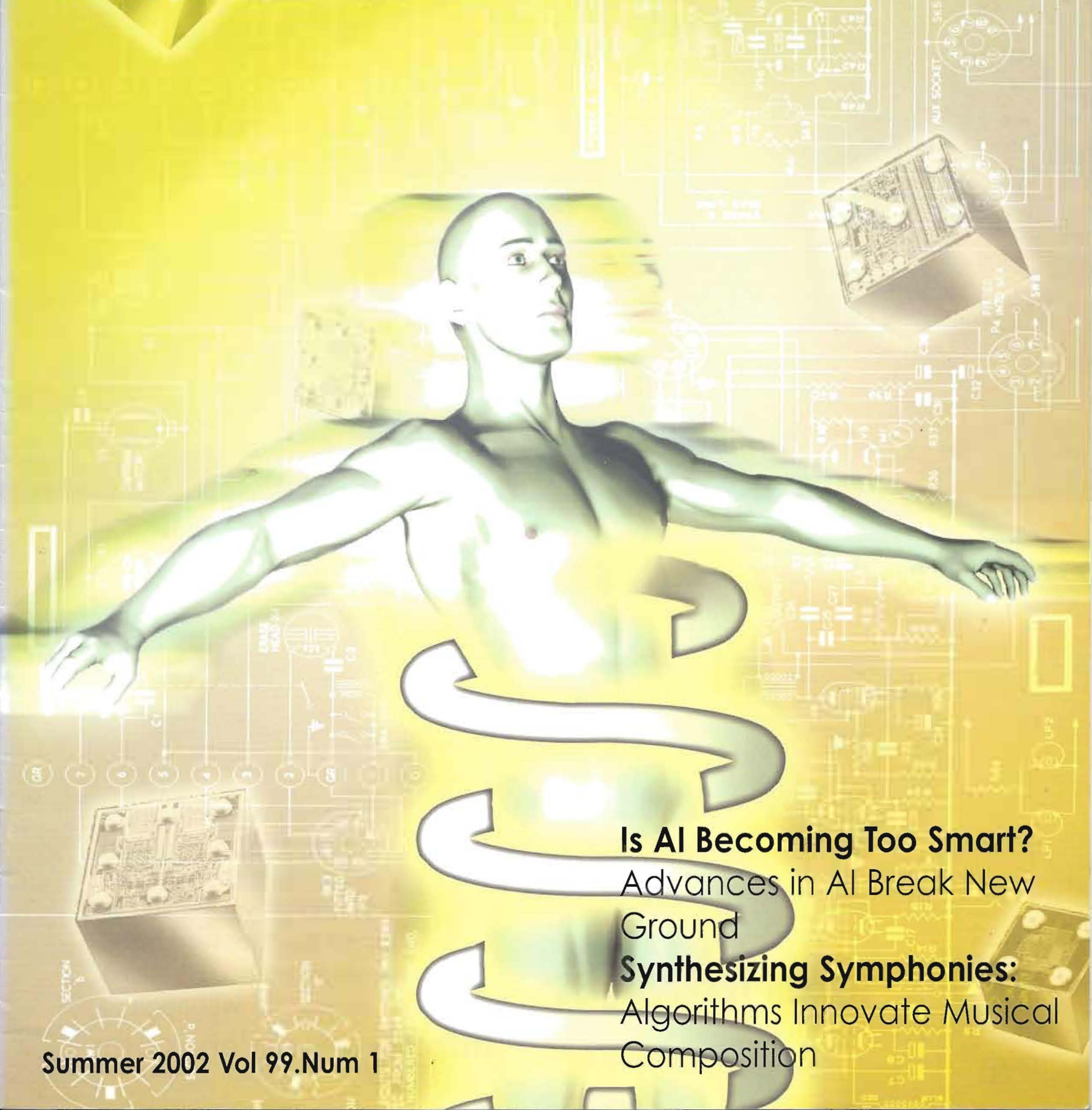
CEM

Colorado Engineer Magazine • A CU [illegible]



Is AI Becoming Too Smart?
Advances in AI Break New Ground

Synthesizing Symphonies:
Algorithms Innovate Musical Composition

Summer 2002 Vol 99.Num 1

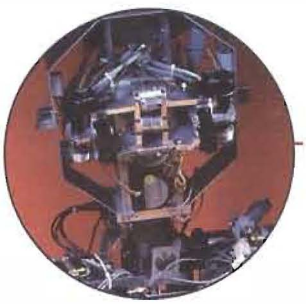
Summer 2002

table of contents

VOLUME 99 NUMBER 1

features

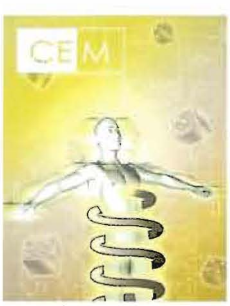
A journey through space... P. 5



The good and bad of AI... P. 6

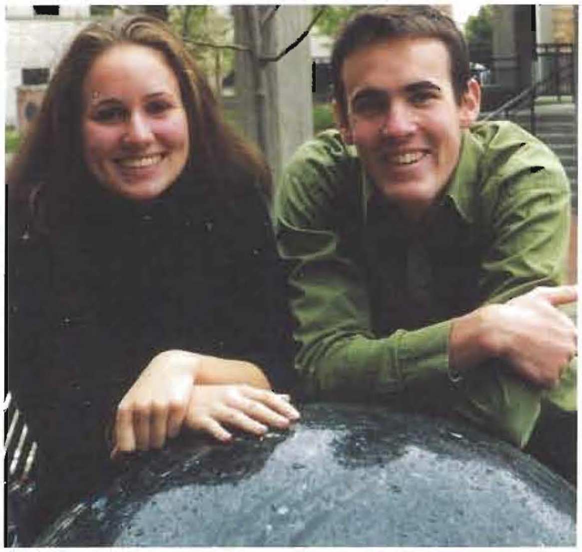
the norm

The many uses of buckyballs... P. 8



Cover: Are innovations in AI making robots too smart? Design by Toni Newville.

editors' note



As the new Editors-in-Chief of the Colorado Engineer Magazine, we'd like to welcome our readers to the summer edition of CEM.

Beginning this issue. we have a fresh staff interested in improving this magazine. Already one of the best university engineering magazines in the country, we intend to improve the quality of both our writing and layout. In the spirit of the College of Engineering and Applied Sciences, we will continue on the path to excellence.

We also intend to make ourselves more visible and available to students both within this college and to the university in general. To this end, the articles in this issue should appeal to all students at CU-Boulder.

First, we are pleased to present the Discovery Learning Center in this issue. Opening in the fall, this new building offers opportunities for engineers of all disciplines. Styled on the idea of vertical integration between undergraduates, graduates and faculty, the DLC will be a place for research ranging from safe drinking water to the Colorado Space Consortium.

SpaceGrant is also covered in this issue; we write about the Gateway to Space class in which students build and launch small CUBESats into the lower regions of space.

This issue of CEM covers many fields of innovation with which engineers are involved. Our cover story on the progression of Artificial Intelligence raises questions of what the future of engineering holds and how it will affect the future of our society.

