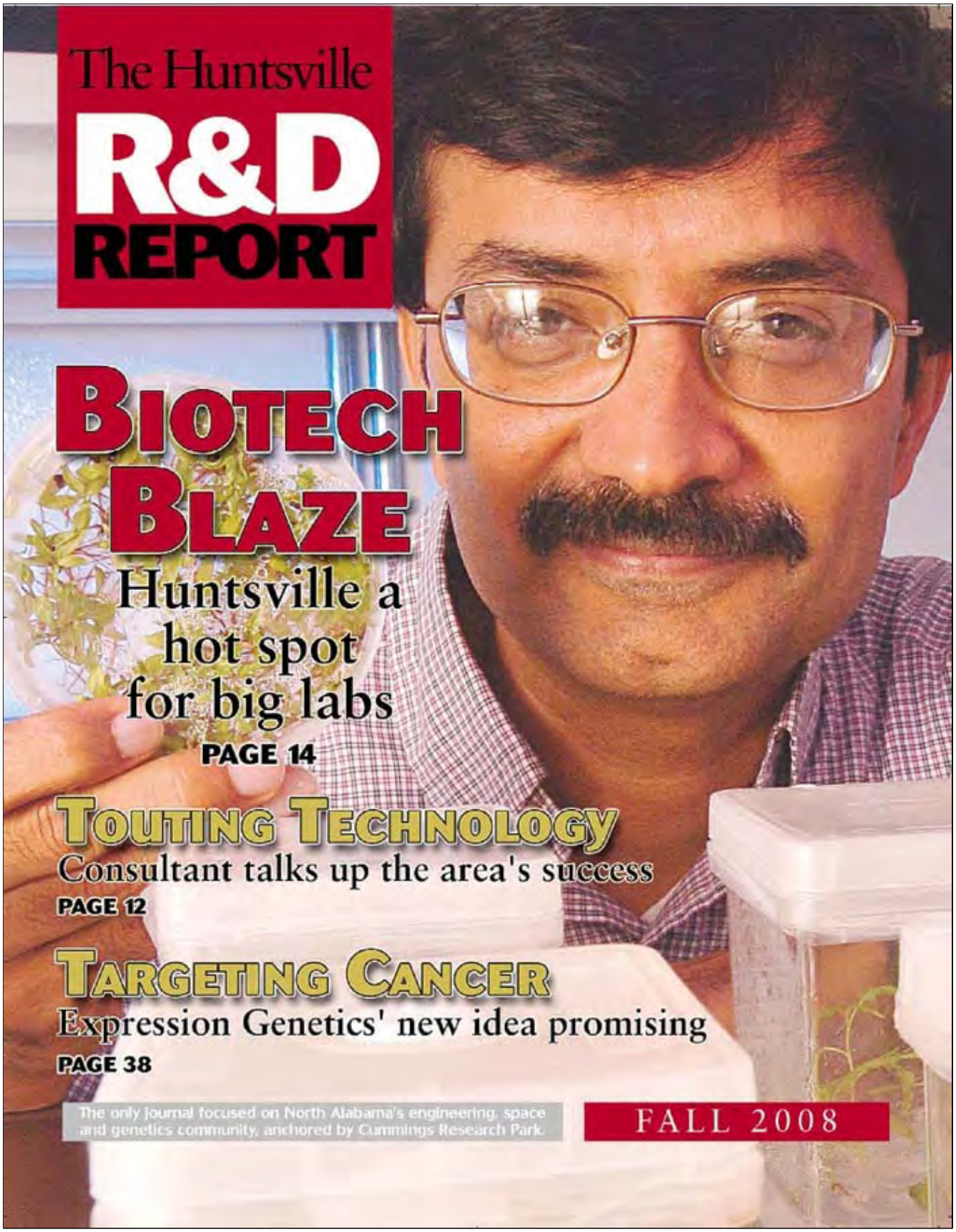
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CONCEPT

Simple math for calculating the complexities of life

Control and System Theory can provide useful guideposts to future probabilities

By Kimberly Ballard

"When will I ever use this in life?" complains nearly every child struggling with math in elementary school. Below 7th grade the answer is easy: You need it to figure how much change you get back from a dollar when you buy a piece of bubble gum; you will need it to balance your checkbook, figure commissions, calculate the savings discount on a new dress, and so forth. But for the student at an advanced level of math like algebra, calculus and trigonometry, it is more difficult to justify the everyday use of z (t) = x (to) + tfto r (_) x (_)d_ - _(t).

