ISSN: 2321-8169
3346 - 3351

Challenges to Computing

G. Donald Allen
Department of Mathematics
Texas A&M University
College Station, TX USA
dallen@math.tamu.edu

***Abstract*—** In posing the question as to challenges to computing, we consider what will sustain it. That is, we ask if or when will computing and computers come to their end of innovative applications. This is not a discussion about bigger and faster machines. Of course, bigger and faster computers can and will push to new limits ordinary and well explored topics. This is ongoing and will continue for centuries. We are entered into a discussion about the use of computers to solve new, even revolutionary, problems of this world. Innovation is necessary for the simple reason that problems are becoming bigger, more complex, even wicked, and some apparently impossible.

Keywords- *computing, innovation, technology, modeling*

*****

1. INTRODUCTION.

The primary reason to innovate is to solve problems, or to determine what the problem may be. Therefore, before getting to the principle topic of innovation it is important to understand how we solve problems. What kinds of problems are there? What tools do we use? How do we use them? Only then can our case for innovation, mostly an art, be set forth. These explanations are integrated with numerous computational needs. The tools however must be contrasted with the ideas of computing. Finally, we dive into innovations needed and a few of the dangers that computers eclipsing our abilities can bring. To put things in perspective, we begin with a few examples of innovations now at the end of their road. Terminal technologies, as it were. In their day, they were cutting edge. In their beginnings, they were resembled only roughly what they would become.

- **Watch making** – From the sundial to the water clock to mechanical gearing, keeping time has been important. Long the epitome of fine machines, the watch is now engineered with precision and at least mechanically do just about everything ever desired – extremely accurate time keeping. Even still there have evolved new technologies for this task.
- **Time** – With the advent of the Bulova Accutron, using a tuning fork, and then the quartz crystal, accurate timekeeping now at the atomic level and the technology is basically complete. There is likelihood that no application, aside from the study of cosmological and atomic structures, will require any measurements more accurate than we have now. Remarkably, the GPS device, now ubiquitous, makes a careful differentiated use of signals traveling at the speed of light.
- **The horizontal milling machine**- Just about everything a milling machine can do has been done. They are now programmable, and much of manufacturing has been turn over to this technology. They are complex but simple machines, a relatively simple development that uses the idea of computer controlled devices. Its mission well defined and explored.
- **Data storage** –Exabyte storage capacity now exists. Orders distant from the first data storage device as a wolf bone with etchings dating from 8000 BCE [23], Just about everything we do can be stored in real time – and maybe is. This, while recent, is merely bigger and faster. Yet, this technology is about at its end, considering the effort and expense of achieving such capacity. New problems involve making sense of this data, bringing it to reign and then meaning. bigger A profound leap or innovation will be required to go orders of magnitude further. The *qubit* with the quantum computer is well understood, though remarkably the theory is somewhat complete for a device that does not exist.
- **Art.** The techniques of painting have been developed to such heights that modern artists must change the message just to gain any attention. There are likely no current artists that can even closely match the technique of the masters of only a couple of centuries ago. Thus, the birth of modern art – including many genres. Artists have learned the importance of moving the target to hit the mark. In music, innovation has come to produce code that will generate sheet music from a sound recording or performance.

II. PROBLEM SOLVING

The human brain is a marvelous computing machine and so much more. It is adaptable to situations, adaptable to understanding, and adaptable to innovations. Moreover, it has numerous manners in which it can solve problems. We discuss seven.

You have a set of beliefs and a state of faith, both of which function as guideposts and anchors on how to view problems and resolve difficulties. These are your strongest systems, and can and usually do override all other considerations. The two overlap so much, it isn't really possible to distinguish them. The first is the second, and the second is the first. Naturally, this brief discussion is not only about religious beliefs, but also of beliefs on the plane of any consideration. We can believe in the tenets of quantum physics, or in corporal punishment, or love, the first having considerable associated proof, the second with countervailing arguments, and the third with endless multifaceted discourses.

Indeed, ultimately our beliefs are not unlike a glue keeping us mentally stable – most of the time. Dispensing with them puts us on a floating island in a foggy sea. In the notion of belief, it is significant not to delve into a lengthy discussion how beliefs come to pass. It is sufficient for our purposes to not that all have beliefs [2], [19]. We act on them. Our innovations arise in conflict with and concordance with them. Indeed, when researching any topic it is important to believe something; an ambivalent state leads to little substance.