There is also exciting research being done in molecular sciences, as engineers and scientists investigate the possibilities surrounding "buckyballs," our readers should find these discoveries appealing.

Lastly, showing that there is no distinct line between the arts and sciences, we write about the ties between mathematics and music, and how math can be a true art form for our ears.

As always, CEM invites any responses to our magazine. Enjoy!

Toni Newville
Editor-in-Chief

Evan Thomas
Editor-in-Chief

College of Engineering and Applied Science

editors-in-chief
Toni Newville-SO MCEN
Evan Thomas-SO ASEN

layout editor
Chris Poyzer-JR MCEN/BASA

assistant layout editor
Lauren Segel-JR FINE

accounting manager
Balyn Bates-SR ACCT

circulation manager
Matthew Weber-SO MCEN

layout/graphics
James Barkley-SR CSCI
David Crennen-SO ENGL
Jon Eggers-SO OPEN
Lilly Georgieva-SO CSCI
Mark Middleton-SR ASEN
James Wollmershauser-SO CHEN

writers
James Barkley
Matthew Bonig-JR CSCI
David Crennen
Marnie Richard-JR NSED
Daynna Rodosovich-FR OPEN

business
Michelle McDaniel-JR MEDS
William Shen-SO BUSU

internet
Toni Newville

senior advisors
Daniel Nikolich

faculty and staff advisors
Holly Kleinman
Carol Rowe

printer
D&K Printing

Opinions expressed within do not necessarily reflect those of ECMA, *Colorado Engineer Magazine* (ISSN 0010-1538), its staff, the University of Colorado or the College of Engineering and Applied Science. *Colorado Engineer Magazine* is published three times per academic year by the students of the University of Colorado at Boulder.

Mailing address: *Colorado Engineer Magazine*, University of Colorado, Campus Box 422, Boulder, Colorado 80309-0422. Phone: (303) 492-8635. Fax: (303) 492-2199. E-mail: cem@colorado.edu. Web: http://cem.colorado.edu.

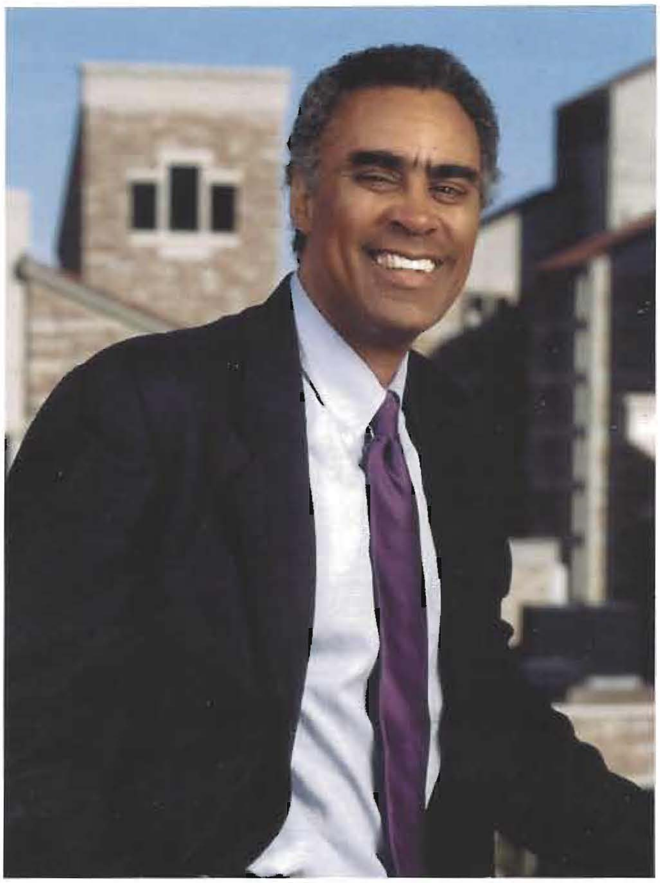


Photo courtesy Ken Abbott, University Photographer

There are compelling reasons why excellence in teaching is almost always associated with engineering programs that have outstanding research activities as well. The Discovery Learning Center in the College of Engineering at the University of Colorado at Boulder is an excellent example of the unique learning opportunities that research provides for undergraduates and graduate students. What specific opportunities will be made available to undergraduates and how will the educational environment be changed by Discovery Learning?

Imagine a College in which most of the undergraduates have the opportunity to work with a team on a significant research or independent inquiry project. This alternative to formal coursework will provide an introduction to the process of creating new knowledge, the tools available, and the final impact of the research in the real world. In the process, students will be meet with representatives of the companies supporting the research and have an advantage in being hired by the company.

Research projects in the DLC will cover the range of engineering disciplines. In the Center for Lifelong Learning and Design, faculty and students are developing novel techniques for human-computer interactions. In the Space Experiments Institute ocean temperature and depth are being measured from satellite observation stations. Biodegradable implants are under development in the Biomaterials Laboratory, while MEMS implants that monitor body function and dispense medication in an emergency are being tested in the MEDICA center.

Other projects that relate arts and humanities to the world of science and engineering are envisioned. Engineering undergraduates working along with journalism students will create high-tech displays of the goals and accomplishments of our research for the computer controlled video wall in the lobby of the Discovery Learning Center. Still other students will be provided the opportunity to investigate the ethical or socio-economic implications of new technologies in collaboration with faculty from the humanities and social sciences.

Outreach innovations will need to be developed in the DLC to extend the impact of the new paradigm for research and learning. Summer internships will bring K-12 math and science teachers to the facility to participate in research projects to provide a better understanding of engineering for themselves and their students. These teacher experiences could be pared with special summer programs for their students already in place in the Integrated Teaching and Learning laboratory.

Although no formal coursework is planned for the DLC, there are major curricular impacts. Research experiences may be taken for academic credit as well as for a financial stipend. Independent study graduate credit can be used to satisfy the graduate degree requirements for the 5-year Bachelors-Masters program in the college. A project initiated as an undergraduate could be extended to graduate study, including the possibility of financial support as a paid graduate Research Assistant.

The Discovery Learning Center, with its focus on vertical integration to involve undergraduates, graduate students, faculty and industry partners will be a model for creating the future of engineering by educating the engineers of 2010 and beyond.

Melvyn C. Branch

Melvyn C. Branch, Associate Dean
College of Engineering and Applied Science

THE FUTURE OF DISCOVERY

Toni Newville

The Discovery Learning Center, opening this fall, will offer undergraduates countless research opportunities.

In 1997, the College of Engineering and Applied Science's Integrated Teaching and Learning Laboratory (ITLL) opened, initiating an innovative, hands-on learning environment and providing numerous new research and design opportunities for undergraduates. This October, a sister center to the ITLL, the Discovery Learning Center, will open its doors to the public, launching a new era of inquiry-based learning and outreach at CU-Boulder. The reasons for building the new, 45,000-square-foot center are to provide undergraduates with more research opportunities, create increased community outreach and, not surprisingly, to make more space for research facilities.

Given that undergraduate enrollment is expected to increase by ten percent over the next five years, construction of new facilities is a must in a college that already has one of the lowest ratios of available square feet of space to number of students in the nation. The DLC will also house many of the college's most prominent laboratories, including the Colorado Space Grant Consortium, the Center for LifeLong Learning and Design and the Interdisciplinary Telecommunications Systems Laboratory.