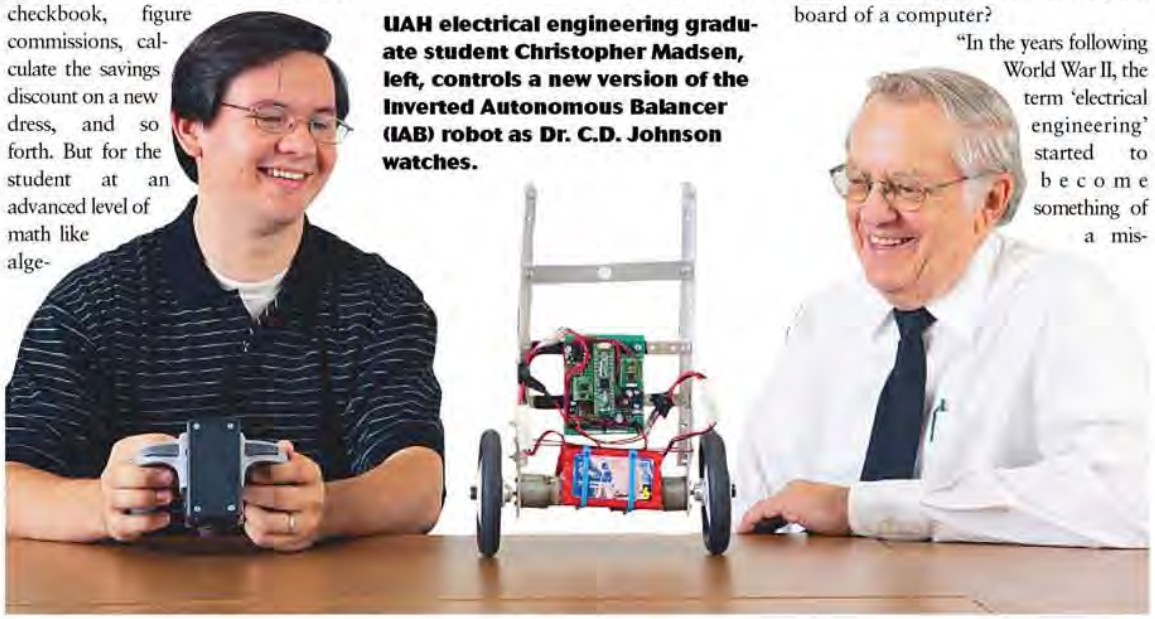
Dr. C.D. Johnson, professor of electrical and computer engineering at the University of Alabama in Huntsville, specializes in an interdisciplinary branch of electrical engineering known as Control and System Theory – a study that concentrates on developing and using mathematical formulas to predict and control the behavior of dynamic systems such as rockets, space vehicles, etc.

But isn't electrical engineering all about building electrical machines, wiring the space shuttle and installing electrical conductors on the motherboard of a computer?

"In the years following World War II, the term 'electrical engineering' started to become something of a mis-

GLENN BAESK

UAH electrical engineering graduate student Christopher Madsen, left, controls a new version of the Inverted Autonomous Balancer (IAB) robot as Dr. C.D. Johnson watches.



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nomer," Dr. Johnson explains. "Electrical engineering today embraces a much broader range of studies that have a basis in the creation, gathering, manipulation and transmission of 'information' we receive – to transmit data, encode, decode or decipher it, and then use it to make important decisions, such as calculating the probability or improbability of events occurring within a given system." Simply put, Control and System Theory can predict and detect unforeseen problems in almost every facet of our lives, including consequences of various financial decisions, halting the launch of the space shuttle, predicting the marketability of products based on models of human behavior, and calculating the improbabilities of the existence of life, to name a few.

