of Simon's important contributions, which means to accept an adequate rather than an optimal solution.[11] Chess was so important in this area that it has been called the Drosophila of AI.[12]

Samuel's survey paper "Programming Computers to Play Games" illustrates the state of art in games and computing around 1960.[13] The paper, which primarily addressed chess and checkers, had a noticeable noncomputer flavor. Samuel not only opened with Baron von Kempelen's chess machine from 1769, a canonical mechanical game-playing device, but also noted that "modern work along these lines does not often lead to the construction of actual machines. Instead a program is usually written for an existing digital computer" (p. 167).[13]

Nim

The two-person mathematical game Nim (see Figure 1), which many believe originated in China (p. 12),[3] is probably one of the oldest games in the world.[14–16] The name *Nim* is attributed to Charles Bouton[3] and is possibly related to the German term *zu nehmen*, or "to take."[17]

John H. Conway describes the game play: "This game is played with a number of heaps of matchsticks [or other kinds of tokens]. The legal move is to strictly decrease the number of matchsticks in any heap (and throw away the removed sticks).

Figure 1. A Nim game with three heaps that contain 3, 4, and 5 tokens. Players can use the nuts shown here or any type of token.

Table 1. Example game play for a Nim game.

Heaps	Moves
A B C	
3 4 5	Player I takes 2 from heap A.
1 4 5	Player II takes 3 from heap C.
1 4 2	Player I takes 1 from heap B.
1 3 2	Player II takes 1 from heap B.
1 2 2	Player I takes entire A heap.
0 2 2	Player II takes 1 from heap B.
0 1 2	Player I takes 1 from heap C.
0 1 1	Player II takes 1 from heap B.
0 0 1	Player I takes entire C heap and wins.

A player unable to move because no sticks remain is the loser.''[18] Table 1 shows a game between two players.

The game can be played with almost any tokens (such as stones, matches, or coins) and only requires a plain surface, though game boards with rows corresponding to heaps do exist. The game is also flexible, with a variable number of heaps and number of tokens in the heaps. Hence this simple game remains challenging even for experienced players. Three heaps with 3, 4, and 5 tokens is a common variant, but the four-heap 1-3-5-7 Nim game gained fame after it appeared in the 1961 French movie *Last Year in Marienbad*.

Nim has influenced game theory on several fronts.[1] First, numerous Nim-playing machines have been devised such as Nimatron, built by Westinghouse for the New York World's Fair in 1940 (http://www.goodeveca.net/nimrod/nimatron.html),[17] and the British Nimrod developed for the Festival of Britain in London in 1951. Second, Nim has a rich mathematical theory behind it. Third, the game has influenced terminology in combinatorial game theory (i.e., nim-addition and nim-sum).[19,20] Finally, numerous variants have emerged such as one-pile pickup, Moore's Nim, and Fibonacci Nim.[3,15,20,21]

In addition, Nim was allegedly the first combinatorial game to attract the attention of a professional mathematician (pp. 137, 145),[19] when the Harvard University French-American mathematician Charles L. Bouton published an in-depth mathematical analysis of Nim in 1902.[22] He wrote, ''It is the writer's purpose to prove that if one of the players, say A, can leave one of a certain set of numbers upon the table, and after that plays without mistake, the other player, B, cannot win.

Table 2. Bouton's binary decomposition of a Nim game.

Tokens	Binary Decomposition			
	8	4	2	1
4	0	1	0	0
9	1	0	0	1
15	1	1	1	1
Sum	2	2	1	2

Such a set of numbers will be called a safe combination.'' Bouton succeeded and provided a simple method that let players analyze the game. By conceiving the number of tokens in the heaps as binary numbers and applying a simple adding rule, the player can easily tell whether a position is safe. In the words of Donald Spencer (see Table 2), the procedure is

> To determine whether a position is safe or unsafe, the number of objects in each pile may be expressed in binary notation: if each column adds up to zero or an even number, the position is safe. For example, if at some stage of the game, three piles contain 4, 9, and 15 objects, the calculation is: Since the second column from the right adds up to 1, an odd number, the given combination is unsafe. A skillful player will always move so that every unsafe position left to him is changed to a safe position.[3]

