

# Grzegorz Rozenberg: A Magical Scientist and Brother

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**Abstract** This is a personal description of Grzegorz Rozenberg. There is something magical in the fact that one man, Grzegorz, has been able to obtain so many and such good results in so numerous and diverse areas of science. This is why I have called him a “magical scientist.” He is also a very interdisciplinary scientist. In some sense this is due to his educational background. His first degree was in electronics engineering, the second a master’s in computer science, and the third a Ph.D. in mathematics. However, in the case of Grzegorz, the main drive for new disciplines comes from his tireless search for new challenges in basic science, rather than following known tracks. Starting with fundamental automata and language theory, he soon extended his realm to biologically motivated developmental languages, and further to concurrency, Petri nets, and graph grammars. During the past decade, his main focus has been on *natural computing*, a term coined by Grzegorz himself to mean either computing taking place in nature or human-designed computing inspired by nature.

## 1 General

Everyone who has worked with or otherwise followed closely Grzegorz Rozenberg has been profoundly impressed by his overwhelming enthusiasm in doing research. *One can do great science and have fun doing it* is one of his thoughts often expressed. Grzegorz has contemplated thoroughly the qualities of good science, and is ready to discuss and give advice about questions such as the choice of your research area or topic, what is important and what is not, or what is applicable and what is not. Sometimes a widely investigated research area begins to stagnate. Often an invigorating new idea, perhaps from a different field of science, changes the situation. These and related thoughts usually come up in discussions with Grzegorz. While some science writers talk about the “end of science,” meaning that one already has walked through all significant roads, Grzegorz has quite an opposite view: we are in many respects only at the beginning of the road. In particular, this is true of computer science and natural computing. I will next outline some of Grzegorz’s thoughts about these areas.

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Computer science develops tools needed for ICT, information, and communications technology. Such tools include computer networks and software methodologies, the theoretical basis being essential. Computer science is more than ICT, it is the general science of information and information processing. The European term *informatics* is much better than *computer science*. The former term does not refer to any device or instrument for information processing. Such instruments always presuppose a paradigm of thinking about information processing, whereas if one speaks of “informatics”, no devices or paradigms are stipulated.

In particular, informatics should study computing and information processing taking place in nature, and develop paradigms based on it. Research in natural computing, as Grzegorz understands it, is genuinely interdisciplinary and bridges informatics to natural sciences. Evolutionary computing and neural computing are older examples of such bridges. Human-designed computing inspired by nature includes such paradigms as molecular computing and quantum computing.

This is no place to overview Grzegorz’s huge scientific production (hundreds of papers, some eighty books or edited books), or to discuss his contributions to the scientific community. (For instance, he was EATCS President much longer than anyone else, not to mention his more than twenty years as the editor of the EATCS Bulletin.) I will still return to our scientific cooperation in terms of three glimpses of it, in Sect. 3. Next, I will discuss other matters.

## 2 Personal Recollections

### 2.1 Grzegorz and Bolgani

You get a good picture about Grzegorz as a human being by reading [7]: what is important for him, what he likes to do, where he has been, and whom he has been with. He has surely had a many-faceted, even adventurous life, centered around family (most importantly Maja, Daniel, and Mundo), science, and also magic. Before I add some personal comments to the matters in [7], I mention a couple of things, covered very little or not at all in [7].

Life changed for Grzegorz when his grandson *Mundo* came into the world in August 2005. After that, much of his conversation has consisted of telling people about recent happenings with Mundo. Our email has piles of pictures of Mundo. I have a big picture of Grzegorz and myself, standing in snow during a sauna intermission in 1980. It has the text *Happiness is being a Grandfather*. I am glad that this is now true also for Grzegorz.

*Owls* are briefly mentioned in [7]. Grzegorz has a huge collection of owl figurines, real stuffed owls, and material dealing with owls. This exhibition is a real wonder to a visitor in Bilthoven. Grzegorz calls owls *magicians of nature*. His interest in owls was initiated by some pictures taken by Juhani Karhumäki in the 1970s.

