Recollections of Norbert Wiener and the First IFAC World Congress

By Bernard Widrow (as told to Barbara Field)

With this issue, we are pleased to introduce a new column. *Tales of Automatic Control* will feature personal reminiscences of personalities and events in modern control science and engineering. Readers who have stories to share are encouraged to get in touch with the Editor-in-Chief.

I was an undergraduate student in electrical engineering at MIT, graduating with a bachelor's degree in 1951, and then stayed on at MIT and got a master's degree in electrical engineering in 1953. I continued further in electrical engineering and got a doctorate—it's called an Sc.D. at MIT. I finished the doctorate in 1956 and, upon completing that, became an assistant professor in electrical engineering and taught at MIT for three years. Then in 1959 I joined the faculty in electrical engineering at Stanford, where I have been up until this day, still teaching, researching, and writing. I tell you all this about my own history so that when I tell you stories, you will know about my time frame and it will help in piecing the stories together.

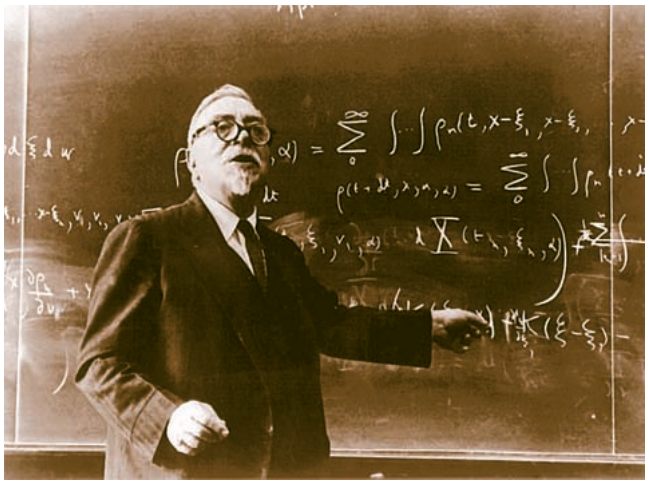
Professor Norbert Wiener

When I was a student at MIT, the most famous professor was Norbert Wiener. He was one you couldn't miss. He was a rather enormous man—I would estimate his weight at around 300 pounds. How tall was he? I would say probably about 5 foot 9 inches. We'd see him there every day, and he always had a cigar. He'd be walking down the hallway, puffing on the cigar, and the cigar was at angle theta—45 degrees above the ground. And he never looked where he was walking. Because of his size, I don't think he could see his feet. So he would walk along with his head cocked back and his cigar at angle theta, down the long, long hallways at MIT—all the buildings at that time were interconnected with hallways. It seemed that the only way he could guide himself and not bump into the walls was by looking up to see where he was in the corridor. I think he was navigating based on the line between the ceiling and the wall. But he'd be puffing away, his head encompassed in a cloud of smoke, and he was just in oblivion. Of course, he was deriving equations. So he'd come down to the end of the hallway, at the end of which were steps going down, and the steps were concrete, and the edges were steel. It was an unforgiving hallway, and if he ever took a fall, it would not be very nice. And here would be Prof. Wiener coming down to the end of the corridor, and he'd be puffing away on his cigar, and looking up and not looking down—not knowing where the heck he is—and his head busy with mathematics. And now what do you do? You can see he's going to kill himself—he's going to fall down those steps—but if you disturb him, you might break his train of thought and set science back like ten years! There was always that problem.

He was the absolute absent-minded professor. I heard one story about him—whether it's true or not, I don't know—that showed this very well. It was around lunch hour, and he was going on the sidewalk across a green on the campus, heading away from the communal dining hall cafeteria, called Walker Memorial, where one had lunch. As usual, he doesn't know where he is, or where he's going, or what he's doing. So he's walking along, and he stops a student and says to him, "Am I going to Walker Memorial, or am I coming from Walker Memorial?" And the student said, "You're coming from Walker Memorial." And Prof. Wiener said, "Oh, good, then I must have eaten."