Bouton's paper has been widely cited in mathematical game-theory communities. The work generalizes to the misère version of Nim[15] and the multiple game.[15,21] The impact of Bouton's analysis was illustrated in Samuel's 1960 paper:

> The history of game-playing machines is replete with attempts to devise algorithms which can be used to guarantee a win . . . As an example, the game of Nim falls into the category of games. However interesting some of the many machine realizations may have been to the nonmathematical public, this game remains essentially trivial to anyone knowing the binary number system. We will not concern ourselves with such games, at least not when played in this manner. (p. 166)[13]

In other words, Nim had fallen in disgrace.

Piet Hein's response

The Danish game developer, mathematician, designer, and poet Piet Hein was put off by Bouton's analysis: ''The game was thereby changed to an elegantly solved mathematical problem, but at the same time destroyed as a game . . . [This] called for a response . . . that could reestablish the lost dignity as an unbeaten game.''[23] Later, Hein even referred to Bouton's analysis as the ''murder on Nim'' and wrote, ''I asked myself the question if the ancient game could be given a twist without increasing the number of tokens and without changing the rules . . . taking it beyond the scope of analyses like Bouton's.''[14]

In Nim, each token can only be a member of one heap. Hein's idea was to allow the tokens to be part of several heaps. After trying out a number of layouts, he succeeded in 1945 with the Nimbi game, which has simple rules like Nim but is much more complex due to its geometry.[23] Figure 2 shows Hein's original drawing of the Nimbi board layout, where the dots denote the token positions.[23] As opposed to Nim, the game starts with a fixed number of tokens (12), one on each position on the board. Nim's heaps correspond to the lines in Nimbi. This layout increases the complexity because each token can now be a member of three lines (lateral, diagonal up-left, and diagonal up-right). The rules are as follows: ''A move consists in removing one or more tokens from the board. If more than one token are removed, they must be consecutive on the same line. The one removing the last token has lost.''[14] Hence, Nim's basic simplicity is largely unchanged—take as many tokens as you want in one line (heap).

Hein marketed the game under the label Nimbi in 1957,[24] and the game made its way to Martin Gardner's prestigious game column in *Scientific American* in 1958.[17] I've therefore chosen to use the name Nimbi throughout this article, even though it was also referred to as extended Nim[25] and geometric Nim.[26]

Hein had managed to create a simple, yet hard-to-crack game. Even Hein himself was unaware of a winning strategy, but he thought that computers could be useful here.[27] The Nimbi game brochure elaborated on the game's complexity:

> During a couple of decades mathematicians have tried to destroy even this new game, attempting to find a general principle that would cover all versions of it with varying numbers of stones, as Bouton's analysis did in respect of Nim. Their efforts hitherto have been in vain and there are considered to be fair chances that Piet Hein has succeeded so thoroughly that this game will never be destroyed.

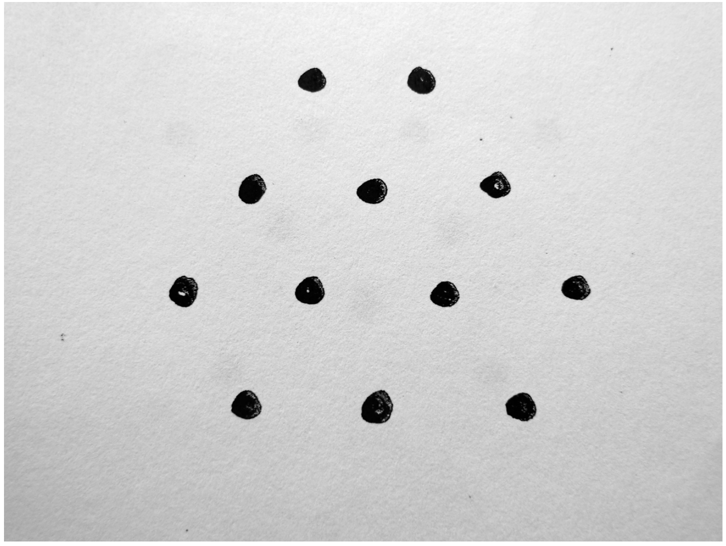

Figure 2. The spatial layout of the Nimbi game board. (Original hand drawing by Piet Hein.[23])

