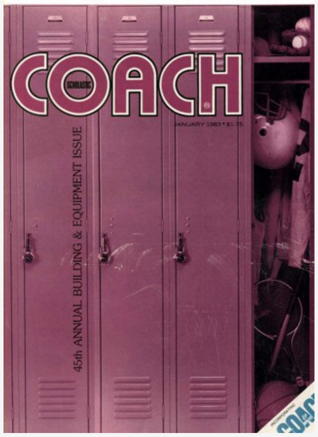
The Man Behind the Computer of the U.S. Olympic Sports Medicine Committee

Gideon Ariel, The guru of computer science, tells us what he's doing with our athletes



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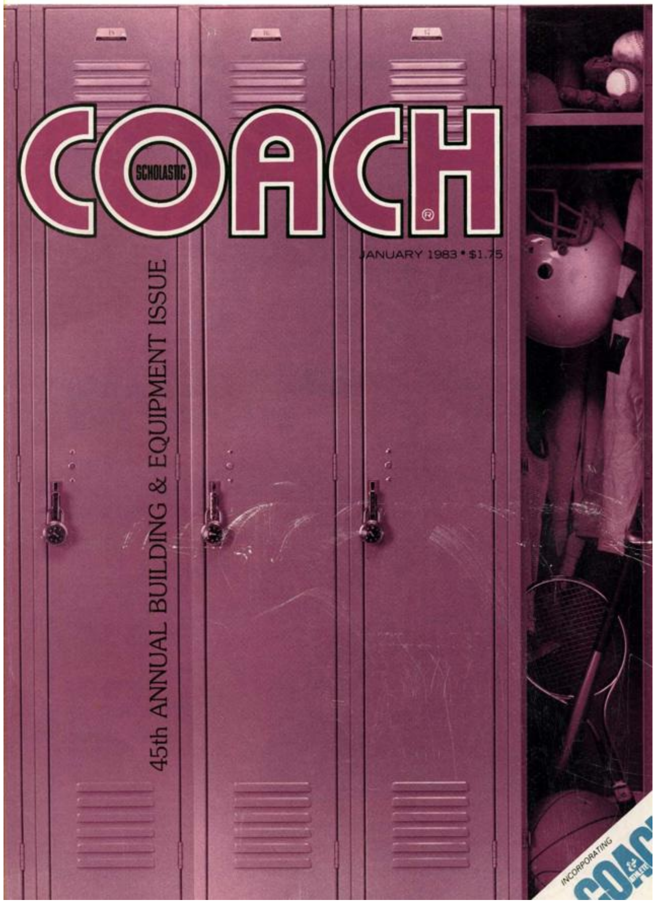
This article discusses the work of Gideon Ariel, a computer science guru who uses computerized biomechanical analysis to improve the performance of athletes. Ariel, a former Olympian, uses his expertise in computer science and exercise science to analyze and optimize the movements of athletes in various sports. His work involves both direct and indirect methods of analysis, using high-speed filming and computer calculations to identify and correct minute flaws in technique. Ariel's work has been used to improve the performance of athletes in sports ranging from discus throwing to volleyball, and he believes that his methods could be applied to virtually any sport.

Article Synopsis

The article features an interview with an expert who argues that the use of technology in sports is not destroying the essence of sports, but rather providing coaches with sophisticated tools to enhance their athletes' performance. The expert uses the analogy of engineers designing a bridge to illustrate how technology can expedite processes and improve outcomes. He suggests that the same principle applies to sports coaching, where technology can provide precise data on an athlete's performance, such as running speed or the speed of a wrist movement. The expert also challenges traditional coaching wisdom, using high-speed photography evidence to dispute common beliefs about the mechanics of throwing a baseball. He concludes by emphasizing the need for coaches to adopt these sophisticated tools to improve their training methods.

