OutPost on the Endless Frontier©

EPRI e-News on Recent Key Developments in Energy Science and Technology
By Paul M. Grant

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Dolly and Deep Blue

This is a story about two developments of 20th Century science and technology that will play dominant roles in all aspects of life in the 21st, one of them most assuredly being energy.

Once upon a time…well…actually, in 1954, I was fortunate to be have been taught computer programming by IBM engineer Dr. Arthur Samuel, one of the legendary figures of the early days of computers. Art Samuel was held in high awe by we fledgling 701 programmers, partly because he had a PhD, rare for an engineer in those days, but mostly because he had written a checkers-playing program[1] which reputedly could defeat reasonably expert players.[2] This was the first instance of a computer successfully competing with humans on a "serious" game of skill.[3]

Naturally, as time went on, the Holy Grail became the creation of program that could play chess, the supreme board game of all time, on the Grandmaster level. Many believed this would never be accomplished. Yet, by the late 1980s several programs were running that were capable of doing just that. The "cup" was finally won on May 11th, 1997, with the victory in Game 6 of the program "Deep Blue" over Gary Kasparov, the reigning World Champion.[4] In my opinion, the event was inevitable. The programmers of Deep Blue had been continually refining the code to anticipate and accommodate the vagaries and surprises of human intuitive behavior…and introduce a few of its own. The day may not be far away that will see the creation of the long-awaited "Turing Machine," a computer whose responses cannot be differentiated from those of a human, in other words, the dawn of artificial intelligence.[5] The implications for energy will be enormous.

Continuing on to the second part of this tale, eight years later, in the summer of 1962, I was just beginning work on the experimental part of my doctoral thesis. Across the hall from my lab in the Applied Physics Department of Harvard were a group of students with three or four x-ray diffractometers, running almost day and night, whose data output was automatically fed to a bunch of punched card machines, producing a terrible din. About once a day, these students would lug out a substantial number of card boxes to the University's computer center (a Univac) and return on the next with reams of computer printouts. With the printouts spread out on the floor, they would then draw with crayons contours of atomic charge density on square-foot plates of plexiglass, that would subsequently be mounted on vertical rods to depict the structure of a very special molecule – DNA.

At least once a week, the professor in charge, a scrawny, almost emaciated individual, would appear to collect the "3D models." We solid state physics students paid little attention until October of that year, when the announcement came that the Nobel Prize in Medicine and Physiology[6] had been awarded to Francis Crick, Maurice Wilkins and…and, James Watson, the skinny Harvard biologist running all the action on the other half of our floor, for discovering the crystal structure of DNA, the basis of the genetic code. This discovery opened the door to understanding and controlling the structure of living matter, including, eventually, ourselves. Just as inevitable as Deep Blue was a consequence of the stored program digital computer, progress in understanding the cellular components of life that began with DNA eventually led to the first successful cloning of a mammal, a sheep named Dolly, as reported by a team of Scottish biologists in the February 27th, 1997, issue of Nature[7]. The implications for energy are going to be enormous.

These stories are only beginning…just consider one topic of current and future concern for us in the energy business.

The major issue our industry faces at the dawn of the next millennium (which begins January 1st, 2001!) deals with climate, industrialization and population growth. Note I didn't say "climate change," or "global warming," simply "climate." It may be that there will be substantial anthropogenic effects on weather and climate, and maybe not. What seems certain, unless there occurs an apocalypse on the order of worldwide thermonuclear war, is the continuing expansion of industrialization and population with its requirement for ever more energy, and the resulting influence either from or on climate and weather. For example, in the face of the negative economic consequences of drastically reducing CO_2 emission, it may be more prudent to seek technological solutions to living in a warmer, wetter (or colder, dryer!) climate. On the other hand, as industrialization and population growth progress, clearly more of mankind and his infrastructure will be in the way of normal weather patterns in any event.[8] A relatively new discipline has arisen, called "adaptation," to address these challenges. Adaptation seeks to understand the manifold of climate/weather conditions likely to occur, assess their impact on global and regional quality-of-life and economy, and develop technical solutions that "adapt" to, by circumvention, or, even better, exploitation of, the consequences.[9]

A critical component of adaptation is the extent to which we can model and predict weather and climate in the long term, the next 10 to 100 years hopefully, under a variety of physical inputs and forcing conditions. Recently your correspondent spent a few hours with climate scientists from NCAR, the NSF-sponsored National Center for Atmospheric Research in Boulder, CO. The NCAR climate model software[10] is state-of-the-art, "a priori" as possible in its physical/chemical foundations, and is often run on the same national laboratory supercomputers used to design (and test) our nation's nuclear weapons. I asked for how long could they predict local weather conditions given as initial conditions to the model today's weather. Their answer? "Three days."