When all else fails, and all considerations are equal, what do you do? Throw the dice. This means just take a guess. We all do this from time to time, usually when there is little time to use your more considered systems to respond. This study of this behavior called *random choice theory* lends itself nicely to mathematical analysis, using utility functions and stochastic processes [20], [21], [22].

The logical part of your brain does the analytics. It channels you through issues using the strengths of deduction and induction. You try hard to use accepted logical rules to make conclusions. Concomitant with logic are beliefs in the premises used. All argument needs premises; though sometimes subtle and unspoken they are present. We may say logic is an excellent vehicle to get you to another place, but you can't get anywhere unless you start from somewhere, your base premises. You may believe you have reasoned them out, but somewhere at their base is the belief in their certainty.

Another part of your analytic functionality is your ability to reason by analogy. That is to say, you have a problem and note it is structurally similar to a problem you have already solved. So, you convert the old problem and solution into the new problem setting. This generates the analogous solution, as best a nonlinear projection to another "idea" space. Not perfect, with not great regard for information lost, this method is an excellent way to make progress, but also explain what is not understood. For example, it is now accepted that the electrons orbiting a nucleus must be described by a probability density function. However, in the schools this is taught as an electron cloud, an analogy which only preserves the information that it cannot be known where the electron is, but loses everything else [3].

More subtle aspects of your problem solving toolkit, instinct and intuition, are well known, if not well understood. Literally hundreds of books and scores of websites discuss the various versions of these. But most agree they furnish a shortcut to analytical reasoning. You have a sense of what to do. It just comes to you. You have to react quickly. So, you rely on instincts of what to do. Sometimes, it is those gut-instincts that save your life, your job, your family, and sometimes they help with the next step of a proof. They are substantially low information mechanisms. Intuition and instincts are reasonably different, but overlap somewhat depending on the action at hand and the other factors. When you meet a stranger who promises to help you in some difficulty, do you use your intuition and instincts or analysis to decide? Often the former two are employed. More likely you will have an intuition about the person based on a myriad of experiences you simply can't recount, or upon instinct, the origins of which are even more vague. Certainly, you may not wish to flip a coin. Importantly, intuition bumps up against innovation in problem solving.

Through life you program yourself to carry out certain complex actions. While at one time you used the other tools to draw conclusions or take actions, you now rely on a set of internally programmed steps. Internal programs are used for similar situations, implying a risk of imperfection of the solution to the problem at hand. Note that the *similar* is not the *same*. You've heard the expression, "I did this on automatic pilot." This is you internal programming at work. Often these are classed as intuition and/or instinct, but we distinguish them here. The nurse knows just how to find the vein of the patient, and this comes from a long-programmed and developed skill. The student knows exactly the route from class to her parking place.

There is a eighth, that of *innovation*, but it is not strictly a tool or method. A commodity so treasured by all investigators and worshipped in the business world, it remains elusive as to definition, and how it works. We postpone a discussion to Section III.

Several guidelines are available to approaching a problem. They are used at numerous levels of the process. The most relevant of them below are given with the thought that computing may and probably will assist one day.

- Perceptually recognize the problem
- Identifying relevant information that applies to the current problem
- Comparing the problem to others for which you a solution is available.
- Eliminate irrelevant and misleading information
- Develop heuristics

Many problems types learned in the schools and college are familiar, linear, nonlinear, well-posed, and ill-posed. Many solution types are familiar, unique, stable, bounded, and so on. These are the kinds of solutions computing helps establish. Though often difficult, they furnish definitive structures to action. They challenge computing right to the limits of algorithms and machine cycles. But there are other problems for which innovation and insight are especially required. First there are the *wicked* problems, problems having no clear solutions, even no clear definitions, and possibly no end point.

Often they come up in the areas of design or business in general, though it is easy to see wicked problems in politics. While there may be no definitive formulation of wicked problem, they have definite characteristics [3],[4],[5].

1. There is no definitive formulation of a wicked problem
2. Wicked problems have no stopping rule, i.e. a rule to stop solving.
3. Solutions to wicked problems are not true-or-false, but good-or-bad.
4. There is no immediate and no ultimate test of a solution to a wicked problem.
5. Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.
6. Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions,

ISSN: 2321-8169
3346 - 3351

nor is there a well-described set of permissible operations that may be incorporated into the plan.