Below find a reprint of the 7 relevant pages of the article "The Man Behind the Computer of the U.S. Olympic Sports Medicine Committee" in "Scholastic Coach":



MAN BEHIND THE The Computer of the U.S. Olympic Sports Medicine Committee

PERSON TO PERSON

SC: *How did you get involved in the field of computerized biomechanical analysis?*
ARIEL: I was born in Israel and competed in two Olympics (1960 and 1964) as a discus thrower. I came to the U.S. on an athletic scholarship to the U. of Wyoming. After graduating with honors, I moved to the U. of Massachusetts for my M.D. and PhD in exercise science. I then jumped into the PhD program in computer science. I was teaching in the computer science dept. when I decided to start my own company—the Coto Research Center in California. It is a co-venture with Penn Central. Our $5-million complex in Coto de Caza is probably the most sophisticated sports research center in the world.
SC: *What specific projects are you working on at the moment?*
ARIEL: We're working with the U. S. Olympic Committee in analyzing our top athletes in the throwing events and we have a permanent training center for the women's Olympic volleyball team. We're also working on various designs and inventions such as tennis rackets and shoes.
SC: *You have said that your theories are based on Newtonian physics. Could you elaborate a little on that?*
ARIEL: Anything that moves obviously has to observe Newtonian physics, which means force equals mass times acceleration. That's basic, something you learn in high school. Now, when athletes try to throw a baseball faster or kick a soccer ball harder, they have to obey the same principle because basically they're trying to overcome gravity and create inertial forces in their body systems.

To do that, they need internal mechanisms—muscles and other physiological aspects. Say an athlete wants to throw a javelin farther. The javelin had better leave his hand at a certain velocity and a certain angle. We can calculate these velocities and angles and see which are the most efficient to get the most distance. That's the point—to get the most distance. They don't measure how beautiful you look, but how far you throw.

On the other hand, we are also working with gymnasts and other aesthetic athletes, such as divers and figure skaters. We want to quantify the feedback that the judge is looking for so that he will say the performance is 9.6 and not 9.2.
SC: *But how can a judge be that accurate?*
ARIEL: We try to define the factors that affect judgment. For example, in figure skating we found that the wobbling effect of the trunk is extremely important. In other words, the skater can go up and do a double axel, but if his trunk is wobbling a bit, he'll usually wind up with a low score. It's not so much how straight the leg is or how beautiful the fingers are in the air, it's mostly the massive parts of the body that are sending the message to the judges.
SC: *How about a non-gravity event, such as swimming?*
ARIEL: We try to measure what kind of interaction between the body surface and the water will produce the greatest propelling force. Sometimes it's not necessarily what makes sense. For example, it used to be thought that if you stretch your arm as far as possible and pull it as fast as possible through the water—the classic Johnny Weismuller style—you

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might find it inefficient.

Maybe you want to turn your hand with a bent elbow to create more surface against the water. Also, the speed of the arm through the water shouldn't be too fast or you'll miss too much resistance; you'll create water movement that isn't advantageous. You want to move the arm at a certain velocity. We want to find out what that is. Of course, different people have different velocities.

Also, we want to learn how to reduce friction with the water. For example, should you really shave your body or not? What kind of suit should you wear?
SC: *We know that you're also working with our top sprinters and hurdlers. So how do your theories apply to the explosive events?*
ARIEL: With sprinters, you want to know what stride length will produce the best results. With Ed Moses, the great hurdler, we know that he has characteristics we can't take credit for, that are genetic.

For some reason, when he comes over the hurdle and touches the ground, there is no blocking force. In other words, his center of mass is already ahead of his feet. Most hurdlers, when landing, have a force that pushes them backward. They stop themselves just a little.

With Ed Moses, there is no braking force, so that even though he's not the fastest person in the world, he becomes that when he runs over the hurdles. He has taught us what to look for in other hurdlers, to learn whether they are running the hurdles most efficiently. Moses also takes 13 steps between hurdles in the 440, where most athletes take 14 or 15, and other things like that.

We try to define the characteristics that contribute the most to each event. Another example: Al Oerter, 45 years old, threw the discus over 240 feet two weeks ago, far surpassing his gold-medal throws in the 1956-60-64-68 Olympics (184-10½, 194-2, 200-1½, and 212-6½).