Also, *Hieronymus Bosch* is only briefly mentioned in [7]. During the past decade, Grzegorz has become a real expert on Bosch. He has a comprehensive library of

books on Bosch, in numerous languages. I was sorry to tell him that I have found no such book in Finnish. Grzegorz likes to go to “Boschian” lectures and meetings. My favorite Bosch site is

[www.abcgallery.com/B/bosch/bosch.html](http://www.abcgallery.com/B/bosch/bosch.html)

I do not know whether Grzegorz has seen it or likes it.

I will tell at the beginning of the next subsection about my first meeting with Grzegorz. Some years after that Grzegorz started to visit Turku. In 1976, one purpose of the visit was the Ph.D. defense of Juhani Karhumäki. Grzegorz has had many excellent Ph.D. students of his own, and has been an external examiner or opponent in many other Ph.D. defenses. The reaction of the candidates has been overwhelmingly positive. How helpful, constructive, and friendly he has been, can be seen from many contributions to [1].

Grzegorz stayed with my family many times in the 1970s and became famous, among many other things, for eating huge amounts of blueberry pie. I was called “Tarzan,” and Grzegorz wanted to become a member of the Tarzan family. We decided that he will be *Bolgani*. Later on, “Bolgani” became his official name as a magician, and it also appears on his visiting card. In the following, I will use the two names interchangeably.

Although most of the time a scientist, Bolgani has also periods when he lives with *magic*. He has developed the performing art of close-up magic to a high professional level. I have watched him in numerous shows, both in private homes and at conference gatherings. I have long given up trying to explain or understand the illusions. I just enjoy the show. When Bolgani gave a performance in my home, one of the guests came up later with the “explanation” that he was wearing contact lenses of a special type. Illusions have no explanation.

Undoubtedly, Bolgani is a born magician. The maiden name of his mother is Zauberman. The name of his wife Maja means “illusion” in Hindi. His hands are very sensitive; I have not seen anyone handle a deck of cards as gently as Bolgani.

A magician likes to give a performance. Grzegorz is a great lecturer. The community knows this: he always has numerous invitations. It is difficult to match his sense of humor, and probably impossible to match his capability to include magical illusions in his lectures. Many people make easy things difficult in their lectures. Grzegorz has the talent of making difficult things easy. As Maurice Nivat has said, Grzegorz is *always enthusiastic, always optimistic, always amusing, and never boring*.

Bolgani often presents a sequence of illusions within the framework of a story, such as the following. Bolgani explains that in Chinese the names of the suits *hung tao* (heart) and *hei tao* (spade) are similar and, therefore, some confusion may arise. But now we try to be careful. He then shows the audience some hearts and puts them on the table, as well as some spades and puts them also on the table, far from the hearts. “So this pile is *hung tao*?” The audience agrees. “And this is *hei tao*?” Again consensus. Bolgani then entertains the audience and talks about various matters; about owls, and about the sauna. That laughter and for him, nowadays Mundo is the best medicine. That one should never assume anything. That the only place where success comes before work is in the dictionary. Then Bolgani goes back to

the cards. “So this is *hung tao* and this *hei tao*?” General agreement. But when he shows the cards, it is the other way round. “Too bad, let us see what happens if we put everybody in the same pile.” He first puts the pile of hearts on the table and the spades on top. Again, there is some entertainment. “Now let us see if they interchanged again.” Bolgani picks up the cards and shows them. “This is absolutely crazy. They are all *zhao hua* (club, grass flower)!”

## 2.2 Brother

Grzegorz had been<sup>1</sup> in Holland about one and a half years, and was running a countrywide seminar in Utrecht, where foreign speakers were also invited. I got an invitation (by ordinary mail, not by phone) from G. Rozenberg in May 1971. I was not familiar with the name previously. He waited for me at the airport and arranged our meeting through loudspeakers. He looked much younger than I had anticipated. He drove a small Volkswagen. We got immediately into a very hectic discussion about parallel rewriting and L systems. This was contrary to all principles about driving, expressed by Grzegorz later. After about one hour, I started to wonder why we had not yet arrived at my hotel in Utrecht, well known for the model railroad upstairs. It turned out that we were still on some side streets of Amsterdam.