7. Every wicked problem is essentially unique.
8. Every wicked problem can be considered to be a symptom of another problem.
9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.
10. The planner has no right to be wrong.

Not all are necessary; about five suffice to designate a problem as wicked. Thinking of them in terms of computer assisted solutions is even more challenging. Nonetheless these problems, bordering on the impossible, do require solutions. At this point, regular problem solving tools seem to fail.

In the clean and tidy mathematics world, wicked problems have not been recognized. Their problems are wicked in another way. For those working with computers, epsilons are present in the theory and calculations to gauge how close to the closed or exact solution is possible.

Second are impossible problems. In mathematics, there are many problems essentially impossible in the sense they have been around for a long time unresolved. The Fermat Theorem was among them until the 90's. Proving the Goldbach Conjecture is another. Determining an odd perfect number remains elusive. But with the work of Gödel, there are some problems that are undecidible, and in this sense impossible. In medicine, determining a cure for anthrax required formidable intellectual innovations of many kinds. But it was impossible for millennia.

Several guidelines are available for approaching a problem. They are used at numerous levels of the solution process. The most relevant of them below are given with the thought that computing may and probably one day will assist.

- Perceptually recognize the problem
- Identify relevant information that applies to the current problem
- Compare the problem to others for which you a solution is available.
- Eliminate irrelevant and misleading information
- Develop heuristics

These are familiar as common procedures our minds activate, with a spectra of success rates. Achieving them often require leaps of intuition. Yet intuition, despite the folk understanding of it as a "super brain" within the brain, is based on deep knowledge combined with experience [16]. Indeed, intuition is often wrong, highly biased, and has little cognition of statistics [17].

In Appendix A, we suggest a generalized problem solving flow that recognizes many of the issues.

III INNOVATION

What is innovation? We could say an entity is self-aware and conscious if it can innovate, i.e. create, on the basis of itself and on stimuli it receives. Innovation is beyond mere problem solving. Stimuli or thoughts occur and the entity can somehow innovate a new idea or recourse over and beyond the expected response. It implies a higher order of thinking, well beyond the single-celled organism, and well beyond the comprehensive climate control systems, well beyond the dog or cat, and all other species. As valued as innovation is and as important it is to computing, we simply cannot call it up. The business world is more-or-less obsessed with innovation, such as a process, primarily as vehicle to generate earnings. In the coding world, it is required to produce the next "killer app."

With these examples, we distinguish even types of innovation, the one being an innovation for which we need to invent technology, the other being an innovation which works within extant technology. Surely Facebook was an innovation, but it did not push limits of either computing or any other technology.

But innovation is also well beyond many humans. All this is a gentle attempt to resolve an ancient question. The question remains unsolved. It seems that the definition of consciousness is rather undefined (because there are so many definitions), and that is if the question of consciousness is well-posed in the first place. We identify four types of innovation.

A. Device – save time, money, health, increase food, decrease pollution
B. Process – way to think, way to organize, way to produce
C. Concept/paradigm (paradigm shift) – a new idea to affect how a society, industry, or specialty institutes its functionality
D. Principle – a statement given or accepted as true, upon which structure are built

The first two are clearly within the domain of computing, while the second two remain only within the realm of human thought.

IV. THE CURRENT STATE

Computing furnishes us with a generalized tool for doing new things, though only things for which quantification, numbers, and information are at play. Practitioners have now spent several decades devising ways that quantitative data and information can be made qualitative. We say *some decades* because that is the currently longevity of computing machines. As usual, it was the real world that spawned the need for machine encoding and processing of large quantities of data.

Beginning with the complexities of processing census data, Herman Hollerith (1860-1929) devised the punched-hole card that could be machine read and input data analyzed using mechanically complicated but pre-electronic simple machines. This was years before the computer, but note that complex processing machines were developed years before computers as we know them. Indeed, the most striking aspect of computers was originally the concept of a stored program and now the adaptive program.

Our mission here is not to recount historical aspects of computing, but rather to suggest where it is going, and importantly where and when it may reach an end. Yet, important to note is the idea of computers evolved from the works of Alan Turing, with the Turing machine leading to programmable computers, Georg Cantor, with set theory, and Kurt Gödel, on the incompleteness of our mathematical systems which concluded there are problems within any mathematical system that cannot be solved. This is to say, that within any logical system, there must be impossible problems not solvable within it. The implication is the system must be expanded, but then the expansion will lead to new impossible problems. Therefore, a natural question is whether the origin suggests an ultimate end?