Maybe Al Oerter is still 25 biologically. We've tried to determine whether aging can really deteriorate performance. Well, in the case of Oerter, it does not. He has more problems with technique than with age. So we concentrate on the technique.
SC: *Is there a theoretically correct way to execute specific skills in order to produce the best result?*
ARIEL: Let's take the discus. We know that if the discus leaves the hand at a certain velocity and a certain angle, it will go a certain distance. We want to maximize the velocity. Let's assume that the angle is a technical problem that anybody can correct. But it is very difficult to generate the speed.

Now, speed obviously doesn't come from the hand. It comes from the lower part of the body: the trunk, the hips, the shoulders, the upper arm. There is a coordination that produces a certain whipping action. Not everyone can produce that. Doing it with the whole body, which consists of about 16 segments that interact with one another, is very difficult.

Now, suppose you have a deficiency in one of those 16 segments, or springs. It could be the thigh or the shank or the trunk. You can only be as strong as your weakest link—you cannot be stronger. If you don't use your legs correctly—the harder you push with your arms—the energy will not go into the implement, but back into your legs.

So you have to execute in a way that will transfer all the energy to the last segment—in this case, the wrist and the hand—and then be transferred to the discus.

There is a way for each person to do this in order to maximize his efficiency. We can calculate it with our methods. The only reason we use a computer is because there are about five million calculations in every skill.
SC: *Could you go through some of the basic processes you use in biomechanical analysis?*
ARIEL: There are two methods of doing it: direct and indirect. The direct method has the athlete coming to our laboratory, where we put electromyogram electrodes on him to determine how his muscles fire. We let him throw from a force platform, and every time his foot hits the platform, we get the amount of force generated in his feet.

At the same time, we film him at a very high speed—200 or 300 frames per second, sometimes 500 frames per second. In golf, it's even higher than that—5,000 frames per second. Then we project these pictures into a digitizer, a screen that is sensitive to each of the coordinates of the body. We utilize either a manual digitizer with which we cannot see the body segments very well, or an automatic digitizing system which uses image analyzers that can look at the picture and define certain points on the body.

These values then go into the computer, which give us the parameters of the athlete's motion in three dimensions, as the human body is always changing its plane of motion.

The three-dimensional analysis requires sophisticated equipment, but it gives us the velocities, the accelerations, the forces, and the energy in the physical space in which the athlete produced them. That gives us the efficiency and deficiencies of every motion.
SC: *How does this differ from your indirect method?*
ARIEL: In the indirect method we try to see what the East Germans are doing, or what the Russians are doing, or what the Japanese are doing—in volleyball, for example. When we prepare for the World Championships or the Olympics, we go out and film our rivals and bring the information here.

Let me give you one example: Our women's volleyball team went to Peru for the world championships three weeks ago. When we played against China, Japan, and Russia, we knew exactly where to spike the ball and where to be on the court when they spiked to us. We knew at what velocity they could move to the right or to the left or forward. We knew how high to go to go over their blocks.

For the first time in our history, we beat China easily, 3-0 in 54 minutes. We beat Russia 3-0 and we beat Japan 3-0. Now, I'm not saying our computerized analysis was the entire reason for our success. But our one failure lent even