The same day Grzegorz told me more about L systems, at the university and during dinner at an Indonesian restaurant. This turned out to be an area where our scientific cooperation has been most vivid. The most important outcome is the book [8], but L systems play an important role also in [10, 11].

I had four lectures during the seminar, and Grzegorz also arranged a big party in their Marco Pololaan apartment. Although the twenty people present were quite noisy, the baby Daniel slept all the time. There I got to know many of my friends for the first time, notably *Aristid Lindenmayer*. L systems seemed to be a really fresh idea. I got carried away, and already decided to include a chapter about them in my forthcoming book on formal languages. During the next few weeks, I exchanged numerous letters with Grzegorz about the topic.

At this stage, I would like to tell two stories about our joint books. In some way, they illustrate very well Grzegorz’s friendliness, efficiency, and professionalism.

When working on the book [8], we had many specific deadlines, depending on mutual trips, etc. Once, I got very nervous that Grzegorz was too involved in other research topics, and could not possibly make the deadline. I wrote a very angry letter to him. His answer was very brief. “Tarzan has never before written such an angry letter. The reason is simple. In your letter you mention that you did not go to sauna in two days.” That was it, and he made the deadline.

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<sup>1</sup>To justify the word *brother* appearing in the title of this paper, I quote Grzegorz from [7] where he describes his “wonderful family.” *Then I have two brothers of choice, Andrzej and Arto. It is difficult to imagine better brothers (an interesting aspect of this brotherhood is that Andrzej and Arto have never met).*

In March 1994, Grzegorz suggested to me: “Let us make a handbook on formal languages.” We started planning it immediately. In less than three years, a copy of [11] (three volumes, more than 2000 pages, 3.6 kilos altogether, more than 50 authors) was in the library of Turku University. Are there similar examples of such speedy editing of such an extensive handbook-type of scientific work?

Very soon Bolgani became a close family member. My wife tells him everything about our cats and often wears blouses given by him as presents. He is a coauthor in my son’s first scientific publication. My daughter always liked to travel to Utrecht because “it is the town with the Orange Julius.” My grandchildren call him *Äijä-Bolgani* (grandpa-Bolgani). My grandson was very impressed because Bolgani drew many coins from his ears, and my granddaughter because of his expanding command of Finnish. On the other hand, Bolgani’s late mother treated me as her own son. I myself have, more and more during the years, learned to ask his advice in difficult decisions and situations.

Bolgani always brings carefully selected gifts, not only to me but also to everybody in my “clan.” In 1975, he gave me a very special memory device. It was with me everywhere for thirty years, until it finally wore out. No substitute was available, and I had to be satisfied with miserable alternatives. But in 2007, Bolgani gave me a substitute, even better than the original!

My brother has an immense supply of jokes and anecdotes, always suitable to the occasion. Often a fatiguing situation entirely changes with his comments. When I came, exhausted in the airport bus, together with some other conference participants to Waterloo in 1977, Bolgani was there to meet us. Instead of greeting me, he went to the driver, pointing toward me, “Did that fellow behave well in the bus?”

Sometimes, I have experienced real surprise. I had forgotten my slippers in Bilthoven. The next time I was there they were not to be found, and Bolgani just remarked that maybe the cleaning lady had somehow misplaced them. Sometime afterwards, I was staying in Hermann Maurer’s (a close friend of both of us and a marvelous scientific collaborator) house in Graz. When I entered my room, my slippers were there!

Bolgani claims that I have a good memory, whereas he has a bad one. I am not sure of this; it could be the other way round. For instance, in Bolgani’s writings to me, the expressions “Rabbit Ph.D. Story” and “Dog Paper Story” appear many times. I do not remember what they refer to.