Walking into the Discovery Learning Center, students will find the new building to be a welcome change from the bland interior of the Engineering Center. The lobby will showcase undergraduate engineering projects. Additionally, a 16-panel video wall will display real-time examples of the research happening in the ITLL. There will also be a satellite 3-D visualization room in which students can put on goggles that allow them to view simulations in three dimensions.

Perhaps the most important part of the DLC will be the research opportunities it creates for engineering students. The DLC is based on the idea of Discovery Learning: by being involved in the discovery process and asking questions, students will gain a much deeper understanding of engineering principles than they would by sitting through traditional, classroom lectures. At the DLC, undergraduates will work alongside graduate students, faculty members and industry representatives in vertically-integrated research teams. In fact, one of the requirements for each of the DLC tenants is to have ample research opportunities for undergraduates. Beginning this fall, students interested in researching degradable biomaterials, micro electro-mechanical systems (MEMS) or drinking water optimization will find numerous opportunities at the new center. Nearly all engineering disciplines, as well as several interdisciplinary groups, have laboratories in the DLC. With the numerous opportunities available to undergraduates and graduates alike, the Discovery Learning Center will certainly transform the engineering learning experience at CU-Boulder. ◆

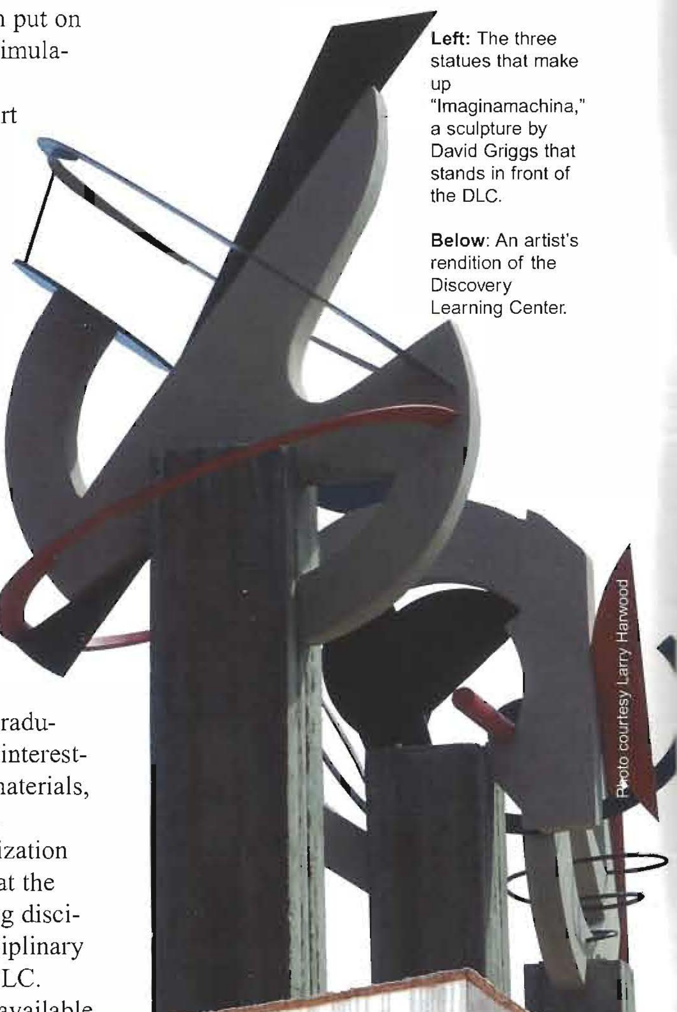


Photo courtesy Larry Harwood

Left: The three statues that make up "Imaginamachina," a sculpture by David Griggs that stands in front of the DLC.

Below: An artist's rendition of the Discovery Learning Center.

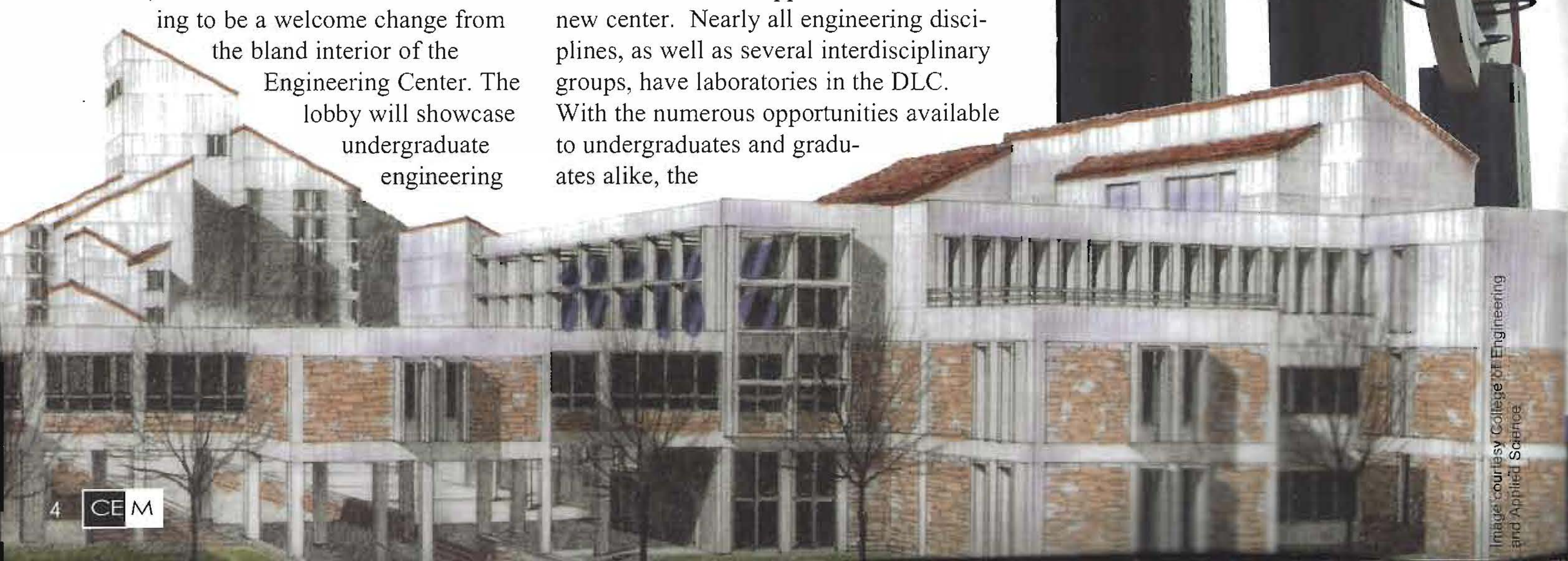


Image courtesy College of Engineering and Applied Science

Thrill of the *Chase*

Daynna Rodosovich

A caravan of seven SUVs, minivans, and cars speed along I-70 East, far beyond DIA. A voice crackles across the long-range walkie-talkies in each vehicle.

"The balloon just popped. We may have the chance to be the first group to see it land, but we'll have to pick up the pace."