Nevertheless, game theorists Aviezri S. Fraenkel and Hans Herda made some headway, when in 1980, they proved that the second player always has the possibility to win.[28]

Regnecentralen

The *Nimbi* computer game was developed by Regnecentralen,[29] the first Danish computer company. It was founded in 1955 as a Committee of Computing Machinery under the Danish Academy of Technical Sciences and reorganized as a limited company in 1963. The company's first substantial project occurred from 1955 to 1958 when it built the vacuum tube computer DASK, largely a copy of the Swedish computer BESK. Denmark in the late 1950s witnessed extensive deliberations in government regarding the need for computer power in the public and private sectors. Regnecentralen untiringly tried to promote a Danish computer industry, but ministerial civil servants, politicians, and CEOs were skeptical about Regnecentralen's initiatives, not least because of Regnecentralen's turbulent financial situation and informal organizational culture. This left Regnecentralen in a vacuum regarding a business strategy. Regnecentralen employee Peter Naur, one of the founding fathers of computer science, commented on this: ''The civil servants in the Ministry of Education would not dare to get involved . . . with an independent institution like Regnecentralen.''[30]

In 1959, Einar Andersen, director of the Danish Geodetic Institute, cut through this confusion when he single-handedly

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ordered a new computer from Regnecentralen to support the institute's calculation needs,[31] even opposing a ministerial order. Regnecentralen named the computer Gier and completed it with transistors, a ferrite core, and drum memory in 1961.[32] Gier had an excellent Algol compiler, and it sold reasonably well, especially in Eastern Europe because of the Cold War embargo on American computers.

Regnecentralen operated in a competitive market with foreign companies, primarily IBM. Around 1960, Regnecentralen suffered two blows that curtailed its market opportunities. The public computing center Datacentralen based on IBM computers was established, and IBM donated an IBM 7090 computer to the Technical University of Denmark. Peter Naur commented on this later: "Strangely enough such caution [close collaboration with a company] had no weight when the American giant concern IBM made a similar offer."[30]

CEO Niels Ivar Bech

Niels Ivar Bech became CEO of Regnecentralen in 1957 and held the post until 1971 when Regnecentralen went bankrupt. Educated as a teacher, he had worked as a human computer for the Copenhagen Telephone Company, where he gained experience with administrative data processing on IBM punch card machinery and thereby became aware of the technology's shortcomings. Bech was considered a genius in employee management because he could make people deliver beyond their expectations.[30] He was unusually visionary and had a brilliant sense of innovation.[33] When most decision makers considered the computer a calculation engine, he saw computers' potential in information processing and for society at large. He prioritized diversity in Regnecentralen's tasks and accepted projects that seemed impossible. Bech's taste for the unusual and informal showed also in Regnecentralen's organization where *moling*—to work against official procedures when it served a purpose—was a key principle.[29]

One of his visions was to educate the general public about the potential of computers. This was illustrated by Regnecentralen's somewhat risky provision of computer support for the parliament election in November 1960, which was broadcast on television.[34] Contrasting earlier mixed experiences in Sweden and the US,[35] the election predictions turned out to be precise, and the event gave Regnecentralen a lot of good publicity. However, the election project caused other projects to be delayed, much to the dismay of some staff members. This project revealed the flip side of Bech's visionary style: the election support project was effective but it caused frustration among the staff due to delay of other projects and it was financially risky. In this case, the payment from the customer, the Danish Broadcasting Corporation, in no way matched the resources the company had allocated. Another manifestation of his educational vision was asking key staff members to write programming textbooks, which many regarded with skepticism because they seemed to serve the interests of society rather than the company.

Bech also worked tirelessly to create a joint Nordic computer industry and helped establish the International Federation for Information Processing (IFIP) and the Nordic conferences NordSAM/Norddata. In addition, he helped establish the academic field of computer science by supporting the Nordic computer science journal *BIT*[36] and encouraging his staff members to stay at universities abroad. In fact, the backbone of many computer science department staffs in Danish universities emerging in the late 1960s were largely former Regnecentralen employees.

