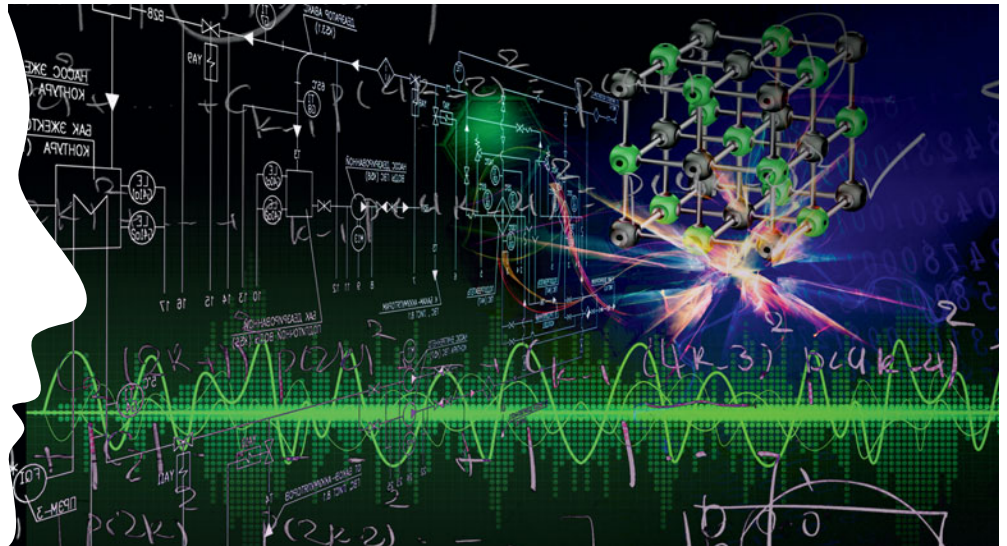# One algorithm to rule them all

"One algorithm to rule them all, one algorithm to find them, one algorithm to bring them all and in the darkness bind them."

(with apologies to J.R.R. Tolkien)[1]

I recently bought an Amazon Echo.[2] For those of you who don't know, Echo is a hands-free speaker you control with your voice, whose capabilities are managed through mobile apps. Echo connects to the Alexa Voice Service, which responds to voice commands, such as "Alexa, play music by Ian Tyson." Alexa will then announce that a sampling of music by Ian Tyson will be played, and the music begins. One can manage an almost continuous *ad hoc* playlist in this fashion, limited only by your memory and whether the music is available. I can request the local weather forecast, or the forecast for distant cities, such as Paris and Buenos Aires. Alexa can order pizza delivery for you. With the right hardware, Alexa can even control your lights, air conditioning, door locks, or any number of other household appliances. The Echo can also answer a range of questions on a variety of topics; its other capabilities are too numerous to list in this short article.

I note that Google has a similar system that is based on Google Assistant.[3] It can answer questions, play music, including from playlists that you've developed, control your smart home, and cast videos to your television. Other voice-activated personal assistants are Apple's Siri[4] and Microsoft Cortana.[5] My experiences with Siri have been mixed. I have no experience with Cortana. Apple recently released the HomePod, a speaker with voice control and Siri intelligence.

There was an incident featured on television some time ago in which a child was able to use the Echo to order a dollhouse without her parent's permission.[6] This problem has apparently been fixed.

There are some who worry that personal assistants, such as Alexa, are part of a government or big business (or both) conspiracy to know everything about us. This is based upon their understanding that Alexa keeps a record of everything that is said as part of the interaction. Such a record was subpoenaed by prosecutors in Arkansas as part of a criminal case involving a murder that occurred in the vicinity (dare I say presence) of an Echo.[7] Amazon recently complied with the subpoena after the defendant approved the release.

I occasionally experience false responses from the Echo, even when I have not asked for anything. I often watch the game show *Jeopardy*, whose host is Alex Trebek. Sometimes, when a contestant or the announcer says Alex's name, the Echo will respond. Sometimes, it will just say that it didn't understand the question. At other times, it will respond with statements that are meant to be a real response to the statement that has been made, but without a clear connection with anything that makes sense. In rarer cases, I will sometimes hear a response from Alexa to something triggered by random television shows. Apparently, there are still issues with the speech recognition algorithms used for the Echo.