The drivers in the caravan look at their speedometers, smile and press down on the gas.

This group consists of students from the Gateway to Space class, instructed by Colorado SpaceGrant Consortium staff member Chris Koehler. The students are racing toward the culmination of a semester's work. The purpose of the class is to build a CU Balloon Experimental Satellite (CUBESat) small case capable of protecting instruments for temperature, light and humidity readings, among many other possibilities. The class is initially divided into small groups responsible for designing their cubes and deciding what instruments each will use. Each group is given a budget with which to complete this task.

Weeks of research went toward this day. The groups met at seven in the morning in Deer Trail, CO, just East of DIA. As the students stood stomping the warmth back into frozen feet and drinking hot chocolate provided by the local Elks Lodge, the CUBESats were given last minute checks by the teams, and Koehler did the final weigh-in before the groups were allowed to seal them.

The CUBESats were then strung together and attached to a high altitude weather balloon. The preparation of the launch and the provision of the balloon and tracking devices are thanks to members of Edge of Space Sciences (EOSS). The balloon, with a GPS locator attached, was launched just after 9 A.M.

Some students returned to Boulder, and the remaining group divided between the cars going on the chase. After handing out state atlases and the long-range walkie-talkies, Koehler began the chase. The vehicles stayed in order throughout the ride. The chase brought them more than an hour East. Koehler kept track of the balloon, directing the train of cars behind him. The balloon burst at about 97,000 feet and began its descent. A few of the students saw the balloon as it came closer to the ground off in the distance. The chase ended along a dusty county road, barely 25 miles west of the Kansas border in a rancher's field. The EOSS members began to arrive, pulling up in trucks and vans, dust swirling and antennae waving.

Several students commented that the thrill of the chase on a dusty road, surrounded by equipment-strung vehicles, was reminiscent of the movie *Twister*.

Only a few EOSS members were allowed on the field to recover the satellites. Representatives from each group examined their satellites for damage and turned them over to Koehler for data collection. Overall, results were good. Unfortunately, one satellite broke off during the flight and was lost. Many groups had minor equipment failures, but all who recovered a satellite gathered at least some data.

Regardless of the success of the satellites, every student learned something in the process. The launch was a spectacular sight, and those who participated in the chase will never forget the adrenaline-filled rush to get to the satellites.

For more pictures of the launch, visit the class web site at http://spacegrant.colorado.edu/~koehler/SPACE ◆

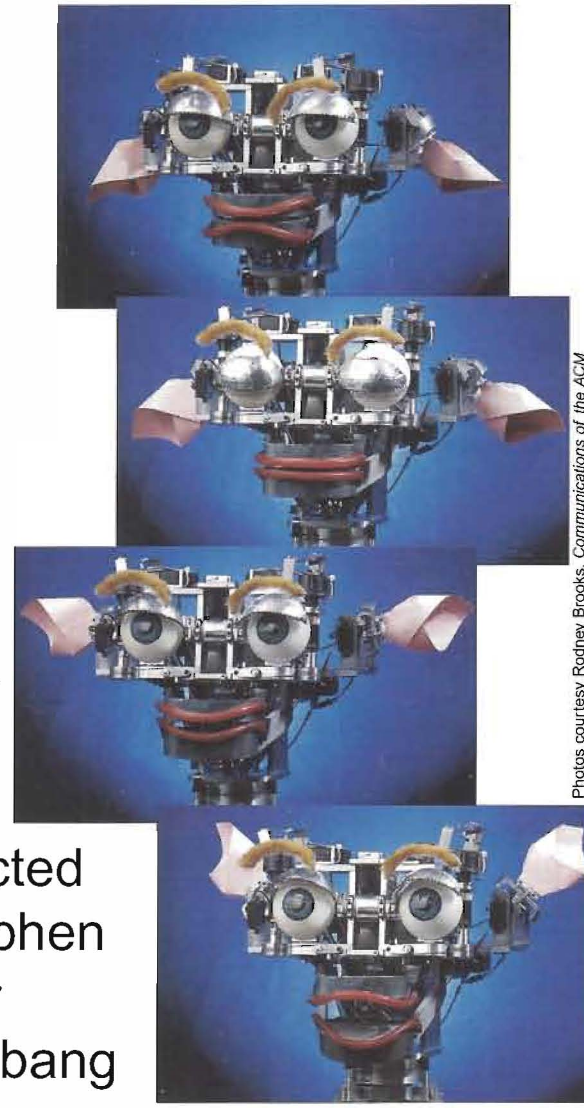
Photos courtesy Evan Thomas

A recovered CUBESat, one of many devices launched and recovered by the Gateway to Space class, is shown in a field in eastern Colorado.

AI: What lies ahead?

David Crennen

"There is a real danger that computers will develop intelligence, and take over." This grim prophesy was espoused by one of the most respected scientists of our time, Professor Stephen Hawking, more commonly known for exploring the implications of the big bang and black holes.



Photos courtesy Rodney Brooks, *Communications of the ACM*

Kismet, a robot recently developed at MIT, mimics several human facial expressions.

In the September 2001 issue of *Focus* magazine, Hawking foretold a future in which computers have exceeded the capacities of humans. He describes a world where, instead of adapting the digital world to us, humans have adapted themselves to it, a world where humans may have to augment their genetic code to create a strain of humanity better able to keep pace with machines, where people may have to create technological systems allowing them to work with computers rather than outside them. This dark, and one can but hope, hypothetical future revolves around the quickly growing field known as Artificial Intelligence.

To understand what could happen with AI in the future requires that we look at what is going on in AI research today, and from this to forecast an educated guess for future development.

Sixty years ago, computers came into existence as huge, inefficient, industrial machines, dubbed "electronic brains." In 1956 John McCarthy, now a Professor emeritus of computer science at Stanford University, called for the first Dartmouth Conference where they coined the term Artificial Intelligence, springing a new field of study into existence. The definition of AI has remained the same over the decades: "An attempt to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans and improve themselves."

The future applications of the burgeoning field of AI are as difficult to fully imagine as any new field of technology, yet there are groups probing the possibilities and potential of the developing technology. The most innovative application of Artificial Intelligence may belong to a Brussels-based company, Starlabs. Their contribution takes the form of clothing infused with computer intelligence. Their concept, termed "I-Wear," centers upon the idea of integrating computing processes into the clothing people wear, blending into the threads the necessary circuitry, and eventually creating a system of clothes that reacts and anticipates the needs of the wearer.

For instance, a Starlabs jogging suit would monitor the environment, taking into consideration such factors as the levelness of the terrain and weather. Additionally, it would keep track of the wearer's heart rate, breathing speed, and any number of other bio-physiological statistics to determine how long, far and fast to exercise. The suit would then compare real-time statistics with a personalized training schedule, urge the wearer on when it senses he or she is fatiguing and modify the future training schedule and identify if medical attention was needed.

While Starlabs is only scratching the surface of the capacities of AI, they plan to soon produce a practical result to introduce the world to interactive computers in daily life. I-Wear's debut is only a question of time, for it touts founding and support from some of the heaviest hitters in clothing and information technology such as Adidas, AT&T, Epson, Energizer and Samsonite.