Toward the end of the 1960s, the team Bech built up at Regnecentralen—colloquially referred to as Bech's boys—had made several significant contributions to computer science, including the Algol 60 report,[37] the Gier Algol compiler,[38] and RC2000, an extremely successful paper tape reader. However, despite

Bech's management strengths, Regnecentralen never managed to find the right balance between the roles of computer service provider, computer manufacturer, and software product developer.[27]

Implementing Hein's dream

Since creating Nimbi in 1945, Hein had a dream of programming a computer to play the game against humans.[39] Hein was aware of earlier Nim machine efforts, among these the success of Nimrod in London in 1951.[23] Around 1961, Hein explained his dream to Norbert Wiener, who lived with him at Rungsted Skovhus while completing the book *God and Golem, Inc.*[40] Subsequently, Wiener introduced Hein to Bech. Piet Hein recalled, "The game problem appealed immediately to Bech's taste for diverse tasks, to create a meeting place, where non-professionals could get contact, even dialog, with a computer and get a convincing direct impression of . . . a computer's level of intelligence."[14]

On 9 July 1962, the 19-year-old mathematics student Soren Lauesen began working at Regnecentralen part time. A week later, he was asked to develop the Nimbi computer game with Piet Hein. They started from scratch because they were not aware of any similar computer game projects. The two collaborated closely on the project, which lasted about a year. (During this time, Hein also took upon himself to educate Lauesen in the arts, being a poet and a mathematician.[41])

The first problem in the development was in identifying a winning strategy. In the fall of 1962, Lauesen devised a solution based on a mathematical analysis with safe positions that occurred to him during a ferry trip. (A *safe* position is one that results in a win, given that the player makes no errors.) He then wrote a Gier program that calculated these positions.[27] At this stage, the implementation medium was still undecided. One option was to elaborate on a mechanical Nimbi playing machine, based on a paper tape with a list of safe positions, which Hein had sketched in 1945 when he developed Nimbi. The second option was the Gier computer, which was eventually chosen. Regnecentralen and Hein agreed that they should be able to demonstrate the game at trade fairs,[27] so Hein and Lauesen opted for a special game board that mirrored the wooden Nimbi game board, contrasting many contemporary games played on computer consoles. As an example, in the Nim program used at the inauguration of the Australian Silliac in September 1956, "the moves of the human player were punched on a teleprinted tape by an attendant demonstrator and the moves of the machine will be typed out on a page-printer" (p. 32).[7]

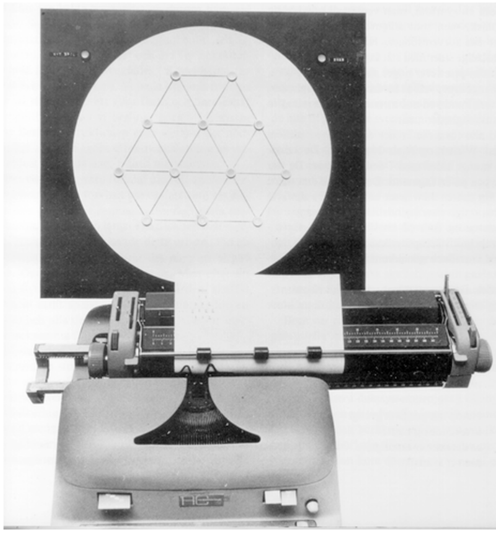

Figure 3. The Nimbi game board and the Gier IBM console.

The game board design resulted in two closely related problems: I/O and representation in Gier of the 12 board positions. Lauesen had extensive discussions with Regnecenralen hardware engineers about the game board because Gier was not designed for I/O beyond its default devices: an IBM console typewriter, line printer, and paper tape reader and punch. The solution was unconventional; bits 28 through 39 in the multiplication register represented the board positions as on/off, and a direct wire connection was made from the 12 bits in the multiplication register to the 12 game board buttons. This solution evidently implied that Lauesen had to write the program without multiplications.

