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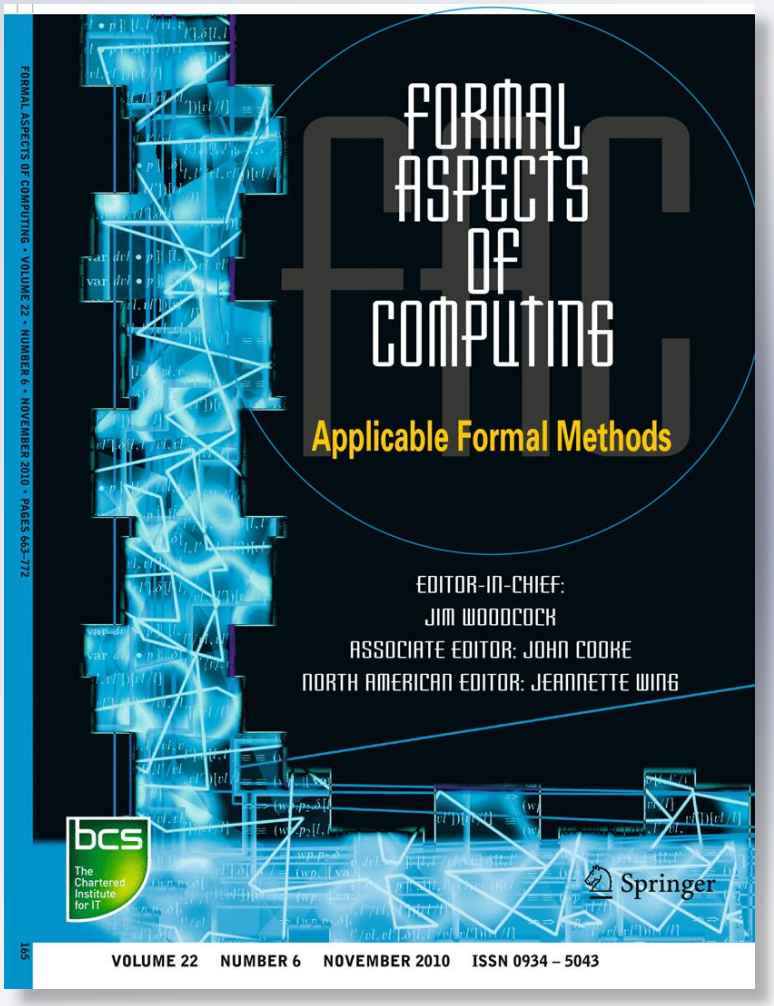
Formal Aspects of Computing
Applicable Formal Methods

ISSN 0934-5043
Volume 22
Number 6

Form Asp Comp (2010)
22:663-665
DOI 10.1007/
s00165-010-0165-0



Springer

DOI 10.1007/s00165-010-0165-0
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Formal Aspects of Computing (2010) 22: 663–665

Formal Aspects of Computing

Amir Pnueli
A Gentle Giant: Lord of the φ's and the ψ's

David Harel

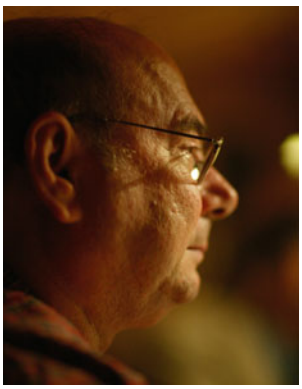

Photo by David Harel

Most of this piece focuses on Amir's personality, since FACS readers are unlikely to need too much introduction to his scientific contributions.

Amir completed his PhD in applied mathematics, the tile of his thesis being *Calculation of Tides in the Ocean,* under Chaim Pekeris, who was the founder of our department at the Weizmann Institute. He then switched to computer science during a brief stint at Stanford and at IBM Yorktown Heights. He was then at the Weizmann Institute until 1973, with two other young, brilliant computer scientists: Shimon Even and Zohar Manna. The three of them left Weizmann within a year of each other, each one for a completely different reason. Amir went to Tel Aviv University, and it was during that period that I did my Master's thesis under him. In 1980 he returned to the Weizmann Institute as a professor. In fact, four people returned together to Weizmann to form the new computer science group there—besides Amir there was Adi Shamir, Shimon Ullman (computerized vision) and myself.

For the last ten years of his life, between 1999 and 2009, he remained on the faculty at Weizmann but spent a significant portion of his time at New York University. He died in New York on November 2, 2009, and is buried not far from our Institute.