Starlabs is certainly not alone in pioneering the AI field. From nearly the inception of the study of intelligent machines MIT's Artificial Intelligence Laboratory has been in the forefront. The Lab was founded in 1959 by the very man who coined the term, Professor McCarthy, as well as by fellow pioneering professor, Marvin Minsky. The MIT team has pursued new possibilities and made such important developments in their quest as the AI languages of LISP and LOGO, the foundations of AI programming. Currently the AI Lab, under the direction of Professor Rodney Brooks, is exploring innovations in the categories of mobile robotics, speech recognition software, intelligent rooms, bio-machines and machine learning, and a multitude of other new ideas. The researchers involved in the projects are broken into groups that focus on different problems or needs of a particular concept and build their way to the conceptualization of the central idea.

A group called the Machine Learning group is working on the most formal concept of an artificially intelligent system. Their goal is to develop a computer system capable of learning from the world around it. For instance, team member Jake Beal is developing the next step in "agents", or programs that perform some information gathering or processing task in the background of a computer. It is in fact postulated that the human mind essentially consists of thousands of agents all working in parallel. Beal is creating a way for two unrelated agents to communicate with one another, not with a universal language, but by creating a system that allows the units to create a language for themselves. Other students are working on projects for synthesizing incomplete information with complete information so as to allow accurate problem solving without complete input, much the same way that humans react to problems that face them.

Other units compliment different groups goals. For instance Computer Architecture is studying innovative ways for building better computers, while Bio-Machines is researching robust, disorganized computing systems. What is the ultimate goal of all this research? As AI Labs puts it, the objective is to understand how the human mind works. The enigma of the mind is one that has vexed scientists and philosophers alike since the origins of western civilization. Now, science is perched on the cusp of unraveling this mystery, no longer by abstract methods, but through the artificial creation of a new frame of mind.

While these developments are important to the field, they do not approach the future Professor Hawking prophesied. Much closer to home are the experiments that have been carried out in the University of Reading in the United Kingdom. On March 14th of this year the Department of Cybernetics carried out Project Cyborg 2.0, an operation at the Radcliffe Infirmary in Oxford that implanted a microelectrode array onto the median nerve of Professor Kevin Warwick. This is in fact the second microchip that has been installed into the Professor of Cybernetics. The first was implanted in the August of 1998 and interacted with the intelligent building that the Department is located in. The chip allowed doors requiring Smart Cards to automatically open in Prof. Warwick's presence, and let his computer acknowledge his presence whenever he entered his office. While the last chip was removed after nine days and executed only basic functions, the new implant engages in far more complicated actions. This microchip is connected to the nervous fibers in his left arm through a matrix of pins and injected through the membrane that surround the fibers. From that point, there is a connection to the main part of the implant which contains a battery, a radio transmitter and receiver, and a processing unit. The purpose of the experiment is to transmit signals from Warwick's nervous system to a computer and vice versa, yet this is only a another step in what Warwick sees as the continuing process of cybernetic development. While his immediate goal is to restore functionality to the paralyzed and otherwise enfeebled people, ultimately Warwick predicts a future not unlike Hawking's, one where in cyborgs are the next step of human evolution and where, "we will need to do it [become cyborgs] if we are to compete with intelligent machines."

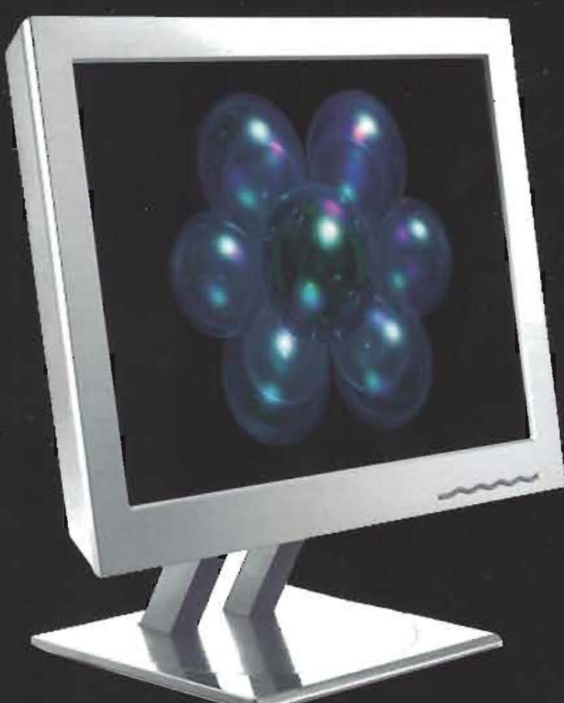
Hawking's black prediction seems to be an overreaction to the relatively benign technologies making use of Artificial Intelligence. For the present and immediate future it would appear that the aim of AI is to make the lives of humanity better in a number of diverse and useful ways. Yet it is what lies beyond the short term that has Hawking and others concerned. With the capacity of computers doubling every 18 months, more and more scientists believe it is only a matter of time before computers with artificial intelligence superior to human intelligence are developed. Whether this accelerating rate of technology will yield horrors or aid to humans in the future can only be waited out. ◆

Developed by Dr. Rodney Brooks of MIT, the first humanoid robot, Cog, approximates the sensory and motor dynamics of a human body.

Photo courtesy Rodney Brooks, *Communications of the ACM*

a little bit of BUCKY

Matt Bonig



The buckyball; the molecular soccer ball of the future. Discovered 17 years ago, this wonder is stirring up the worlds of physics and chemistry. The buckyball is being studied for uses ranging from medical to commercial use. Researchers are constantly finding new ways to use these marvels of science. One day, the television you watch, the shirt you wear and the medicine you ingest may all have a little bucky in them.

The buckminsterfullerene, or buckyball as it is more commonly known, is a perfect geodesic sphere, like a molecular soccer ball. In 1985, Harry Kroto, a Professor of Chemistry at the University of Sussex, observed certain unusual strains of carbon molecules found in deep space, which he hypothesized could be produced near red giant stars. Richard Smalley and Robert Curl, two US researchers at Rice University, were approached by Kroto to help him prove his theory. The three of them, simulating conditions in space, hit a block of graphite with an ultra high-intensity laser in helium gas and discovered much of what remained were "buckyballs," just like Kroto hypothesized. These balls are composed of 60 carbon atoms bounded together in a geodesic sphere, a structure similar to a soccer ball. The geodesic sphere was first created by U.S. architect R. Buckminster Fuller, hence the name buckyballs.

Kroto, Curl, and Smalley received the Nobel Prize in 1996 for their discovery. Since then, the buckyball has changed the world of chemistry, being the largest symmetrical molecule and the strongest molecule to date. Additionally, numerous practical uses have been found for buckyballs.

Trauma patients may be some of the first to benefit from buckyballs. When someone crashes his or her head against something hard, the body creates "free radicals." Free radicals are molecules that are highly unstable because of an unpaired electron they contain. They join with other molecules in the brain, creating more free radicals and causing a chain reaction. In excess, these radicals can easily destroy nerve cells. Researchers have found that water-soluble buckyballs appear to soak up and hold the free radicals, protecting the nerve cells.