Lauesen completed the game in August 1963. The final program was but a mere four pages of Gier assembly code and four pages of tables.[42] Given that this project was Lauesen's first major programming task at Regnecentralen, the program was remarkably short. Hein was pleased with the completion of the game and commented later: "Thanks to Bech's diversity and our good contact, the task was completed in all regards, also the transparency for non-specialists."[14]

Figure 3 shows the final Nimbi game board, with the 12 board tokens lit buttons

The Nimbi project took place in an uncertain market context that included strong international competitors and a persistently difficult financial situation.

along with the start and answer buttons. To play, the human pressed the buttons to be removed and then pressed the answer button. The computer followed with its move. If the answer button was pressed initially, the computer made the first move. A new game could be initiated at any time by pressing the start button. If a human player made an illegal move, the program made the buttons flash and reestablished the last legal position.[14] The program could play both versions (last player loses or wins), controlled by a button on the control panel. If a game was interrupted, the program printed out a report saying whether it was possible to win the game.[43] The program also provided a log of the game played, which printed out on the IBM console.

Hein emphasized the importance of giving the impression that the computer had to work hard to find the next move. Sound turned out to be handy here. As with many other contemporary computers, the programmer could monitor a running program's progress by way of a loudspeaker connected to the accumulator's sign bit.

Context and driving forces

With the completion of Nimbi, both Hein's dream of a computer playing the game against human beings and Bech's educational vision could be realized. To what extent did this happen? First of all, and quite surprisingly, Hein did not play the game himself and soon lost interest in it. He felt that the potential of the computer version of Nimbi was merely due to the systematic approach and Gier's calculating power.[44,45]

But what about Regnecentralen's use of *Nimbi* to support Niels Ivar Bech's vision? Other, earlier publicity experiences with Nim-playing machines had proved fruitful. At the New York World's Fair in 1940, Nimatron played 100,000 games and won 90,000 of them. Each playing visitor received a button labeled, "I have seen the future" (http://www.goodeveca.net/nimrod/nimatron.html). At the 1951 Festival of Britain in London, Nimrod took on all comers.[8,21] The acknowledged British computer scientist Michael Jackson, among the founding fathers of structured programming in the 1970s,[46] witnessed Nimrod's capabilities while still a schoolboy.[47] Christopher Strachey was Jackson's teacher in public school and he inspired the young Jackson to build a Nim machine using relays and electromechanical rotating switches from London surplus shops.[48] Nimrod was later shown at a trade fair in Berlin that attracted crowds in the thousands. Nimrod generated such excitement that it was necessary to call out special police for crowd control, and according to Alan Turing, "the visitors entirely ignored a bar at the far end of the room where free drinks were available" (p. 5).[23] The machine became even more popular after it had defeated Economics Minister Ludwig Erhardt in three straight games.[8,21]

Regnecentralen's promotion opportunities seemed abundant because the Gier computer was exhibited at many trade fairs in Denmark and Europe in the 1960s,[49] including at the Palace of Culture and Science in Warshaw in November and December 1963 where a Nim game was demonstrated. It was, however, the traditional Nim game rather than *Nimbi*.[50] Similarly, Lauesen participated in exhibitions in Denmark, but he has no recollection of *Nimbi* being used, although he recalls other successful game demonstrations, such as *Guess a Country*.[44]

So why was *Nimbi* not promoted more successfully? A number of factors undoubtedly were at play, but two stand out: hardware constraints and organizational culture. As I mentioned earlier, the *Nimbi* game board was wired directly to the Gier multiplication register. This was an extremely cumbersome and inflexible solution, so in all probability this modification was only performed on one Gier computer.[51] Regnecentralen produced many Gier computers later, but seemingly none of them could play *Nimbi*—a strong limitation in using *Nimbi* to promote computers.