My wife told me another story about him from our days at MIT. It was around 1955, and at that time, she was my girlfriend. I was in a laboratory group, and she was the secretary of our group. We used to call her "The Chief" because she ran the place. We were located on the third floor of Building 10, which is the building under the famous big dome at MIT. In those days almost the whole electrical engineering department was in Building 10. Now, of course, it's spread out all over the place. Well, she always had her door open, and it was right on the main corridor, and she'd often see Prof. Wiener come wandering by, puffing on his cigar, in a cloud of smoke. One day he just came wandering into her office. She had a typewriter called an IBM Executive, which at that time was state of the art in IBM typewriters—IBM was primo in those days in typewriters. She had removable keys so that she could pull the keys out and replace them with keys that had Greek letters to type mathematics. Norbert Wiener was fascinated with her typewriter—the fact that you could replace the keys and type mathematics with a typewriter, without having to handwrite the Greek symbols in the manuscript. So he just had a big talk with her about that and wanted her to demonstrate, and she did. Then he just wandered out and disappeared down the hallway.

I had two close friends at MIT—one was Mark Beran and the other was Victor Mizel—and the three of us were in the same dormitory. On Sundays, they didn't serve food in our dormitory, so we had to go out and get food. On one particular Sunday, we didn't get up too early, so the thing we went out to



Prof. Norbet Wiener with his beloved mathematics. Photo courtesy of The MIT Museum.

get was brunch. A typical place where we went to get brunch was a place called The Smith House, which was located on Memorial Drive, facing out over the Charles River. My understanding is that The Smith House is no longer there—it's in The Smith House heaven. In any event, we all got into my car, which was a Plymouth, and drove over to The Smith House to get brunch. As you came in through the main entry from the parking lot, right there was this L-shaped bar—actually more like a counter—with stools. Now you could eat at the lunch counter or you could go straight back and get a booth, which the three of us did. But when we went by the lunch counter, who did we see perched up on a stool, eating his brunch, but Norbert Wiener. Well, I looked at that and I said to myself, "What an unlikely looking scene that is! To see the distinguished Prof. Wiener sitting on a stool having brunch at The Smith House." It looked like he could fall off easily.

So we went back and had brunch, and when we finished, we paid the check and took off for the parking lot. I had the keys to my car out, and I was dangling them, talking with the other two boys, and we noticed out in the parking lot, sitting in his battered old Chevrolet, was none other than Prof. Wiener. As we were going right by him to get my car, he rolled down the window and said to me, "I say, I can't get my car started. I wonder if you could give me a push?" I said, "Prof. Wiener, absolutely! I'd be happy to give you a push." As soon as I called him "Prof. Wiener," you could see a big smile on his face. He was happy because people knew him and he was with family. I think he assumed that would be the case, I guess because we looked like students.

So I got my little Plymouth behind the battered old Chevrolet. In those days, practically all cars were stick shifts. So I got behind his car, bumper to bumper. I was in first gear because I needed the force to push him. I started to let the clutch up, and I found my engine slowing down and practically ready to stop—and he *and* I are not moving. So I told the boys in my car, "I know exactly what's happening—he's got that car in first gear and he's got the clutch up." And that's exactly what you don't do to get a car rolling and started. You've got to get it rolling first and then let the clutch up. So I said to the boys, "What should I do? Should I go try and explain to him what to do—how you start a car by pushing? He'll never understand anyhow. So I'll just gun it and practically burn my clutch out, but we'll get him going and it'll be easy." So I just gunned it, and let the clutch out gradually, and slowly I started to creep forward, and he started to creep forward. And all of a sudden, after just a few feet of pushing, his engine caught. You see, when you're in first gear, and the clutch is out, even if the car is moving slowly, the engine is moving fairly rapidly. And because he was in first gear and had his foot on the gas, he took off like a rocket. Meanwhile, he's blowing his horn and waving his hand to thank me, and because of his great weight, his car lurched forward. Now we just deduced this . . . we didn't talk with him about it . . . as he was in his car and we were in ours. So as his car lurched forward, the speed of the car under him caused his body to lurch backward, and that probably took his foot off the gas pedal. And when you're in first gear, the moment you take your foot off the gas pedal, the engine braking practically stops you. So the car practically stops and his body lurches forward, and his foot hits the gas pedal again, and he goes lurching backward again. We can hear his engine going "Vroom . . . vroom . . . vroom." Meanwhile, he's still busy waving his hands—"Thank you, thank you!"—and blowing his horn, and he goes shooting out of the parking lot and right onto Memorial Drive, with two-way traffic in each direction and no island in the middle. And we can hear the brakes screeching and the horns blowing, and we can see he's still waving to us, and I said to the boys, "My God, we've killed him!" You know, Prof. Wiener wrote a book on cybernetics, which has to do with how man and machine are similar and related and how they work together. And here you've got man and machine, and the thing was practically unstable and into oscillations, and he had no clue. Somehow he kept going forward and managed to turn left onto Memorial Drive, crossing three lanes of traffic, and the last we saw he was headed back to MIT.