To computationally attempt longer range prediction requires making a number of simplifications to the rigorous mathematical model, and results obtained can vary considerably in the types of scenarios thus derived. For example, the June 10th, 1999, issue of Nature reports on an improved model of the North Atlantic sea circulation, the so-called "central heating and air conditioning system of Europe.[11]" This model, developed by workers from the Hadley Center(re) of the UK Meteorological Office in England[12], treats the heat exchange between atmosphere and ocean "exactly," and predicts, under certain conditions of continuing atmospheric CO_2 loading and precipitation, a total collapse of the North Atlantic deep water circulation system, primarily affecting the Labrador Current, perhaps within the next two to three decades, with draconian consequences for European climate (the authors, living and working in Great Britain, are, as you might expect, quite concerned!). This paper was widely reported throughout the popular journalistic media, usually with a "Chicken Little" spin. Nonetheless, even given the advance in technique, several key assumptions were made about precipitation amounts and, particularly, the model does not take into account the flow of fresh water into the Sea of Labrador. Moreover, even under generally accepted evidence that average global temperatures have increased in the last 3-5 decades, no experimental indications of instabilities in the Labrador current have emerged…yet. In any event, the British findings do illustrate the sudden onset of instabilities that can occur under conditions of positive feedback in a highly non-linear system, a happenstance well-known to you power engineers out there.

Most climate models are presently based on some form of the nonlinear, three dimensional Navier-Stokes integral-differential equations of fluid dynamics. It has often been pointed out that it may be futile to use any purely deterministic system, irregardless of its exactness or lack of approximations, to predict long range conditions of climate/weather due to its extreme sensitivity of the result to the precision of the initial conditions applied. The reader may have heard this situation referred to by the term Deterministic Chaos, or, more prosaically, as the "Peking Butterfly Problem.[13]"

One wonders, in fact *OutPost* speculates, whether climate modeling and adaptation isn't more like a game of chess. Chess is "deterministic" in that it is played by a well-defined set of rules with a specific goal, to win by capturing the opponent's king. But each board situation presents a number of possible opportunities, of which only a few may prove optimal to achieving the goal, and additionally may result in an unexpected move by the opponent. At the risk of over-simplification, let's say the goal of adaptation might be stated in Bentham-Mills terms as "the greatest good for the greatest number" at end of game. The function of modeling would then be determining the optimal ecological-economic move from a given climate "board position" with the ability to evolve strategies appropriate to natural and societal response to structure its next move. The principal difference from chess would be that our adaptation goal as stated would most likely result in a series of equilibrium states (stalemates?), perhaps century-long in time scale, rather than a single and permanent checkmate. Think about it.

Enough about climate modeling. Let's turn to Dolly and see what she might have to say about adaptation.

Nature, in the form of living organisms, has been adapting to climate variations, both sudden and gradual, for many eons. Occasionally, such adaptation has resulted in the disappearance of species. Let's hope we can avoid this particular outcome for ourselves. Man has often taken advantage of transferring the results of natural evolution from that portion of the globe where it arose, to those where it was suddenly needed. The success of Russian winter wheat in the American Midwest, and that of native Texas and California grape stock grafting to ward off the "grape-dust" fungus that threatened French vineyards in the 19th Century, are examples that come readily to mind. However, do we now have time to wait for Nature to supply us with biological solutions to climactic changes that may occur far faster than evolution and natural selection can accommodate? Much has been made of mining the planet's rain forests for medicinal gold. Some early nuggets were quinine, digitalis and derivatives of other plants (many labeled "controlled substances" these days) which provided the future chemistry for local anesthetics. However, to date, less than a half-dozen natural species with promise for medicinal exploitation have been discovered from tens of thousands screened.[14]

There may be more advantage – with quicker payoff for energy – in bio-engineering specialized plants for both agriculture and efficient carbon dioxide utilization. For example, new species of Douglas fir and salt-water halophytes, both relatively rapidly propagating plants, if their lifecycle could be doubled, would at the same time help move toward planet-wide zero carbon balance and provide material useful for human consumption. The same argument could be made for pursuing the "artificial evolution" of more robust plant and animal food stocks, tolerant to a wide variety of temperature and moisture climate.

Want to fly on the wild side? Then try on these wings.

OutPost predicts that sometime between 2010 and 2020 the human race will have accumulated the knowledge and developed the tools to modify at will the genetic code of anything…including ourselves. The social and political accountability for the consequences to *Homo Sapiens* will be staggering, well beyond the scope of our discussion in this *OutPost*. Reflect on this, though…the "thermodynamic first law" efficiency of mammals in converting the latent energy in food to growth and physical/mental activity is a few percent at best. Moreover, the temperature range within which we humans feel "comfortable," that is, without externally supplied space conditioning, is probably 65-85 F. Suppose we could genetically engineer the mid-21st Century generation of humanity, in effect, our great-grandchildren, to be twice as efficient in biological energy utilization, and, in addition, tolerate as "comfortable" a 5 F extension to each end to the present range. Now, that's energy efficiency. A more admirable social goal, I should think, than assuring all our progeny will have multihued hair, or whatever other genetic characteristic might be deemed fashionable by generations to come.