As to Regnecentralen's organizational culture, the Nimbi project took place in an uncertain market context that included resistant government officials, strong international competitors, a persistently difficult financial situation, and Regnecentralen's own difficulty in balancing its products and services.[27] On the one hand, this organizational culture in and of itself made such an unusual development possible. On the other, *Nimbi* might have been exploited more fully if more Gier computers had been equipped to play *Nimbi* and if the company had pursued a dedicated *Nimbi* promotion effort. The organizational limbo surfaced when Regnecentralen questioned the costs of the Nimbi project. Allegedly, Hein refused to pay the development costs because he argued that the game was a publicity opportunity for Regnecentralen.[44]

The Nimbi development involved an interaction between the two unusual personalities of Hein and Bech. No records apparently exist concerning Bech's view of the Nimbi project, but despite the game's low visibility, Hein wrote favorably about him in a book edited by former Regnecentralen staff after Bech's death in 1975, particularly praising Bech's ability to face difficulties: ''Those who perform especially well, don't—as many believe—by having fewer obstacles, on the contrary by having the will and ability to address all the obstacles.''[14]

Piet Hein's role as poet also manifested in their interaction. He wrote a *grook* (a punchy, light verse) about Bech, addressing this feature of Bech's personality. Unfortunately the grook is in Danish and is virtually impossible to translate. However, *Scientific American* game columnist Martin Gardner had spotted Hein's ability to pinpoint this human feature. On the occasion of Piet Heins's 90th birthday in 1995, Gardner quoted one of his favorite grooks: ''Problems worthy / of attack / prove their worth / by hitting back.''[52] This grook happens to cover the very essence of the grook dedicated to Bech.

Conclusion

The Nimbi project combined fundamental facets of game traditions, Hein's dream of having humans play games against a computer, and Bech's vision of the role of computers in society in the early 1960s. Nevertheless, the *Nimbi* game was not employed successfully in the promotion of computers, seemingly as a result of hardware constraints and organizational culture. However, it is tempting to speculate on other avenues of development. The simple, ancient game Nim was the project's focal point. The contrast between Nim's simplicity and the complexity of the Nimbi project is striking: the flurry of Nim variants, Nim's impact in mathematical game theory, the highly successful earlier Nim-playing machines, the burgeoning merging of games and computers in the 1960s, Regnecentralen's remarkable achievements under Bech's leadership, and the influence of Piet Hein in design, architecture, poetry, and games. We can only speculate about the possible reverberations had the game been promoted successfully by individual endeavors and organizational initiatives alike.

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References and notes

1. U. Blass, A.S. Fraenkel, and R. Guelman, ''How Far Can Nim in Disguise Be Stretched?'' *J. Combinatorial Theory,* series A, vol. 84, 1998, pp. 145–156.
2. J. Juul, Half-Real: Video Games between Real Rules and Fictional Worlds, MIT Press, 2005, pp. 3, 5.
3. D. Spencer, *Game Playing with Computers,* Hayden, 1968, lists even more variants.
4. M. Jackson, ''Christopher Strachey: A Personal Recollection,'' *Higher-Order and Symbolic Computation,* vol. 13, 2000, p. 73.
5. S. Egenfeldt-Nielsen, J.H. Smith, and S.P. Tosca, *Understanding Video Games: The Essential Introduction,* Routledge, 2008, p. 50.
6. J. Deane, *SILLIAC: Vacuum Tube Supercomputer,* Science Foundation for Physics and Australian Computer Museum Soc., 2006, chapt. 2, p. 32; http://www.physics.usyd.edu.au/foundation/silliac/book.html.
7. S.L. Kent, *The Ultimate History of Video Games,* Prima Publishing, 2001, p. 20.
8. L. King, ed., Game On: The History and Culture of Videogames, Laurence King, 2002.
9. A.L. Samuel, ''Some Studies in Machine Learning Using the Game of Checkers. II—Recent Progress,'' *IBM J. Research and Development,* vol. 3, 1959, pp. 601–617.
10. See C.E. Shannon, ''Programming a Computer for Playing Chess,'' *Philosophical Magazine,* 7th series, vol. 41, no. 314, 1950, p. 256; and A. Newell, J.C. Shaw, and H.A. Simon,