Some of our best times together have been in the sauna. Bolgani has a special sauna certificate and many sauna records, for instance, the shortest time between the plane landing and him sitting in the sauna, or seeing special animals from the sauna window. I let Bolgani himself speak (“löyly” is the Finnish word for sauna heat, and “supikoira” for raccoon dog):

When you come to Tarzan nest  
You get sauna at its best  
Where you can admire  
Löyly and birch wood on fire  
A lot of flora and fauna  
Can be seen from Salosauna

But with Bolgani and nice weather  
You can see two supikoiras together

### 3 Case Studies of Scientific Cooperation

#### 3.1 *Quasi-uniform Events and Mostowski*

One of the early papers on automata by Grzegorz [6] deals with *quasi-uniform events*. “Languages” were often in the early days called “events,” but I will now speak of *languages*. A language  $L$  over an alphabet  $\Sigma$  is *quasi-uniform* if, for some  $m \geq 0$ ,

$$L = B_0^* b_1 B_2^* b_3 \dots b_{2m-1} B_{2m}^*,$$

where each  $b_i$  is a letter of the alphabet  $\Sigma$ , and each  $B_i$  is a subset (possibly empty) of  $\Sigma$ . Observe that  $B_i^*$  reduces to the empty word when  $B_i$  is empty. Thus, there may be several consecutive letters in the regular expression, but the subsets are always separated by at least one letter. Grzegorz shows, for instance, that it is decidable whether or not a given finite automaton accepts a quasi-uniform language. The reader might want to prove this, especially because the reference [6] is not so easily available.

Much later, when studying subword occurrences and subword histories, I noticed that the language defined by a subword history of a very natural form always is a finite union of quasi-uniform languages (and hence, star-free). This is an example where we have worked separately on similar questions. Indeed, because Grzegorz and I never have time to cover all topics, I have never had a chance to explain to him the connection between quasi-uniform events and subword histories.

The paper [6] was communicated for publication by the famous logician *Andrzej Mostowski* on August 7, 1967. Grzegorz tells about him [7] as follows.

Mostowski was a very kind man of very good manners. He always had time whenever I wanted to talk to him. I still remember the interview when he offered me a job. Looking through the papers he said at some point: “I see that you will be the youngest member of the Institute,” he paused and then he continued “but this problem will resolve itself with time.”

I also met Mostowski a few times, long before I met Grzegorz. He wore very elegant suits, quite unlike the casual attire now common. He was polite and considerate to me. For instance, he was chairing a session in a big logic conference in Helsinki in 1962, where I gave a talk about infinite-valued truth functions. I was somewhat nervous, and this was apparently noticed by Mostowski. There were some simple questions after my talk, but Mostowski did not want to embarrass me with his involved question. Instead, he came to me later asking, “How do you actually obtain the decidability?” Then it was no problem for me to explain to him the details.

### 3.2 *Developing Cells and Lindenmayer*

My cooperation with Grzegorz was centered around developmental languages and L systems for about two decades. I already told about my first meeting with Aristid Lindenmayer. Grzegorz had gotten to know him somewhat earlier [7], after studying a paper by Dirk van Daalen. Aristid became a close friend of ours. Apart from biological matters, we used to consult him about many other things, for instance, the English language.

We edited a book [9], for Aristid's 60th birthday. It also contains information about the early stages of L systems and the people involved. Aristid did not know about our plan. One evening in November 1985, Grzegorz phoned him, inviting him for a cup of coffee. Aristid was surprised to see me also in Bilthoven. Grzegorz told him that we knew about his birthday and bought him a book as a present, giving Aristid a parcel containing [9]. After that, the representatives of Springer-Verlag and other friends who had been hiding upstairs came to congratulate Aristid.

After Aristid's untimely passing away, we wanted to organize a conference dedicated to his memory. It was originally planned to take place in Lapland. But there were many practical difficulties. The conference, the first DLT, took place in Turku. All participants signed a special greeting to Jane Lindenmayer. The letter "L" in "DLT" was originally intended to refer also to L systems.

One of our early joint papers on L systems was the widely referenced article [3, 4], where Mogens Nielsen and Sven Skyum were also coauthors. Much of the work was done during the Oberwolfach conference in 1973 in my family apartment. Sometimes, Grzegorz was shouting so enthusiastically that my family thought we were fighting. The paper has a strange editorial history: part II appeared several months before part I.