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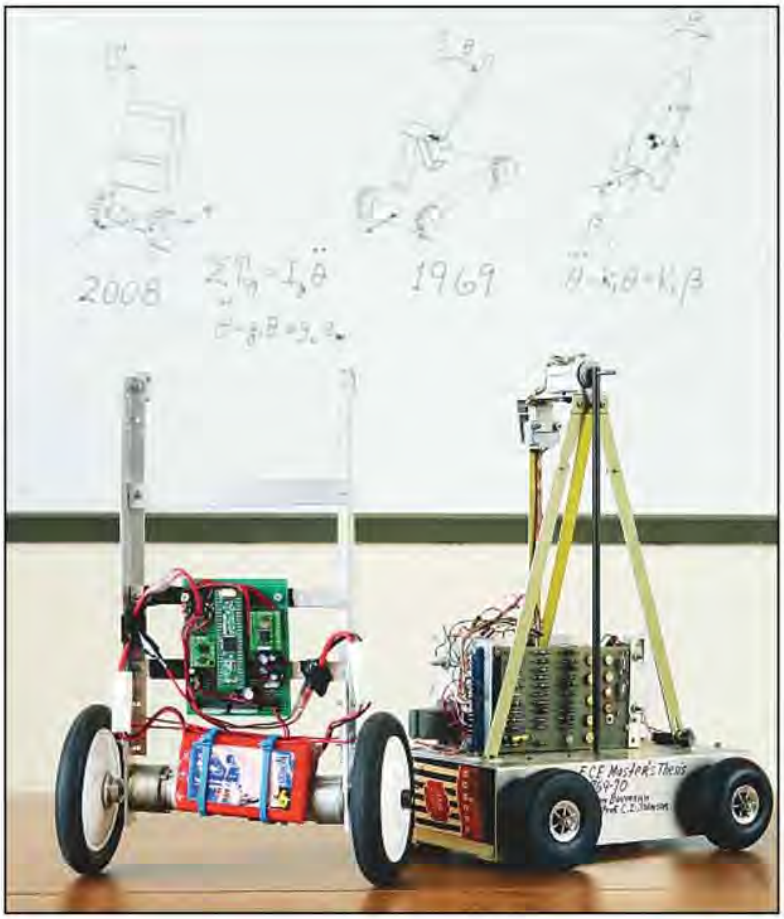
children squealing in the background or music playing in the distance; or it can be subtle, like the sound of your cheek rubbing against the mouthpiece of the phone or the wind blowing across a microphone. "Now our noisy data can be filtered to maximally reduce the noise, to better reveal the embedded information, and the better the information coming in, the more useful it becomes," says Dr. Johnson.

The gist of Control Theory is to find a way to make smart real-time decisions while events are happening. In many cases, it is Control and System Theory calculations that persuade NASA to scrub a shuttle or spacecraft launch, all the way up to the last minute, even though to the general public, it may seem tedious when a fuel gauge reading isn't registering properly. To the untrained mind, surely they remembered to fill 'er up with petrol before toting her to the launch pad, right? But an irregularity in a fuel gauge may have nothing at all to do with the fuel level, but a great deal to do with something causing that gauge not to register properly.

"We use Control and System Theory to create procedures for designing 'smart' data-processing and control algorithms that, in principle, can automatically detect the presence of, identify the spatial location of, and automatically correct for (and even optimally exploit) the occurrence of unmeasured faults, failures, and similar disturbances that can arise during the operation of rockets, missiles and many non-engineering dynamic systems," Dr. Johnson says. More simply, it helps eliminate unforeseen problems by giving us a better means of foreseeing them from system measurements.



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The new version IAB robot, left, made by electrical engineering graduate student Christopher Madsen sits next to an older version made by Dr. Jim Baumann as a student in 1969-70.

REVEALING CERTAINTIES

Yogi Berra was purported to have quipped, "It's tough to make predictions, especially about the future," but according to Dr. Johnson, "The successes of our studies in a field we have called Real Time Optical (RTO) Decision and Control Theory have led to a new way of characterizing and decomposing many practical forms of uncertainty to reveal useful, underlying behavioral certainties." In other words, we can use RTO Decision and Control Theory to more accurately calculate future consequences of current events so we can make smarter real-time decisions in everyday life, with fewer unintended consequences. Imagine if we could learn to predict the probability of certain outcomes by paying closer attention to the burning sensation running down the left arm warning us to make a smart decision about our cardiovascular health; the slight tugging to the left as we drive 80 mph down I-565 warning us to make a smart decision to check the tires.