"Chess-Playing Programs and the Problem of Complexity," *IBM J. Research and Development,* vol. 2, Oct. 1958, pp. 320–335.
11. H.A. Simon and J. Schaeffer, *The Game of Chess,* 1989, p. 7; http://www.cs.ualberta.ca/~jonathan/Papers/Papers/simon.ps. Appeared also in T. Aumann and K. Hart, eds., *Handbook of Game Theory with Economic Applications,* North Holland, 1992.
12. J. McCarthy, "Chess as the Drosophila of AI," *Computers, Chess, and Cognition,* T.A. Marsland and J. Schaeffer, eds., Springer-Verlag, 1990, pp. 227–237.
13. A.L. Samuel, "Programming Computers to Play Games," *Advances in Computers,* vol. 1, F. Alt, ed., Academic Press, 1960, pp. 165–192.
14. P. Hein, "Hjertets renhed" [Purity of the Heart], *Niels Ivar Bech—en epoke I EDB-udvikling I Danmark* [Niels Ivar Bech—an epoch in the EDP-development in Denmark], P. Svejstrup et al., eds., Data, 1976; http://www.datamuseum.dk/site_dk/rc/NIB.
15. T.S. Ferguson, "Game Theory," 2008; http://www.math.ucla.edu/~tom/Game_Theory/comb.pdf.
16. M.H. Albert and R.J. Nowakowski, "Nim Restrictions, Integers: Electronic Journal of Combinatorial Number Theory," *Integers,* vol. 4, article G1, 2004; http://www.integers-ejcnt.org/vol4.html.
17. M. Gardner, "Mathematical Games: Concerning the Game of Nim and its Mathematical Analysis," *Scientific Am.,* Feb. 1958, p. 104.
18. This is the normal play rule where the last player to make a move wins; in another version (misére), the first player unable to move is the winner.
19. J.P. Neto and J.N. Silva, *Mathematical Games—Abstract Games,* Publicida, 2007, p. 19.
20. J.H. Conway, *On Numbers and Games,* AK Peters, 2000.
21. B.V. Bowden, *Faster than Thought,* Pitman, 1953, p. 304.
22. C.L. Bouton, "Nim: A Game with a Complete Mathematical Theory," *The Annals of Mathematics,* series 2, vol. 3, nos. 1/4, 1901–1902, pp. 35–39.
23. P. Hein, "En variant af spillet Nim og et udkast til en maskine, som spiller det ny spil mod en menneskelig spiller" [A variant of the game Nim and a sketch of a machine that plays the new game against a human player], c. 1945. (See the author to access this material.)
24. M. Gardner, "The Recreational Mathematics of Piet Hein," *Sin egen: Piet Hein 90 år* [His Own: Piet Hein 90 years], Borgen, 1995, p. 58.
25. In a letter to Soren Lauesen on 13 Nov. 1962, Piet Hein called the game presented in the February 1958 *Scientific American* article "extended Nim."
26. S. Lauesen, "Geometrisk Nim—mit samarbejde med Piet Hein 1962-63" [Geometric Nim—My Collaboration with Piet Hein 1962-63], presented at IT-University of Copenhagen, Dec. 2006. (See the author to access this material.)
27. S. Lauesen, "Compiler-gruppen: Teknisk perfektionisme kontra nytte" [The Compiler Group: Technical Perfectionism versus Utility], *Regnecentralen Dansk Institut for Matematikmaskiner—Festskrift ved 50 året for oprettelsen 12. oktober 1955* [Regnecentralen Danish Institute for Mathematics Machines—Festschrift at 50 Years for the Founding 12 Oct. 1955], Dansk Datahistorisk Forening, 2005, pp. 55–64; http://www.itu.dk/~slauesen/SorenDansk.html.
28. From the *Nimbi* game brochure, quoted in A.S. Fraenkel and H. Herda, "Never Rush to Be First in Playing Nimbi," *Mathematics Magazine,* vol. 53, no. 1, Jan. 1980, p. 22.
29. I'm using the Danish name *Regnecentralen* rather than the lengthy *Danish Institute of Computing Machinery* because the company was known internationally as Regnecentralen. This section draws on the thorough analysis of the first period of Regnecentralen by P.V. Klüver, "From Research Institute to Computer Company: Regnecentralen 1946–1964," *IEEE Annals of the History of Computing,* vol. 21, no. 2, 1999, pp. 31–43.
30. P. Naur, "Niels Ivar Bech: The Man Who Created Regnecentralen," 1971; http://www.naur.com/comp/c10-4.html.
31. E. Andersen, "Hvordan Gier blev født" [How Gier was born], *Niels Ivar Bech: en epoke I EDB-udvikling I Danmark* [Niels Ivar Bech: An Epoch in the EDP Development in Denmark], P. Svejstrup et al., eds., chapt. 7. Data, 1976; http://www.datamuseum.dk/site_dk/rc/NIB.
32. C. Gram et al., "GIER—A Danish Computer of Medium Size," *IEEE Trans. Electronic Computers,* vol. EC-12, no. 6, 1963, pp. 629–650.
33. P.B. Hansen, *A Programmer's Story: The Life of a Computer Pioneer,* 2008, p. 78; http://brinchhansen.net.
34. A. Melbye, "Valgudsendelser i tv," *Niels Ivar Bech: en epoke I EDB-udvikling I Danmark* [Niels Ivar Bech: An Epoch in the EDP Development in Denmark], P. Svejstrup et al., eds., chapt. 22, Data, 1976; http://www.datamuseum.dk/site_dk/rc/NIB.
35. M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine,* Westview Press, 1996, p. 123.
36. I. Auerbach, "Bech in the International Computer Milieu," chapt. 18, and C.-E. Fröberg, "Bech og BIT," *Niels Ivar Bech: en epoke I EDB-udvikling I Danmark* [Niels Ivar Bech: An Epoch in the EDP Development in Denmark], P. Svejstrup et al., eds.,