First IFAC World Conference

A number of years later—I had already gone to Standford and Wiener was still at MIT, still doing all the usual stuff, as far as I knew—I went to the first IFAC Conference in Moscow. This was my first time going to Europe, in fact, the first time I'd ever been outside the United States. In those days, if you were traveling on contract funds, you had to fly a government-run airline called MATS, an acronym that stood for Military Air Transport Service, or something like that. So we flew to New York, and from there to New Jersey, to McGuire Air Force Base, where you picked up your airplane. We flew

in a DC-6, a four-engine propeller plane, to London, with a stop in Labrador and another stop in Scotland for refueling. Those planes didn't have the range of a modern airplane.

So we landed in London and spent a few days there. It was 1960, and there was still damage in London—neighborhoods that had been bombed out in the Second World War. From there, we flew to Paris, where we got on Air France to fly to Moscow, with a stop in Warsaw. The airplane was a French Caravelle, a twin jet, which was up and flying well before the Boeing 707. It was the first time I'd ever been in a jet airplane, and it was quite an experience. We landed in Warsaw and went into the airport terminal, a one-room terminal. Out the window we could see the Polish commercial air fleet—a whole bunch of DC-3's—and were trying to figure out where the Polish had gotten them. We realized they must have been leftover Lend-Lease equipment that we gave to Russia during World War II, and they ended up in Warsaw as the Polish commercial air fleet. There was sort of a gift shop where you could buy little Polish things, and to our surprise, the currency in the little gift shop was dollar bills. I was amazed, as this was 1960, during the height of the Cold War, and was feeling sorry for those dollar bills so far from home.

What happened next is that the French pilot who flew us to Warsaw took the copilot's seat, and this Russian pilot—a short, squat guy with medals all over his chest—came strutting out of the Warsaw airport with his black briefcase to fly that Caravelle. I guess it was not possible for anyone to fly over Russian territory except a Russian pilot. Now the time frame was June, as I recall, and two weeks before that flight, a U-2 aircraft piloted by Francis Gary Powers was shot down over Russia, and I was saying to myself, "I've got to be crazy." But everything seemed up and on, so we went into Moscow. It was extremely hot when the Caravelle landed. Things were not like they are now, where they plug in an air conditioning unit and you immediately get cold air on the airplane. It took quite a while from the time we landed before we could get on the bus to take us to the gate, and we were baking in that airplane. I mean, absolutely roasting! There was no air movement, nothing, and we're going nuts. The Caravelle is smaller than a DC-9 or the smallest MD-80. I think the DC-9 was modeled after the Caravelle, although the designers would probably deny it, but that was sort of the layout.

As I was getting off the plane, I saw that up ahead of me was Prof. C. Stark Draper. Today at MIT there's a lab called Draper Lab, named after him. He was a heavyset man with rimless glasses and a very pleasant person. It was so hot, and we were all drenched and carrying our bags. I saw that he had a lot of hand carries, so I introduced myself to him and said, "Prof. Draper, can I help you with your bags?" "Oh, that would be wonderful!" he said, and I could see by the look on his face that he was grateful there was someone who knew him and could help him. I got his bag into the terminal, where it was much cooler. We got checked in through Customs, and the bus finally took us to our hotel.

All the foreigners were staying at a hotel called the Hotel Ukrania. The architecture of the Hotel Ukrania was exactly the same as that of the University of Moscow and of City Hall. In fact, there were a whole bunch of major buildings that all had a seemingly identical design—you know, "the system." I thought the hotel was quite fine, but then I was not much of a world traveler at the time, so I didn't have much to compare it to. This hotel had 2000 rooms, and the lobby was enormous. I was there chatting with some friends when in the distance I saw Prof. Wiener, wandering along, puffing on his cigar. He seemed to be talking to himself, muttering away. Now the Russians absolutely lionized Norbert Wiener. He wrote a book called *Cybernetics,* and in those days the Russians called the whole field of control theory "cybernetics," and the esteem they had for Norbert Wiener was far greater than that accorded him anywhere else in the world. In the United States, we didn't use the word *cybernetics* very much. At MIT, Prof. Wiener was lionized by engineers, but I think the fact that engineers were interested in his work was not a plus among his fellow mathematicians. In other words, if the mathematics threatens to be useful, it's probably not too good.

At MIT, Prof. Wiener was lionized by engineers.