Another use of buckyballs is in optics. Buckyballs absorb light to a point, and then will clamp it off. Normally, sunglasses just lower the intensity of the incoming light. If there is a bright enough light source the eyes can still be damaged. Rather then blocking a certain amount of light like conventional sunglasses, "Bucky-glasses" would allow only a certain amount of light through. Air Force and Navy pilots will be the first to sport these new shades.

The copier you use may have buckyballs one day. Xerox has already registered patents to use buckyballs in their copiers. The resolution would be 1000 times sharper using buckyballs rather then drops of ink. Other large printing companies like Hewlett-Packard, Epson and Canon could be close behind.

Companies are developing uses for buckyballs that may still require many years of research. Since buckyballs are similar to tiny ball bearings, significant research is being done in the industrial lubrication field to see if they can be used as motor oil. Additionally, a research team at the University of North Carolina at Chapel Hill has recently found that buckytubes, straw-like versions of the buckyball, do not behave as expected. Instead of rolling along, the team found that buckytubes slide forward. This slide-over-roll characteristic contradicts the physics seen in larger objects, like rolling pins. However, this hasn't stopped the idea of using buckyballs as micro-ball bearings in everyday use, and research is still going strong.

Scientists at Bell Labs have found buckyballs highly useful in superconductors. Superconductors are materials that exhibit no resistance to electrical current. By inserting chloroform and similar chemicals between groups of buckyballs, they found that this new material becomes super-conductive at temperatures as high as -249 degrees Celsius. This may seem cold, but the previous materials had to drop down to –366 degrees Celsius before becoming super conductive. Many people are hoping these super conductive materials could be used to create computers, but it may be several years before they make materials that superconduct at temperatures warmer than –249 degrees Celcius.

Some European researches found that when they compressed buckyballs and attached them to a sheet of copper, the electrical conductivity increased tenfold. Last year, a Swedish scientist, Tatiana Makarova, working at Umeå University found when she heated and compressed the buckyballs into a sheet similar to microscopic bubble-wrap these sheets became magnetic. Until this point, the warmest a non-metallic material remained while staying magnetic was –255 degrees Celsius. These bucky-sheets will get up to 200 degrees Celsius before losing their magnetic properties. For computers, this could mean lighter and more durable electronic storage devices.

Another field of study being explored is in field-emission displays. Currently, CRT screens (used in computer monitors and televisions) hurt users' eyes, and LCD screens only last a few years. The researchers involved in designing field-emission displays hope to create high-quality, harmless displays. These screens work by having pinpoints with charges created on them. An electron is then given off and is used to light up a phospor. The advantage they pose is that you can make an array of the field-emission tips, making the CRT-like display only a couple inches thick. The difficult part in this technology is that those pinpoint tips degrade rather quickly, making the screen fail early in its life. Researchers are trying to use buckytubes as the pinpoint because of their strength and durability. However, this is still years away since the average buckytube field-emission screen would cost nearly a half a million dollars.

Clearly, there are many possible uses for buckyballs and buckytubes. New ideas appear everyday. Before long we will probably start to see buckyballs and buckytubes in everyday life. ◆

Synthesizing Symphonies

James Barkley

Music is so important to society that we have tied it to our most vital technological tool, the computer. Although algorithms – detailed sequence of actions to perform to accomplish some task – were used to some extent in the development of music in past centuries, their use still was quite limited. For example, many elite composers used to play parlor games in which each number of a die was assigned to a sub-phrase of music; rolling a certain number on the die selected the sub-phrase assigned to that number. The next throw of the die chose one of the remaining sub-phrases. This process continued until all of the sub-phrases had been ordered. Any selection of the given measures produced a viable combination. This is one of the earliest examples of using math to modify music. Nowadays, the modern computer allows complex mathematical algorithms to be utilized in reasonable amounts of time.

Algorithms in the composing process have two main categories: those that determine the notes of a piece (note-based algorithms) and those that determine waveforms (and therefore actual sounds). Thanks to sound synthesis research over the years, such as Olson and Belar's 1951 experiments with weighted probabilities and sawtooth waveforms, we have many interesting new sounds that can be used in both the composition and performance process. On digital keyboards you can often find sounds that do not belong to any instrument, such as "Pearl Drop" or "Synth-Pad" (synthesized pad). These sounds have been created through the analog creation of their waveforms. Perhaps even more important in waveform-based algorithms is the ability to mimic other sounds such as a trumpet, cello or even an entire string section of an orchestra. Unfortunately, this waveformsound synthesis, while an important use of algorithms in music, does not help composers express a musical train-of-thought such as composing a symphony.

Besides wave-based algorithms, note-based algorithms determine the actual notes of a piece and have been used repeatedly throughout history. For example, Johannes Kepler calculated a melody based off the orbit of the Earth in his "music of the spheres" in 1619. Unfortunately, the result was nothing more than endless chains of "ma, fi, ma" (in the musical scale do-re-mi-fa-so-la-ti-do). Nevertheless, Kepler's renowned methodology is still important in the study of algorithmic composition. Today, there are massive, complicated computer programs dedicated to various parts of the music-writing process. Over the last fifty years, there have been thousands of experiments done with algorithmic composition.

Music is an emotional and creative process and any attempt to reduce it to a set of rules begs the question: What is music?

Much of the work in this area, especially in the early stages, was based on random number generation, stochastics (designating a process in which a sequence of values is drawn from a corresponding sequence of jointly distributed random variables) and Markov chains. Other interesting mathematical structures that have been introduced into algorithmic development include Poisson distributions (time-based statistical functions), factorial algebraic geometry and fractal interpolation, the most popular of which come from the Mandelbrot set .One such deterministic algorithm takes a piecewise linear function and constructs a fractal through an iterative process, with the output at each stage being another piecewise linear function. The bulk of research in algorithmic composition has been focused on set theory and applying permutations to sets of notes. Some people have even gone as far as describing music entirely as a context-free grammar – a language based on rules that describe a change in a string without reference to elements outside of the string. Two such languages are TREE and COTREE, which describe musical notation and compositional notation, respectively. Both were developed from formal language theory by Curtis Roads in 1978.

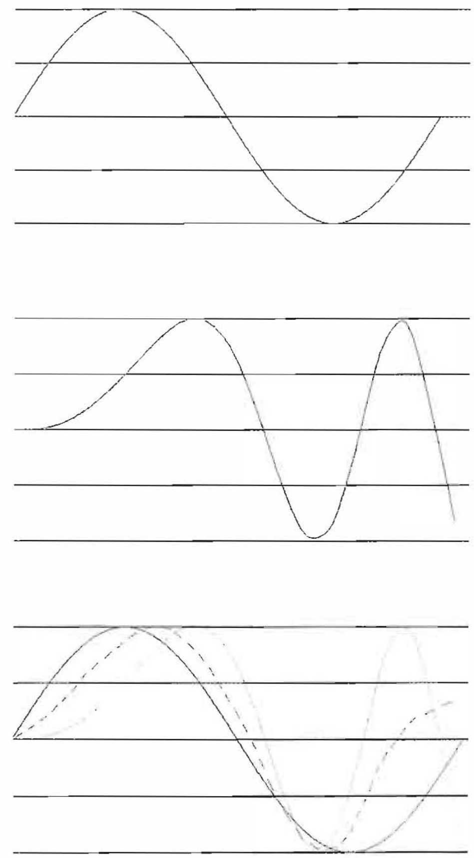
However, many music experts argue against the use of set theory transformations in analyzing and creating music. Music is an emotional and creative process and any attempt to reduce it to a set of rules begs the question: What is music? Indeed, if you listen to many of the pieces generated mostly by algorithms, they seem to be bland and lacking in musical style, despite following many formal constraints. On the other hand, Dr. Michael Theodore, professor of music at

CU-Boulder, believes that intuitive composing and more mathematical composing can both yield similar results. One of the main problems with generating music algorithmically is the number of levels at which music must be structured. The individual succession of notes must be aesthetically pleasing, but a piece of music must also have unifying elements that give meaning to the piece. A musical work can be considered a musical train of thought; if it lacks guidance and direction, it will lack coherence. Perhaps Debussy, an important French composer of the late nineteenth and early twentieth centuries, said it best: "The work makes its own rules."