Dolly and Deep Blue. Two achievements of the 20th Century human intellect with portent most profound, be it good or evil, for the future of our species since the first primate dropped down standing from the trees, or Adam awoke in Eden, as was the discovery and use of the energy within the atomic nucleus.

When I began this issue of *OutPost*, relating my own personal "close encounters" with these momentous events , an eerie feeling of kinship with the character Forrest Gump came over me. As we ponder the nature of their coming impact on humanity on all sides, not just energy, perhaps it is fitting to close with one of Forrest's folk-wisdom insights: "Life is like a box of chocolates. You never know what you're gonna get." Let's hope our legacy from Dolly and Deep Blue is the one with the maraschino cherry.

[1]These were the days before Fortran. In fact, "assemblers," programs that could translate alphanumeric mnemonics into binary, were just coming into general use. It wasn't called "programming" then, it was called "coding." I've since learned that Samuels wrote his checkers code in the late 1940s, before IBM developed its first computer, the 701, on paper, in binary, on an "imaginary" machine…which I guess we would now term "virtual!" Samuel's program made its TV debut in 1956. Thomas J. Watson, founder and Board Chairman of IBM, predicted the stock would rise 15 dollars. It did.

[2]Computer checkers has since progressed to an almost complete state of development. A few years ago, a program called "Chinook," written by Prof. Jonathon Schaeffer and his students at the Computer Science Department of the University of Alberta, defeated Marion Tinsley, generally considered to be the greatest checkers player of all time. The story of Chinook's creation and the human impact it had on the international checkers community is related by Schaeffer in his book, *One Jump Ahead: Challenging Human Supremacy in Checkers*, (ISBN 0-387-94820-1). For a review, visit *http://www.cs.ualberta.ca/~chinook/OJA/icca.html*. The Chinook home page is at *http://www.cs.ualberta.ca/~chinook/*.

[3]In the late 1940s the "Manchester Machine" in England had been programmed to play unbeatable games of tic-tac-toe and "nim" (we Americans call this the "odd man out" game, usually played with sticks or matches)…neither quite in the class of checkers.

[4]Details of Deep Blue's development and current status can be found at *http://www.chess.ibm.com/home/html/b.html* . The story of Deep Blue (written before its ultimate victory over Kasparov) is recounted in the book, *Kasparov versus Deep Blue: Computer Chess Comes of Age*, by Monty Newborn (ISBN 0-387-94820-1).

[5]A "Turing Machine," named after the British mathematician Alan Turing, would behave in normal human discourse in a manner indistinguishable from a "real" human (visit *http://www.maxmon.com/1937bad.htm*). Many workers in computer science accept this

statement as the definition of "artificial intelligence." Is Deep Blue a Turing Machine? "Blind tests" with Kasparov, involving the analysis of past matches played by Deep Blue and between humans themselves, reveal that, on average, he could tell which is which. So we're not there yet.

[6]To view the "bio's" of Crick, Wilkins and Watson, and a summary of their prize-winning research, visit *http://www.nobel.se/laureates/medicine-1962.html*. Also, if you haven't already done so, read Watson's personal account of the discoveries, an enthralling account of how scientific research is actually carried out by human beings with all their personal agendas and shortcomings, in *The Double Helix* (ISBN 0684852799).

[7]I. Wilmut, A. E. Schnieke, J. McWhir, A. J. Kind and K. H. S. Campbell, *Viable offspring derived from fetal and adult mammalian cells*, Nature **385**, 810 (1997).

[8]As both population growth and industrialization proceed, there will be more people and their stuff in Nature's way than ever before, thus adaptation to weather and climate becomes ever more urgent irrespective of long term changes in either.

[9]A major EPRI SS&T Initiative addresses Adaptation. For more information, contact Dr. Richard Richels at rrichels@epri.com.

[10]For a description of NCAR climate models in use and under development, visit *http://www.cgd.ucar.edu/csm/models/*.

[11]See the following News and Views column in the June 10th , 1999, issue of Nature, Vol. 399: *Shifting Seas in the Greenhouse?*, Stefan Rahmstorf, p. 524; and the associated technical papers in the same issue.

[12]The Hadley Centre website URL is *http://www.met-office.gov.uk/sec5/sec5pg1.html*.

[13]A popular account of the chaos concept is Jim Glick's book, *Chaos: Making a New Science*, (ISBN 0140092501) very readably written in an "investigative reporting" style. For those desiring more technical depth, especially with regard to energy and materials science, I recommend *Applied Chaos* (ISBN 0471544531), by J. H. Kim and J. Stringer. The latter is rather pricey…$100 from Buy.Com…but I'm sure my colleague John Stringer might be willing to provide complementary copies to EPRI members…perhaps even autographed at no extra charge.

[14]See the provocative and indepth review by Colin Macilwain, *When Rhetoric Hits Reality in Debate on Bioprospecting*, Nature 392, 535 (1998).