Prof. Wiener was just tremendously overwhelmed, I suspect, by the reception he got from the Russians. I could see he was talking to himself while puffing on his cigar, so I told my friends, "I'm going to go and see what this is all about." Now, he's not going very fast, just waddling away like a duck, so I had no trouble catching up. As I got behind him, I could hear him muttering to himself, "I spawned all this." Now, he was a person who was not particularly modest. He really understood his accomplishments. But he was such a kind person, a lovable person—and he was such a fuddy-duddy—that everybody loved him anyway. Everybody knew that he was immodest, but he was immodest in the nicest way, so it didn't matter.

I think there were at least 2000 attendees at the first IFAC conference, about half of them Russians and half foreigners. At that time, there were tremendous political problems between China and Russia. They had already had a total falling out. We would have all three meals in the Hotel Ukrania, and one day at lunch a friend asked me a rhetorical question. "When the Chinese commissars sit down to have lunch with the Russian commissars," he said, "what language are they speaking?" And I said, "Gee, I don't know. Probably Russian." He said, "No, the language they're speaking is English." Today, I think that's easier to accept, because English is so ubiquitous, but not back then. We found that our Russian colleagues spoke English with heavy accents, but they all

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Dr. Widrow is a Past President and currently a member of the Governing Board of the International Neural Network Society. He is Associate Editor of several journals and is the author of about 100 technical papers and 15 patents. He is co-author of *Adaptive Signal Processing* and *Adaptive Inverse Control,* both Prentice-Hall books. A new Book, *Quantization Noise*, is in preparation.

spoke English. Our Chinese colleagues all spoke English as well. The politics was that the Chinese would refuse to speak Russian and the Russians would refuse to speak Chinese, so they all spoke "politically correct" English. We were their common enemy.

With regard to Francis Gary Powers, in Gorky Square, the Russians had organized an exhibit of the U-2 airplane. This was a top-secret U.S. airplane. Eisenhower was president at the time, and before the U-2 got shot down, the Russians were publicly complaining about American aircraft flying spy missions over Russia. Eisenhower absolutely denied it and denied it, but they kept complaining. What happened was that the U-2 flew so high that the Russians couldn't shoot it down. Then they developed missiles that went up higher, so along came the U-2, and, bingo, they shot it down. Poor President Eisenhower had a big red face. Powers survived it, and they captured him, and he was in prison there for years. What they had on display in Gorky Square was pieces of his airplane. They also had his flight jacket, his log book, part of his flying outfit—all sorts of stuff. It was a major exhibit, and the people moved four abreast for ten blocks, waiting to see it. I didn't see it, but some of my American colleagues told me that the Russian cops would grab the Americans or other foreigners who came near the line and take them to the front. There they would push aside the Russians who were a few people back from the exhibit—to make sure the foreigners got to see it and didn't have to stand in line like the Russians. Can you imagine in this country if a cop tried to break into a line and put somebody ahead?

Back in the hotel, we had noticed the elevator never stopped at the 13th floor. One day I was in the elevator alone, and by accident, it stopped at the 13th floor and the door opened. I could look out and see down the hallway—racks and racks of gear with glowing tubes. The whole floor was electronics. So this is why they put foreigners in this hotel. Need I say more? One day, I was in my room and got a phone call from a young Russian guy who spoke with a very heavy accent, but spoke very good English. He wanted to come up to my room and talk with me, so I said, "Fine, sure. Come on up." He was a young Communist who was trying to talk to me about Communism. Now, I wasn't famous, just a young brand-new assistant professor at Stanford, but I think they wanted to see if they could make a convert. After two hours of this, he gave up, as he couldn't make any progress. I remember discussing elections with him and saying to him, "You don't have elections." "Yes, we have elections," he said. "We have one candidate, and the people vote for him. When you have an election, you have only two candidates, so you have only twice as many as we have." I said, "We don't have twice as many as you have, we have infinite times as many as you have." Well, I wasn't getting anywhere, and he wasn't getting anywhere, but it was all probably being caught on tape by those electronics. I didn't see any tape going anywhere, but I saw the electronics.