One computer project, "Experiments in Musical Intelligence," approaches this problem from a unique perspective. A database of a specific composer's works in combination with algorithmic rules allows the program to generate new pieces of music based on the style of the original composer. For example, the rules governing the voice-leading requirements of Bach chorales can be determined from known Bach chorales. Once these rules are known, they can be applied to the generation of new music. By taking portions of a composer's works and piecing them together in new ways, Experiments in Musical Intelligence is using the idea of recombinancy. Of course, some amount of restructuring within the individual portions, such as inverting chords or transposing notes up or a down a fifth, is often necessary. Phrase length, patterns characteristic of the composer, and textual consistency are similarly analyzed and accounted for by the project. There is a question of whether or not the music is actually new, or is simply new combinations of old music.

The music generated in this style is generally distinct enough to be considered different than just the sum of its parts. When considering hidden mathematical structures within a piece, it is difficult to determine whether the piece is truly unique or just new notes draped on top of an old structure. Furthermore, a number of other questions arise. For example, do mathematical structures exist only in formalized music or in all kinds of music? Bach's music is extremely formal with rigorous use of formal devices such as two-part counterpoint and mode changes. In contrast, ambient and new age music are much less formal, often drifting through musical space.

Some would say that music is a mathematical structure, while others would say music is an emotional outpour. It is known, however, that there is a science to music. Many composers follow at least a few mathematical rules, such as chord progression or imitative counterpoint. However, many of the greatest composers in history knew nothing about mathematics when they wrote some of their most famous pieces. To many, music is solely a creative process unrelated to science or math. After all, how would Mozart or Beethoven feel about computer generated music? If a mathematical genius who knows nothing about music creates an algorithm to compose great music, is that person a musician, a composer or an artist? ◆



Top: A perfect sine wave, representative of a pure musical tone.

Middle: A computer-generated wave; in this case the function $\sin(2x^2)$.

Bottom: The top two curves can be combined to construct a new wave with a unique sound which still retains some "pure" tonal quality. Similar to this construction, a wave generated by an instrument such as a trumpet or violin can be deconstructed. Once a waveform is deconstructed into its constituents, the parts can be used to reproduce the sound on a keyboard or computer.

Theta Who?

Marnie Richard

Theta Tau is the only engineering fraternity at the University of Colorado, providing an incredible academic support system for member engineers. Theta Tau's local chapter, Eta Gamma, was established in 1994. Since then, it has since become a tremendous support system for nearly 25 engineering students.

"Our main purpose as a fraternity is to help each other academically," explained Theta Tau's Regent, Shawn Bockstahler. Nationally, Theta Tau has put an emphasis on helping young engineers strengthen their talents and skills, while helping them grow as engineers. "If you're in Calc II, there's always someone in Calc III to help," explains Shawn.

Theta Tau unites older engineers with the younger, which is beneficial to underclassmen as they adjust to the intense courseload of engineers. They "push each other," said member Jason Patterson, "We help each other stay focused." Theta Taus solidify lifetime friendships, knowing someone will always be there when they need a hand. The members are united by common objectives: to learn together and to grow together.

Theta Tau has always put an emphasis on community. In Theta Tau, the "biggest experience is brotherhood," said Chris Gilmer. "It's a really close bond." Bockstahler adds, "We do things that people would (not normally) do." Everyone looks out for one another and, "there's always someone to hang out with."

Theta Tau has a non-discriminatory policy. There is a non-hazing policy, and they are pro-engineering community and pro-student.

While they have a ton of fun and build strong memories, this particular fraternity is "not about getting drunk," insists Bockstahler, and they "have no ties on the hill." In fact, the co-ed fraternity does not have a house. Nonetheless, Theta Tau encourages the community of a social fraternity while also striving to promise its members bright futures.

Theta Taus also have a distinct advantage over their peers with their heightened leadership, organizational and social skills. Theta Tau has found a way to unite engineering students and to stretch their skills.

Scrambled Eggs

Marnie Richard

The famous Engineering Days egg drop is the one time each year when it is completely acceptable to throw whatever you wish from the top floor of the engineering tower, as long as it somehow contains a raw egg. Groups of students put long hours into developing the perfect egg transportation device for the event.

This year, a group of students dazzled the crowd with an especially unique entry. Their contraption was a giant lawn dart that not only delivered the egg safely to the ground, but also set the egg airborne upon impact. Mechanical engineering student Ryan Hughes was slightly disappointed that the machine would not launch the egg as far as he'd hoped: 150 feet.

The team's entry was basically a potato gun, which was nearly as tall as Hughes himself. The egg was delivered safely in a PVC tube filled with foam. There were fins on the outside so that the lawn dart would "hit on the nose."

The chemicals in the hairspray caused a spark between two screws inside the chamber, causing the explosion and sending the egg flying.

Upon impact, a tiny button at the end triggered an explosion in the dart's combustion chamber. Hughes explained that "everything in there has to expand" during an explosion. The expansion inside the tube causes the egg to shoot through the only exit: the top of the lawn dart, thus making the egg shoot straight off. The lawn dart was actually fueled by hairspray.

Just before they dropped it from the Engineering Center's office tower, they sprayed hairspray into a capped section of the combustion chamber for two or three seconds. The chemicals in the hairspray caused a spark between two screws inside the chamber, causing the explosion and sending the egg flying.

His entry took first prize, but there was a little mayhem in the developmental stages. At first, the egg "wouldn't fall straight. It shot at an angle," said mechanical engineering student Bobby Saopraseuth, but "it wouldn't have killed anyone or anything." At first, Hughes, Saopraseuth and their teammate Adam Cox wanted their invention to spin as it fell, but while they were testing it, they noticed that the dart began to spin out of control as it got closer to the ground.

Engineering fraternity Theta Tau sponsors the E-Days Egg Drop. The fraternity has even developed an egg drop competition for high-school students. It began in Spring 2000 and continues to enlighten teenagers about engineering and show them that it truly is a fun career field. ◆

The FUN Page

"Engineering today is a race between engineers striving to build bigger and better idiot-proof programs, and the Universe trying to produce bigger and better idiots. So far, the Universe is winning."