When asking when computing is at an end we are discussing whether computing can resolve any question we need to answer. Not simplistic questions as implied by "Do I love you?" are considered. Such questions are emotional and may never have any meaningful answer as *the* answer may change by the moment. Such simple questions are virtually impossible by constructs of the human mind.

We take up three contemporary examples, numerics, models, and big data. One point of note is that each required multiple innovations of devices, processes, paradigms, and principles.

The world functions on mathematical and statistical models of reality and what they can predict, what they can show, and importantly what problems they can solve. Astonishingly successful, *numerics* generate a wealth of information and lead to solutions of problems impossible to consider, if not pose, well beyond the scope of researchers even a few decades ago.

The accumulation of population, climate, weather, and other statistical data has amassed at such a rate and have exceeded all estimable bounds that it cannot any longer processed without computers to help. Below, we take up the similar-sounding topic of "big data," quite another issue.

The most successful technique for the explanation of phenomena, following Sir Isaac Newton's theory of planetary motion and Euclid's *Elements*, has been the *model*. Clearly, these were mathematical models, but the idea has caught on – despite philosophical debate.

Models and making models is the active task of almost all innovators in almost every human endeavor. We now have all sorts of models including rather powerful statistical models derived from data sets. Most mathematical models have no tight, closed solution coming by way of a formula. Most problems involving these models required significant numerical computing.

Indeed, in the past four decades an entire field of numerical analysis has evolved simply to help provide solutions to such problems. Statistical models are models generated from small and more recently massive data sets to correlate and thus to explain cause and effect. However, there remains the remarkable misuse of models, data, and patterns recognized to derive causes. It is with models, the greatest danger lies ahead as described in the next section.

Big data is one of the newest applications of computing. It is effectively the application of models for complex pattern recognition amidst massive amounts of data. There are specialized software (e.g. RapidMiner, SAS) designed to do just that. Stunning results have been achieved. Patterns in medicine, in finance, in education are just a few of the bigger topics that have been rendered to undiscovered and even unconsidered conclusions.

Perhaps this is the end of computing, or is it just the beginning. The tools for analysis follow rather standard constructive models. When one is found there is celebration. It is then used for predictive ends. Often the models are used to predict backwards in time to validate their predictions toward the future. Herein lays a risk. Unless the reality is time-reversible, validation in this manner must be suspect. Indeed, it can lead to conclusions that are simply false. We could call this *modeling a false positive*.

For example, in a Cornell study [1] of Facebook pages of more than one million participants, there has evolved though big data analysis a predictive of relationship breakups. The study suggests that their models can predict a breakup before even the participants are aware it is underway. They show, though big data modeling, that If you both all have the same set of friends, this is an indicator of a possible breakup. But this is just a model, nothing more. In fact, there may be other factors of the personality types of people having same sets of friends. What conclusions should be determined?

Hundreds or thousands of innovations on what to do with big data will evolve over the next few centuries. Not all of them will be in our benefit.

V CONCLUSIONS

Strogatz [7] has suggested that mathematicians together with their colleagues in computer science and all other sciences will invest the next couple of centuries in solving the highly nonlinear problems of our time. Problems of chaos, synchronicity, and fractals will figure prominently in this venture. Of course faster and bigger computers will play a role, but Lyapunov limits and system sizes will constrain against hardware gains. Serious algorithmic research will be required.

Algorithms for assisted learning are in their infancy and to date only modest gains have been realized. Here, our colleagues in psychology and education need to crystallize correct theories of learning [8-12] for computer scientists to algorithmize. Required will be innovations both in computing, theory, and content. Concatenated with this will be derived a theoretical lower limit on just how much learning must be human-to-human.

Already theorem proving by computer has generated striking results not the least of which there are programs that produced original and new mathematical proofs, e.g. Robbins problem, [13], the four-color theorem, and even a proof that god exists (based on Gödel's modal logic) [14]. The application of computers at the nano-level is another gain, the potential of which is difficult to foresee [15].

These are not simple problems, but they are simple because the problems are well understood, if not thoroughly. Surely, computer machines will achieve a hardware maximality and likewise for data storage. On this account, unless humanity has solved all problems of interest, there will undoubtedly remain essentially unsolvable problems.