Amir was a giant in the area of logic, verification, semantics and many other topics. As we all know, his introduction of temporal logic into computer science in 1977 was his 'most significant bit'; he received the Turing Award for that contribution in 1996. Some of his other contributions, carried out alone or together with other people, include dynamic logic—especially propositional dynamic logic in the 1980s, many contributions to the semantics of concurrency, co-defining the notion of "reactive systems", and of course his many contributions to program verification, including temporal verification and deductive verification, which he carried out jointly with Zohar Manna. Amir also contributed to the semantics of languages like Statecharts. He co-designed the Statemate tool, for which he shared the ACM Software System Award in 2007. The notion of synthesis—especially reactive synthesis—was work he did to a large extent together with Roni Rosner. He was a major player in the definition and initial investigations of hybrid systems, and has done major recent work on compiler validation. He contributed widely to model checking, and to the automata theory and game theory behind model checking, to the notion of abstraction, and many, many more things.

I think there is no doubt that he really was a towering figure in our community and there is no problem identifying his 'most significant bit' in research, However, an interesting question would be "What was Amir's second most significant bit?"; so if you take away temporal logic for a moment, it is far from clear what was the most important thing that Amir did. I think we need to leave this as an open question, especially because the

David Harel spoke about Amir at an invited session at FLoC in Edinburgh in July 2010; Cliff Jones found it a perfect tribute and had a text version generated (by Joanne Allison) from the recording of David's talk; David subsequently edited this and approved its publication.

importance of some of the other things he did may only become clear in years to come. So I suggest we leave this for future research...

That Amir was a giant is clear from his scientific achievements, but the choice of the word "gentle" for the title of this piece comes from a more personal contact with an astonishingly rare gentle man. Many readers may not have known Amir personally, and perhaps have only heard him give talks. So I would like to share a little of my knowledge of him as a human being. Let me first reproduce some of the passages I read at his funeral, including some spoken directly to Amir himself:

> "Amir was first and foremost a human being, a person. A person who was at the very same time a giant scientist and an intellectual whose knowledge and areas of interest spanned the entire world: music, art, science, history, even restaurants. . . , and lots more. But he was also a tremendously gentle and pleasant person, a generous person, shy and humble. A friend, a man of conversation, but first and foremost modest and unassuming in an extreme and rare fashion, of the kind one does not find at all.
> [...]
> "But for us, his followers and direct scientific beneficiaries, we followed him not just for his intelligence, his wisdom and his greatness as a scientist, but also, even mainly, for his personality, for his ability to share with everyone his wisdom and ideas—everyone small and large—and with his hallmark unlimited generosity, which was given with great self-deprecation. Amir never committed any of the sins that are so common among scientists: a large ego, arrogance, superficiality, haste, chase of honour and credit, possessiveness of ideas, and the inability to happily give credit to others.
> [...]
> "And to Amir directly: You were as a brother to me, you were a father figure, you were a friend, someone to consult about anything at all; you were encouraging and faithful, and you gave tremendous amounts of unlimited credit. You were a true intellectual, brilliant and deep. But, most importantly, you were a human being; a special and rare human being of the kind that no longer exists. They've simply stopped making those kinds of people!"

I met Amir in 1974 when he would have been about 34 years old—so I knew him half of his life. Our first meeting is something I like to call the Pini Rabinowitz Miracle. Pini was a numerical analyst in our department, and whom I had known since my undergraduate studies. Back in 1974 I started a Master's degree at Tel Aviv Univesity in pure mathematics, trying to do algebraic topology. After reading the subject for about a year, I concluded that nothing great was going to come of that effort, not being able to see where I could make a significant contribution. So I decided to quit. At the time I was already programming one or two days a week, keeping my young family going, so I figured I would just go back to programming full time. Then I met Pini, who knew that I had done mathematics and computer science as an undergraduate and suggested that I do computer science for my Masters. At the time I thought that computer science was basically programming and languages, but Pini insisted that there was theoretical stuff that might appeal to me and uttered the short sentence that would change my life "Why don't you go talk to Amir Pnueli?". He described Amir as a brilliant young guy who happened to have an office on the same corridor as my algebraic topology professor at Tel Aviv University. Since we are talking about 1975, long before the internet and email, I just turned up and knocked on his door. After spending about an hour with him I'd moved from having a long and rather depressed face to leaving his office beaming. He lent me Zohar Manna's first book on the theory of computation, which was tremendously enlightening. The entire encounter was for me a complete miracle, and from that point on I switched to computer science, did my Master's thesis under Amir and that was that. If Pini had not spoken that short sentence and if Amir was not around and hadn't treated me so nicely during that hour, nothing would have happened.