Data, 1976; http://www.datamuseum.dk/site_dk/rc/NIB.
37. P. Naur, ed., ''Revised Report on the Algorithmic Language Algol 60,'' corrected reprint, Regnecentralen, Copenhagen, 1964.
38. P. Naur, ''The Design of the Gier Algol compiler,'' *BIT,* vol. 3, nos. 2–3, 1963, pp. 123–140, 145–166. Edsger Dijkstra called the Gier Algol compiler a masterpiece; see P.B. Hansen, *The Programmer as a Young Dog* and *A Programmer's Story: The Life of a Computer Pioneer;* http://brinch-hansen.net.
39. This section draws on the paper by A.H. Jørgensen, ''An Early Danish Computer Game: The Case of Nim, Piet Hein, and Regnecentralen,'' *Proc. 2nd Conf. Nordic Computing,* J. Impagliazzo and P. Paju, eds., Springer, 2009.
40. N. Wiener, *God & Golem, Inc.: A Comment on Certain Points Where Cybernetics Impinges on Religion,* MIT Press, 1964.
41. P. Hein, ''Vejen til virkeligheden'' [The road to reality], opening speech at the 4th Scanticon, 25 Oct. 1987.
42. S. Lauesen, ''Assembly code for the Nimbi program for Gier,'' Regnecentralen, Copenhagen, 1963.
43. S. Lauesen, *User's Manual* [for the Gier Nimbi game], Regnecentralen, Copenhagen, 1963.
44. S. Lauesen, interview by A.H. Jorgensen, Sept. 2008.
45. H. Isaksson (who was responsible for the hardware part of the game development), interview by A.H. Jorgensen, Sept. 2008.
46. Among Michael Jackson's most influential books is *Principles of Program Design,* Academic Press, 1975.
47. M. Jackson, ''Christopher Strachey: A Personal Recollection,'' *Higher-Order and Symbolic Computation,* vol. 13, 2000, p. 73.
48. M. Jackson, email correspondence, Sept. 2008.
49. P. Ambeck-Madsen, ''Af en dataarkæologs blandede bekendelser'' [Of a data archeologist's mixed confessions], *Regnecentralen Dansk Institut for Matematikmaskiner—Festskrift ved 50 året for oprettelsen 12. oktober 1955* [Regnecentralen Danish Institute for Mathematics Machines—Festschrift at 50 years for the founding 12 Oct. 1955], Dansk Datahistorisk Forening [Danish Computer History Soc.], pp. 33–42. Copenhagen.
50. J. Madey, interview by A.H. Jorgensen, Sept. 2008.
51. S. Lauesen and H. Isaksson, email correspondence, Oct. 2008.
52. M. Gardner, ''The Recreational Mathematics of Piet Hein,'' *Sin egen—Piet Hein 90 år* [His own—Piet Hein 90 years], Borgen, 1995, p. 60.

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