The more serious problems requiring even deeper insights and innovation will be in dealing with the ubiquitous wicked problems, just now being understood in a pre-technical sense. For these, ultra high-level languages are needed. These languages, not yet conceived, will be able to parse the sparse information available for complex problems to determine what is known and relevant, what is missing, and even suggest what types of problems can be solved.

Given in the form of questions, our conclusions are suggestions of possible futures ahead. Can it be that computing is one of those elusive techniques that like us adapt endlessly to ever new and challenging problems – without end? This positions computing computers to replace humanity as Hawking and others have called the next big step of human evolution [18]. Can it be that we will soon (whatever that means) reach the limits of computing, and a new technology or concept will emerge to offer solutions to ever more wicked and impossible problems? Can it be that modeling will create in us a world of lemmings, wherein we rush to the latest model generated solution to another solution based on systemic changes. Can it be that the tried and tested “cause and effect” paradigms are to be replaced by degrees of correlation?

We are centuries from the end of computing allowing only for what can be achieved with present paradigms. Yet the co-mixture of numerics and modeling of big data give assurances of more sharply defined reality on the one hand and data based predictive modeling on the other. This creates an obvious internal conflict. A darker side is what happens if humanity becomes overly intoxicated with its models, and begins to view results as truths, much less facts? Only a continuous stream of innovations will sustain and be sustained by computing.

References

[1] The Daily Mirror, Facebook can now predict if your relationship is doomed, http://www.mirror.co.uk/news/technology-science/technology/facebook-can-predict-your-relationship-2659859

[2] James, William, The Will to Believe, *The New World*, 5 (1896): pp. 327-347.

[3] Polya, George, *Induction and Analogy in Mathematics*, Princeton University Press, 1954

[4] Rittel Horst W. J and Webber, Melvin M. Dilemmas in a General Theory of Planning, Policy Sciences 4 (1973), 155-169.

[5] Camillus, John, Strategy as a wicked problem, Harvard Business Review, 86, 5, 99-106.

[6] Coyne, Richard, Wicked problems revisited, Design Studies 26, 2005

[7] Strogatz, Steven, *SYNC: The emerging science of spontaneous order*, Hyperion, 2003.

[8] Illeris, Knud (2004). The three dimensions of learning. Malabar, Fla: Krieger Pub. Co.

[9] Ormrod, Jeanne (2012). Human learning (6th ed.). Boston: Pearson.

[10] Yount, William R. (1996). Created to Learn. Nashville: Broadman & Holman. p. 192.

[11] Myers, David G. (2008). Exploring Psychology. New York, New York: Worth. p. 163.

[12] Merriam, Sharan B. (2007). Learning In Adulthood. San Francisco: Jossey-Bass.

[13] W.W. McCune. Solution of the Robbins problem. Journal of Automated Reasoning, 19(3):263{276, 1997.

[14] Knight, David (23 October 2013). "Scientists Use Computer to Mathematically Prove Gödel's God Theorem". Der Spiegel.

[15] Waldner, Jean-Baptiste (2007). Nanocomputers and Swarm Intelligence. London: ISTE. pp. p173–p176, Wiley.

[16] Policastro, Emma (1995), Creative Intuition: An Integrative Review, Creative Research Journal, (8) 2, 99-113.

[17] Kahneman, Daniel, *Thinking, Fast and Slow,* Farrar, Straus, and Giroux, *2011*.

[18] Hawking, S, Life in the Universe, http://www.hawking.org.uk/life-in-the-universe.html, 1996.

[19] Wade, N. *The faith instinct: How religion evolved and why it endures. New York: Penguin Press*, 2009.

[20] Luce, R. D. (1977), “The Choice Axiom after Twenty Years,” Journal of Mathematical Psychology, 15: 215–233.

[21] Train, K. (2009) “Discrete Choice Methods with Simulation.” Cambridge University Press, 2nd edition.

[22] Gul, Frank, Natenzon, and Pesendorfer, Wolfgang, Random Choice as Behavioral Optimization, pre-print.

[23] Boyer, Carl B., *A History of Mathematics*, 2nd Ed, Revised by Uta C. Merzbach, Wiley, NY, 1991.

 ISSN: 2321-8169
3346 - 3351

APPENDIX A

A generalized flow for problem solving. This diagram subsumes the computing aspect of problem solving under the "Formulate Solution Ideas" box.