Again on a personal level, Amir was the first person to appreciate the Statecharts language. Without his encouragement to move forward and write a paper I would probably have just seen this as something people could be using out there in industry and not as a contribution to science, whereas Amir encouraged me in his quiet and gentle manner to examine whether there was more to it than I initially thought.

Amir and I ended up spending almost 30 years living on the same corridor at Weizmann, but interestingly we never really worked together at the Institute. The things that we ultimately did together were almost always initiated on a plane or standing in line for lunch at a conference in Australia or India or some other place. In fact the notion of reactive systems was born on a plane. We were sitting together, and as usual I was describing in an excited way what I'd been doing, describing in an animated fashion the characteristics of the systems for which Statecharts seemed to be good, but adding that I had no idea what to call them. Amir listened quietly, and then said "Why don't we call them reactive systems?". That was a "bingo", from which we went on and worked the notion out together, publishing a paper on reactive systems in 1985.

Amir was very self-deprecating, and almost criminally modest. The Muli Safra story demonstrates this perfectly. Safra was a second year PhD student at our Institute under Amir, and was looking at all kinds of things. Amir went away for a few months and Muli started working on the determinization problem for Büchi automata, which had been open for 20 or 25 years and he solved it; as many of you know, there's the beautiful Safra construction. When Amir talked about this he always claimed that his greatest contribution to science was going

abroad for a few months and leaving Safra on his own, because if he were there he would have told him not to work on this hard problem at all. This was not false modesty; he really believed that this was one of his greatest contributions.

When trying to prepare something to say at Amir's funeral, I tried to think of his vices. We're all human beings and even a person as wonderful as him and a scientist as great as he was has some disadvantages. I found two. One was that he was always late: he was late in delivering his papers and reports, and always had to be prompted. But in his defence, he always did it in the end, often after the end, and he always did it in the best possible way. In seeking a recommendation for someone, for example, you would have to prompt him again and again but in the end you would receive a tremendously detailed letter.

This brings me to the second of his vices: he was always too nice to people when writing about them or talking about them. In fact, when we had our faculty meetings about candidates, although Amir was clearly the star of the faculty, his opinions were taken with a grain of salt because he saw everyone as so good and so wonderful. In his defence again, I'd like to say that he did this because he truly believed it. 15 or 20 years ago I sat on a promotion committee for someone in another university. The way that committee worked was that it only met once all the letters of recommendation had arrived and then it convened to read all the letters, have a discussion and make the decision. I got to the meeting on time, and we were given about half an hour at the start of the meeting to read the letters about the candidate. I started reading and one of the letters was from Amir. In it, among other things, he said... "*Dr. so-and-so is really tremendous; he's a wonderful researcher, and if you take the same time in their careers, he is actually even better than X..., Y..., David Harel, Z..., and W...*" So I read this and smiled, because I knew Amir and also knew the candidate. And, by the way, he was right... However, the chairman of the committee went red in the face as he realised he should have seen this comment and censored my name from the letter. I reassured him, and said that he should just forget it; the candidate got the promotion and I went home. Two days later there was a knock on my office door and Amir came in looking pale, and holding a sheaf of papers. He told me he'd heard about the "fiasco" at the meeting. Against my fierce objections, he said he was going to be insistent in a way he had never been before, and wouldn't leave the office until I agreed to read, in his words "what I write about somebody I think is *really* good". He then he pushed at me several letters of recommendation that he had written about me some years earlier for various of my own promotion or other cases. My attempts to refuse didn't help: he just sat there in my office until I had skimmed through them all. That was Amir.

On a more serious note, I would like to share with you a pledge made in a paper written jointly with Hillel Kugler, who was earlier a joint PhD student of Amir and me, and which was contributed to one of the volumes published in Amir's memory:

> "We are fully aware of the fact that in this paper we have only touched upon the topic of [...] The truth is that not only do we deeply miss Amir Pnueli personally, but we are confident that he would have been the ideal colleague with whom to continue this line of work. His pioneering work on hybrid systems, his unparalleled understanding of semantic issues for reactivity, and his rare scientific wisdom, would all have made the future work on this topic far easier, and the results far better than we can ever expect them to become in his absence.
>
> "Nevertheless we pledge to forge forward with this work, with whatever meagre talents and abilities we can muster, and bring it to a state where it can be seriously evaluated."

In summary, the world has lost a great scientist, and we, his friends and colleagues, have lost one of the most wonderful human beings one can imagine. May his memory and his legacy be with us forever.

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Published online 26 October 2010