Huntsville has long been a leader in technology and innovation, but Dr. Johnson came to UAH back in the days when the school had few full-time faculty. At that time, the campus was a satellite campus offering training support to Marshall Space Flight Center and the U.S. Army Missile Command. "My specialty was then known as Mathematical Theory of Optimal Control. In retrospect, that subject was one of the key technologies that enabled accurate guidance and control of rockets and missiles, as well as the exploration of space." He is still in awe at how UAH has grown into the very fabric of the

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city's reputation for technology, innovation and thinking outside the box. "I have had many brilliant engineers come through my classes with innovative ideas and theories they wanted to try after studying Control Theory under my tutelage. The purpose of a university is to push back the frontiers of knowledge, but UAH is unique in that here in Huntsville we have Research Park with its technology giants right across the street or right down the road. In some cases, they are open and willing to take a student's plausible theory or idea and try it out – test it in the real world. They will even promote it and perfect it if it shows potential. That is rare for a college town."

Dr. Johnson says, "We have tackled a variety of non-engineering problems using the same mathematical theories and techniques developed for the space program, an approach now referred to as employing dual-use technologies." Some of their ideas have challenged Control Theory while others have taken it to new heights and dimensions, applying it to the real world.

Last year, Dr. Johnson had two students who rose to the occasion after witnessing the movements of a stick-balancing four-wheeled robot he uses as a demonstration in class. Those students believed they could use Control Theory to make it a much more impressive two-wheeled robot that could perform more interesting movements. "It was amazing," Dr. Johnson says. "They constructed it with two indpendently-controlled rear wheels and a vertical chassis and ran it up and down the hallways of the engineering building while maintaining a perfectly balanced vertical wheelie-type configuration of the chassis. I was quite impressed with their inventiveness."

Several years ago, Dr. Johnson had a student from Mississippi who grew up on a cattle farm. The student was disenchanted with the blatant manner in which representatives from packing houses seemed to be abusing cattle farmers across the country. His view was that when the farmers first went to auction with their cattle, the packing houses would bid artificially high prices for the farmer's cattle, encouraging them to expand their herds. Later, when it came time to sell, the bidders would drastically drop their prices.

In 1965, Dr. C.D. Johnson, left, briefs Dr. Wernher von Braun on his Minimax Control Technique for load-relief control of the Saturn V Launch Vehicle.

"This student took on a class project in which he derived and simulated a mathematical representation of the optimum control process for buying and selling cattle," says Dr. Johnson. "He interviewed cattle farmers all over the Southeast, (and) observed the auctioneers and interviewed them as well. He derived a mathematical model of the industry, taking every possible factor into account to calculate the very best possible way to optimize pricing variations in the beef-cattle industry." The results of his study may surprise. The study proved that by driving up the price in order to spur larger and larger herds, and then dropping the price when it was time to take possession of the goods, the packing houses were indeed optimizing their profits.

"Back during the early days of Ronald Reagan's Star Wars Program, I had a student taking Control Theory classes that also had a sideline passion for economics. He approached me about developing a mathematical model for the optimal accommodation of uncertain disturbances in economic models." The idea of using mathematical tools from Star Wars research to study economic problems seemed strange to many on campus. But the student's results were revealing and useful.

THE HUMAN EQUATION

Of course there is still the human equation to be considered. "People have said to me, 'I am a unique individual. You cannot build a mathematical model or equation that will tell you how I will act in any given situation,'" Dr. Johnson says. "Every person is unique and in any given situation there will be some prediction of errors, but the truth – if we follow it to the end, no matter where it takes us – is still the truth. And modeling experts today are able to build mathematical models based on human behavioral patterns and other relative information that, with amazing accuracy, can predict how large groups of people will respond under a given set of circumstances."

If you find that z (t) = x (to) + tfto r(_) x (_) d_-_(t) is as frightening now as it was in high school, you might want to reconsider the benefits of brushing up on your math, since this simple equation states in mathematical terms the continuous-time evolution of net worth as a function of advice expenditures and aggregated investment choices. Hint – you might want to call your stockbroker!