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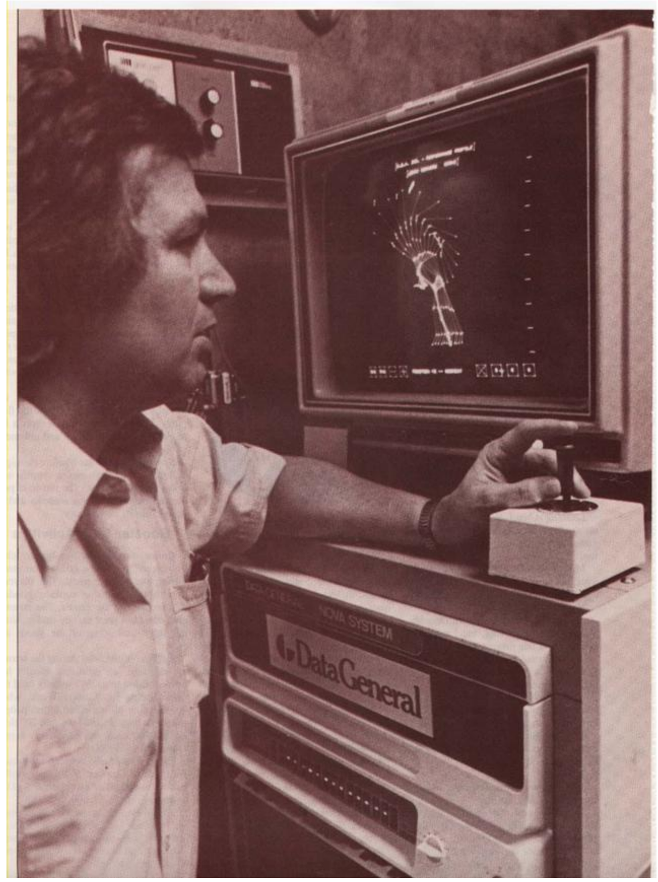

GURU OF THE COMPUTER

more credence to our methods. Peru beat us 3-0—and Peru was *the one team we hadn't bothered to analyze*. We had considered them "easy" and saw no reason to waste time on an analysis!

So China, whom we had beaten 3-0, won the world title. Peru finished second, the U.S. third, Japan fourth, and Russia fifth.

We call this method of analysis "formation analysis." Not only do we analyze the best player on the team, but how this person interacts with other people.

SC: *Don't you have a special kind of analysis for this?*

ARIEL: We use a sophisticated statistical method called cluster analysis. The Air Force uses it to determine the clusters of the enemy and how they are concentrated, and they use probability tests, depending on whether the enemy has or doesn't have missiles. Or if they have so many soldiers that can move so fast. Or what kind of land there is: Are there mountains or are there valleys?

The military can then make a statistical prediction on whether it's best to use the Air Force or to use tanks or to use the Navy—things like that.

We are using the same method for volleyball. We say: "If they are very fast and very strong on the right side and they can move the ball to the left side at a certain speed and they can spike the ball at a certain angle and a certain speed, we concentrate on those specific zones." It worked fantastically against China. They fell completely apart, because we were ready for everything they tried to do.

SC: *How did you get the statistical information for this analysis?*

ARIEL: We went to the World Cup the year before and we went to a few international meets and just filmed them from the stands. They didn't know what we were doing. We had ABC signs on our arms and they thought we were from the media. Then we brought the films back to the Coto Center and did a lot of work—coming away with a 600-page report.

But the thing that most people don't know is that in this high-skill sport, athletes *commit to the motion* before the situation exists. In other words, if Floheimer, our best spiker, is going for a spike, the opponents don't wait for her to spike.

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When they see her running for the spike, they already commit themselves to certain positions. That's because although they may not know statistically, they have the experience to set themselves at certain points.

The same thing was true when we worked with Jimmy Connors. Connors had certain deficiencies in his service motion and positioning. When McEnroe would hit a ball at him, Connors would just randomly take a position. Now, imagine if Connors knew that when McEnroe went to the right at a certain velocity, the ball would go to a certain point 90% of the time. That kind of information could be invaluable in any individual game like tennis or team game like volleyball.

SC: *Didn't we see something about your working with the Dallas Cowboys on the same thing?*

ARIEL: Yes, we are working with Bob Ward, the training coach. We believe that formation analysis is in the future of every team. You know how big football is. But ask a coach what he's going to do next week and how certain he is that it will work in a certain situation, and he'll only give you a guess.

But ask General Motors about car sales or going a certain way or if a motor is going to blow up, and they will bring in a dozen experts in a moment. They've calculated everything to the nth degree—though they did let Japan beat them to formation analysis.