The main benefit of attending that first IFAC meeting was the personal contacts that you made. I made a personal contact with a colleague who became a friend for life. That was Prof. Tsypkin—Yakov Zalmanovich Tsypkin—who died a few years ago. The way he wrote his name was Ya. Z. Tsypkin. The Russians who knew him well would call him Yakov Zalmanovich. "Yakov Zalmanovich did this, and Yakov Zalmanovich did that." When I came to the meeting, he was looking for me. He knew all about my doctoral thesis, which was on the theory of quantization noise, and he had a small group of doctoral students working on that theory. I was astounded that he would know about the work of an insignificant young guy in the United States. How would they pick that up so far way in Russia? Although at the time Russia was a superpower, these scientists were in the backwater. I realized that they were much more systematic about studying our literature than we were about studying theirs. For one thing, they knew English, but we didn't know Russian. We tend to be like that. We're very provincial and think the sun rises and sets in America.

Wherever we went, the people of Moscow welcomed us with open arms, despite the fact that just two weeks earlier an American spy plane had been shot down. They couldn't have been happier to see us. This was the first really big scientific meeting of the Soviet era, where they actually opened up the country and let some foreigners in. We were very carefully controlled. We were programmed where to go and where not to go. One of our colleagues had taken some pictures out of bounds, and they took him down to the jailhouse, took the film out of his camera, chewed him out, and then let him go. You could take pictures, provided you took them in the right places. I took pictures all over Red Square, but you weren't supposed to take pictures at the airport, for instance. When we landed at the airport, we could see, far out on the horizon, a whole fleet of heavy aircraft, probably Russian bombers. Their military and civilian bases were kind of intermingled, whereas we keep them totally separate. It was an interesting period of history, and the reaction of the Russian people to us was just tremendously welcoming. Regardless of the Cold War, I think the Russian people remembered us as allies in the Second World War. We had helped them and given them so much stuff through the Lend-Lease Program, and they had just never forgotten what we did. Even though you have conflict from government-to-government, it seems that, regardless of the propaganda, the people see right through it and are friendly and hospitable. They wanted to shake hands, to touch us, as if to be sure that we were real.

The LMS Algorithm

I can tell you a story about the development of the least mean squares (LMS) algorithm, which is the learning algorithm most widely used in the world today. It was discovered in the fall of 1959 by Ted Hoff and me and is called the Widrow-Hoff LMS algorithm. Sometimes it's called the Widrow-Hoff delta rule. In the field of neural nets they call it the delta rule, and in the field of signal processing they call it the LMS algorithm.

I had just gotten to Stanford and was working with Prof. John Linvill, who ultimately became a famous chair of Stanford's EE Department. Prof. Linvill called me one day and said, "Look, I've got this student whose name is Ted Hoff. He's an extremely bright guy, but all the things I suggest to him don't seem to turn him on—don't seem to get him interested. Could you talk with him and tell him about some of the ideas you have that might interest him?"

My work interested him immediately, and so we collaborated and worked together throughout his doctoral studies. We had a small group of doctoral students—later it grew to about a dozen—and throughout the years I usually had about a dozen students at one time. So, I was at the blackboard one Friday afternoon explaining to Hoff some ideas I had about how to make an adaptive filter. The methods I had of adapting it were classical but tedious. I was using gradient methods, and somehow an idea popped up about a different way to get the gradient. We crossed the hall to where my colleague, Prof. Gene Franklin, had an analog computer, and Hoff programmed that thing to do this algorithm, and we had it up and running within a very short time that afternoon. Over that weekend, we built it in hardware, and by Monday we had a machine working in my office that turned out to be a single neuron that you could train by using your fingers. The weights were potentiometers that were manually controlled. I still have this machine in my office and it still works, and I use it to teach students. So from that came adaptive filters, and years later came adaptive control. In inverse control, the key idea is to use the controller to drive a plant, where the controller would have a transfer function that is the inverse of that of the plant. Then you can feed an input signal or command signal to the inverse controller, and that will produce an output that drives the plant. We are still working on this idea today.

We discovered the LMS algorithm on a Friday afternoon sometime in the fall of 1959, and it was the topic of the paper

Assistant Professor Widrow training the adaptive linear element (Adaline). Photo courtesy of Stanford News Service.

that I gave at the first IFAC meeting. It's still being written about today, as every new algorithm that's developed is compared to that one. Everyone has a better one. Every year, dozens and dozens of papers are written about better algorithms than that one, and the next year you've got dozens and dozens that are better than those from the year before. That's what research is about. Ted Hoff, incidentally, stayed with me through his doctorate and a post-doc, and then became employee No. 12 at a new company that was just getting started called Intel. The development of a computer on a chip was his idea and his project at Intel. He's recognized by the IEEE as the inventor of the microprocessor.

The Control Cryptic

Answers to the April 2001 Control Cryptic