- Rich Cook

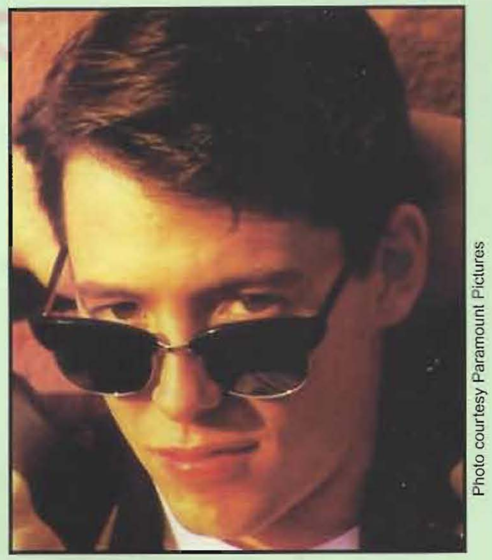


Photo courtesy Paramount Pictures

Fun Questions, yeah, that's it, fun.

1) Who are you?

2) Why are you here?

3) What are you doing?!

4) My God! What is that?!

5) Help! Help! Can anyone hear me?!

Bonus Question:
You know Marta? What's her deal.

Answers Below!

Hints and Tips for a Successful Life.

- No matter how hungry you are, never try to eat a horse, them things fight dirty.

- It might seem like a good pet at the time, but whales can grow up to be quite large.

- Never cheat on a test, often they have over protective older brothers.

- If you drop your keys into a lake, and a piranha eats them, then a shark eats the piranha, and the shark falls into a volcano somehow, get used to it, 'cause baby, those keys are gone.

1) French philosopher Michel Foucault.

2) Just dropping by.

3) Preparing a lecture on the "other-self" exclusionary process.

4) My theory on the procedures humans use to differentiate between the self concept and the antithetical reality of the "other" in the discontinuous pattern of history.

5) No, and I've sealed the exits.

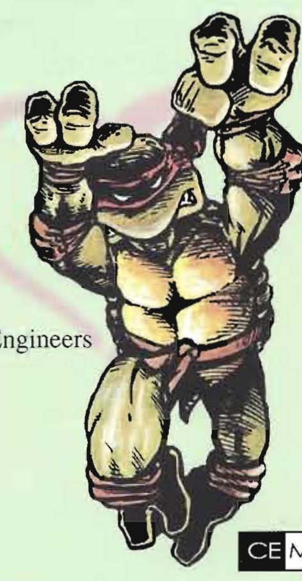
Bonus Question
Freud would attribute her problems to an inferiority complex; arising due to the conflict of sexual tensions amid her Id, Ego and Superego as they struggle to cope with a faltering sublimation internal defense system, most likely formed during the traumatic formation of the unconscious during the resolution of the Oedipus Complex in her youth.

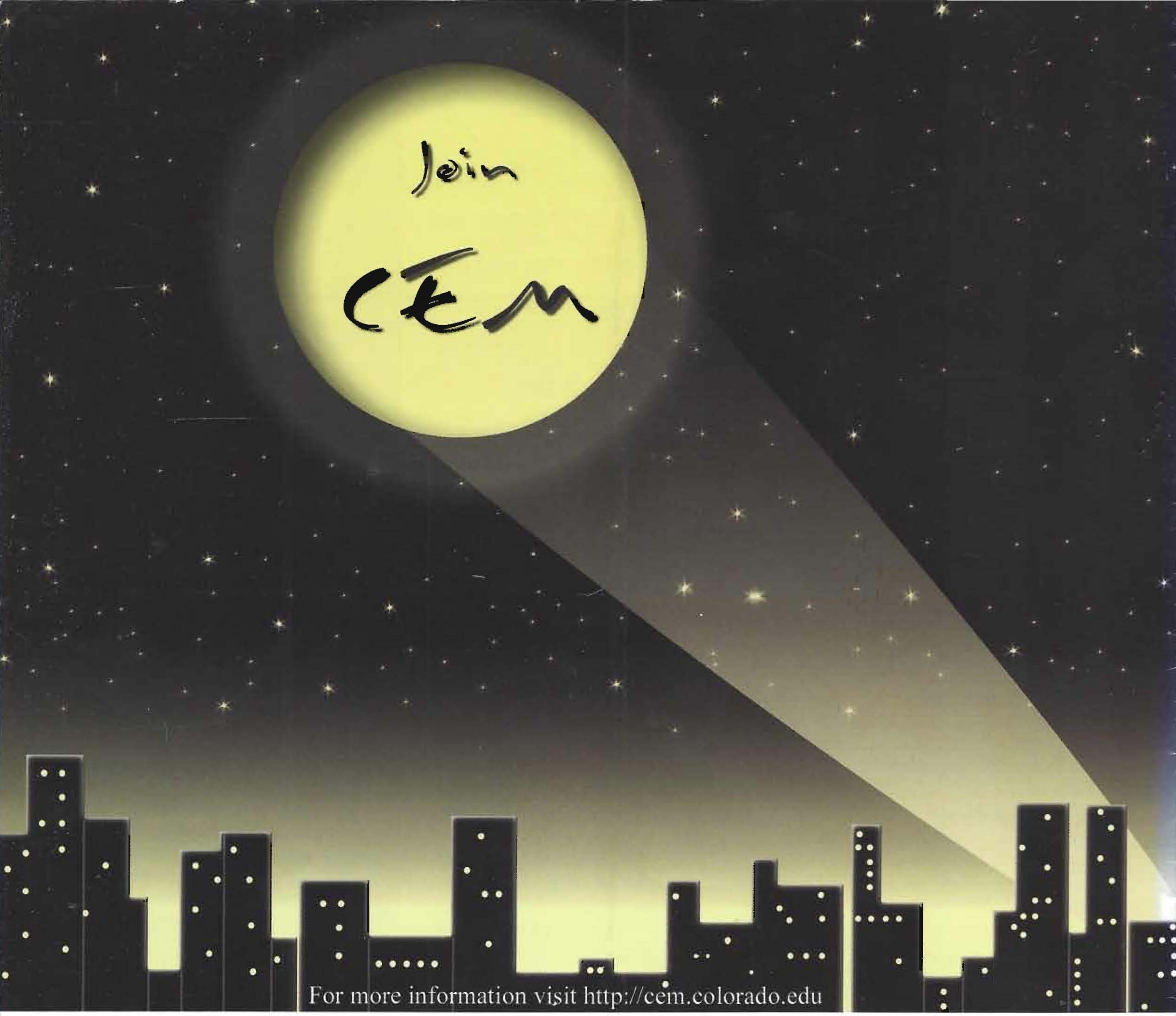
Obligiatory Engineering Related Humor.

To the optimist, the glass is half full. To the pessimist, the glass is half- empty. To the engineer, the glass is twice as big as it needs to be.

Q: What is the difference between Mechanical Engineers and Civil Engineers?

A: Mechanical Engineers build weapons, Civil Engineers build targets.





Colorado Engineer Magazine
University of Colorado
Campus Box 422
Boulder, CO 80309-0422

Nonprofit Org.
U.S. Postage
PAID
Boulder, CO
Permit No. 257