SC: *We'd like to back up a bit to direct analysis. You've said that the human eye can't discern faults in an athlete's technique because the faults are often too minute. Let's say that you put an athlete through the analysis and you come up with the flaws in his motion. If these flaws are so minute, is it physically possible for the athlete to make corrections?*

ARIEL: Sometimes it's difficult. Take someone like Ben Pucknett, the world-record holder in the discus. For him to throw another five feet, he had to correct a flaw in his stance. In other words, when he completed his turn in the discus, he was completely open. He had already lost about 10 inches of pull on the discus.

We can work on such flaws for a week to 10 days and improve a throw by five to 10 feet. With the world-class athletes, very small changes can make a very big difference.

Take weightlifting. A guy can clean and jerk, say, 500 pounds. To get to the 515-pound level, it might take him a year or a year and a half. But if he could just change a minute flaw in his technique—he might be bending his knees a little too late or bending forward a little too much or keeping his body a half inch too far from the weight—it could make a big difference. Adding a half inch to the height of the heel off the floor can affect the weightlifter by 10 to 15 pounds.

SC: *But, can the athlete make these corrections once you have pointed them out?*

ARIEL: Oh, yes. It's not difficult. It's a matter of repetition. It takes only about a week to create a new motor pattern. But you don't change the whole thing. Athletes are changing all the time anyway, and no athlete does the same thing all the time. With Al Oerter, we had to stretch his arm a little. We moved his axis of rotation farther from the body. It took two or three weeks, but he was able to adapt to it.

SC: *Is it possible for this to lead to a decrease in performance? For example, Rod Laver had less than classic strokes, but achieved tremendous success. Now, if you had put him through a motion-analysis study, you might have found a thousand little flaws. Yet, somehow, the sum of the parts resulted in fabulous success. Would it have been detrimental to tinker with his motion?*

ARIEL: You have said a most important thing. It's not how a technique *looks*. It's what it accomplishes. For example, I could have a ballerina throw the shot and she would look beautiful, very smooth. But the shot would land ten feet from her. People will say a player has "classic" form or that he "looks terrible." But it doesn't matter.

We analyzed Laver. He had a good underspin, but he could not "bring the racket under the ball." We filmed him at 5,000 frames per second and found that the racket was at exactly 90°. It *looked* as though he was going under the ball, but the ball was already 20 feet ahead of him!

SC: *Isn't this also true of a lot of field men in track?*

ARIEL: Brian Oldfield looked terrible in the shot, but he could throw the ball 75 feet. Then he tried to look "good" and he threw only 68 feet. He came here about a month ago for analysis. He still looks "good", but he cannot produce the force. When he was throwing like an animal, he just did it better.

The same thing happened with Mac Wilkins. He decided to imitate Wolfgang Schmidt, who had just broken his record by two inches. For years, he tried to imitate the East German, because he thought it was a better technique. Well, it was a better technique—for the East German, not Mac Wilkins.

We had to convince him to throw the way he had been throwing. It was only two inches short of the world record. He had had a good technique. It took him months to get back to where he was before.

SC: *At least one coach has said that training can only produce a 5% gain in sprinting performance. Do you think that's true? Would it also be true of other sports?*

ARIEL: 5% of what? If you can run the 100-meters in 10 seconds, 5% would give you the world record by far. 5% in sprinting is a tremendous improvement. Let's take a guy who can throw the discus 200 feet. 5% would be 10 feet, and that's a big improvement in the discus. Usually, when people say that, it sounds like "*Only* 5%." But from 10 seconds to 9.5 would make a sprinter the greatest athlete of all time.

Take Carl Lewis in the long jump. He has jumped 28'7". Add to that 5% and he would beat Bob Beamon's record. They said that no one would ever beat Beamon's jump. I said it, too. Now, if a guy were throwing the shot 50 feet and he could improve "only 5%," I might tell him to try playing the violin: He might be more successful.

So I think it's relative. In sprinting, you're right. Sprinting is a genetic event—you are a born sprinter. No one can take a guy 20-years-old who runs the 100 meters in 12 seconds and make him run 10.5 even. But if you have a 17-year-old who can run the 100-meters in 10.3, he may be a potential world record holder.