One of the technical contributions of [3, 4] and related papers was to show how to get rid of the erasing rules, that is cell death. I mention one example. A *D0L system* consists of a word and a morphism (rules for the development of each letter). We get the language of the system by iterating the morphism on the word. For instance, starting with the single-letter word  $a$  and the morphism  $a \rightarrow aba$ ,  $b \rightarrow b^3$ , we get the words

$$a, aba, abab^3aba, abab^3abab^9abab^3aba, \dots$$

(A knowledgeable reader will notice the connection with *Cantor's dust*.) A general D0L system may have arbitrarily many letters, and some of the rules may be erasing. How to get rid of the erasing rules? It was shown in [3, 4] (a very detailed proof appears in [2]) that this is always possible if one allows finitely many starting words and applies a letter-to-letter morphism to the end result.

### 3.3 *Twin-Shuffle and Unisono Duet*

Simultaneously with the Handbook [11], Grzegorz and I worked with Gheorghe Păun on a book on DNA-based computing [5]. This was in accordance with Grze-

gorz’s enthusiasm about natural computing. We had already noticed that a property shared by most of the models of DNA computing is that they produce all recursively enumerable sets, that is, are universal in the sense of Turing machines. This property seems to be completely independent, for instance, of a model being grammatical or a machine model. One morning in the summer 1996 Grzegorz called me. We talked for about one hour. He spoke very fast, telling me that there is something *déjà vu* in *Watson–Crick complementarity* which leads to Turing universality. Roughly, the matter can be described as follows.

Consider the binary alphabet  $\{0, 1\}$ , as well as its “complement”  $\{\bar{0}, \bar{1}\}$ . For a word  $x$  over  $\{0, 1\}$ , we denote by  $\bar{x}$  the word over  $\{\bar{0}, \bar{1}\}$ , where every letter of  $x$  is replaced by its “barred version.” For instance, if  $x = 001100$ , then  $\bar{x} = \bar{0}\bar{0}\bar{1}\bar{1}\bar{0}\bar{0}$ . The *shuffle* of two words  $x$  and  $y$  is the set of words obtained by “shuffling”  $x$  and  $y$ , without changing the order of letters in  $x$  or  $y$ . For instance, each of the words

$$0\bar{0}\bar{0}\bar{0}1\bar{1}\bar{1}\bar{1}0\bar{0}\bar{0}\bar{0}, \bar{0}\bar{0}\bar{1}\bar{1}\bar{0}\bar{0}\bar{0}01100, \bar{0}001\bar{0}10\bar{1}\bar{1}\bar{0}\bar{0}\bar{0}$$

is obtained by shuffling  $x$  and  $\bar{x}$  with  $x = 001100$ . The *twin-shuffle language*  $TS$  consists of all words obtained by taking an arbitrary word over  $\{0, 1\}$  and shuffling it with its complement. It was known before that  $TS$  is universal: every recursively enumerable language is obtained from it by a generalized sequential machine mapping. This means that  $TS$  stays invariant for each specific “task,” only the input–output format has to be specified differently, according to the particular needs. By viewing the four bases of DNA as the letters 0, 1 and their barred versions, the interconnection between Watson–Crick complementarity and the twin-shuffle language becomes clear.

These matters were discussed in [12], and later in [5] and in many other publications. They were also discussed during ICALP’99 in Prague [13]. This was something special. Grzegorz and I were both invited speakers. But for the first time in ICALP history, the invitation was presented to us *jointly*. We took the matter very seriously. Both of us were speaking separately; Grzegorz about the wonders of his favorite ciliate Tom. But there was also a joint part where we both spoke *unisono*. This duet had required much practice. Fortunately, the hotel was luxurious, and I had a big apartment. So, there were no complaints from the neighbors.

## 4 Conclusion

Grzegorz writes in [7]:

I have a wonderful family. I have written many papers. I have shuffled many decks of cards. Life has been good to me.

Let us hope that it will continue to be so in the years to come.

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