SC: *What percentage of most athletic performances is due to genetics and what percentage is due to coaching and training? Or is that quantifiable?*

ARIEL: Well, it's quantifiable, but we just haven't done it yet, so I'm just guessing. In the explosive events, where you don't need much technique, like the long jump or the sprints, the technique is not the main thing—the genetic characteristics are. You cannot make a Volkswagen go like a Masserati; I don't care how you tune it. You first need the Masseratti, and if it's untuned, you have to know how to tune it. That's where the coaching comes in.

"Ask a coach what he's going to do next week and how certain he is that it will work, and all he can do is give you a guess."

Now take the discus-thrower: He should have the genetic characteristics, but technique plays a much greater role in his event. He has to turn and he has to time it—he has to use a certain technique to be successful. So in technique events—gymnastics, figure skating, throwing events, high jump (even more than long jump, which is basically a sprint event), pole vault—you've got to have the technique as well as the genetics.

Sometimes, the most talented person will not break the world record because he didn't have the right technique. And sometimes an inferior person—genetically, at least—can still achieve the world record because of superb technique.

Take a guy like Bob Beamon: Obviously, his 29'2½" jump was unbelievable. He never jumped over 28 feet before or after that.

Take Carl Lewis: He has jumped over 28 feet maybe 25 times, but he still hasn't jumped over 29 feet. So Lewis probably has the potential, but he needs to improve his technique. Maybe a little technique change will add the one or two percent he needs to break Beamon's record. I think he can do 29'5" or 29'6".

I don't think anyone will ever jump 30 feet, because you have to produce a level of force that would break the bones. So this is a species limitation. There is some species limitation, of course. No one will ever jump 9 feet in the high jump, for example. You would have to create a force that would break the bones.

SC: *You have said in the past— and this is a direct quote—that "You can provide coaches with the tools to make the best athletes." As you know, Scholastic Coach goes to coaches. So perhaps you could be a little more specific about that.*

ARIEL: Many people have said, "Wait a minute. You are making a science out of sport. You are destroying sport, because everything is becoming computerized. Pretty soon athletes won't have to do anything, they'll just have to look at computers."

That's a false assumption. What I have said is that we have developed a very sophisticated tool for the coach. Let's say that three engineers graduate one, two, three in their class. They have to design a bridge. The first one doesn't have a pencil and paper. I don't care how smart he is. He's never going to figure out a design in his head.

The second engineer has a pencil and paper—thus, he can do everything that the computer can do. He can simulate, he can write formulas, he can draw the bridge. He can design the bridge, but it might take him a year or two. By that time, the materials might already be old and there would be a new technology.

Now, the third one has the computer and cameras and other sophisticated equipment. He can simulate, calculate, bring in historical factors, have cars going over the bridge before actually building it by using the computer to see if it will sink or fall. He has the tools to express his thinking in the fastest way. He's not a better student and he isn't smarter than the other guys. But he has the tools.

It's the same thing with NASA when they tried to land a spacecraft on the moon. They didn't throw out 1,000 space ships and hope that one would hit the moon. They sent out one and missed by 10 feet. From the earth to the moon, and they missed by 10 feet.

Now, what we're doing in athletics is trying to shoot at the moon with 10,000 spaceships. It's all random, because we aren't using the right tools. We don't *have* the tools. What I am saying is that we should provide the coach with the sophisticated tools that will tell him how fast his athletes are running, how fast the arm moves, how fast the wrist moves.

In baseball, for example, there are all kinds of stories about how the ball leaves the hand—a knuckleball or a curveball and all kinds of crazy terms. I read the explanation about why the ball does what it does. But when you analyze it, the explanation has no resemblance to the truth. In fact, Sports Illustrated did a TV show on high-speed photography, and for the first time you could see that the ball leaves the hand way before you follow through with the hand.

Now, if you told a coach that you shouldn't follow through in baseball, he would think you were nuts. If I told the baseball coach that the ball left the hand when it was approximately parallel with the shoulder, he would tell me, "Come on, that's impossible. You stretch forward."

I would say, "Yes, you stretch forward, but that's the result of the movement." I don't say that you shouldn't stretch forward, but the ball left the hand way, way before that.

(Continued next month)