Wikipedia[8] defines speech recognition as "The interdisciplinary subfield of computational linguistics that develops methodologies and technologies that enable the recognition and translation of spoken language into text by computers." Some modern approaches to speech recognition are based upon the idea that speech can be simulated by a Markov model, in which speech is approximated as a stationary process. Other approaches for speech recognition are based upon neural networks and end-to-end automatic speech recognition.

All of these programs operate off of algorithms.[9] An algorithm is a set of instructions listing actions to be performed and the circumstances under which they will be performed. If you are familiar with FORTRAN, then you know about DO loops, which are repetitive, but conditional in the sense that the loop usually contains a logic statement or a counter, which when violated causes the computation to exit the loop. This is a simple form of an algorithm. Most work completed by computers, including the speech recognition approaches described previously, runs off of algorithms. The algorithms that support speech recognition are clearly not perfect. Although orders of magnitude better than ancient speech recognition software from the latter half of the 20th century, there is still much room for improvement. (For those of you whose attention faltered when you encountered the word "FORTRAN," the answer is yes, I am an unrepentant FORTRANosaurus, and proud of it.) I also note that boggling of the mind indicates faulty algorithms at play in the human mind. I don't think that I'm overstating the case to say that algorithms of one sort or another control much of human existence, whether they are in computer software and

hardware, control systems for transportation and appliances, or in the human brain (as well as many other aspects of the human body).
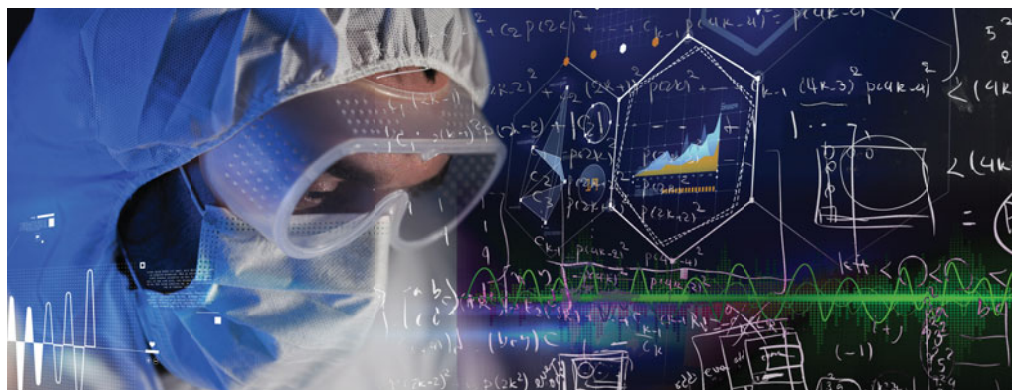
An article in the May 8, 2017 issue of *Chemical and Engineering News* indicated that a software developer wants to take this in a direction that may impact the work of every materials researcher. James Rhodes wants to turn the Echo into our personal laboratory assistant.[10] The Echo would be a repository for a vast treasure trove of scientific information that could be accessed simply by asking Alexa. "Alexa, what is the value of pi to six significant figures?" "Alexa, what is the value of Planck's constant?" "Alexa, what is the melting point of silicon?" If you are in the midst of a complicated synthesis, and need to be 100% certain of the next step, then "Alexa, after I stir in the acetone, what is the next step in this process?"

In a "smart laboratory," the Echo could be used to control instruments and processing tools (hot plates, centrifuges, etc.). The Echo could provide a comprehensive record of all verbal activity in the lab. If the researcher were careful to make statements about every step in a process as well as their observations about the process and the outcomes, then this could represent a comprehensive laboratory notebook and record. Coupling this with control of vision systems in the lab would yield a powerful audiovisual record of all work performed.

Alas, I know that even as I write this, some of the neo-luddites among you are saying to yourself, "Wait a minute. Didn't he just tell us earlier that the Echo has an imperfect response, and the algorithms are not 100% perfect? Doesn't this expose us to accidents and maybe to liability?" I suppose that there is some truth to this. With every new tool that comes along, there also comes an element of risk. At the one end of the spectrum is professional embarrassment if we publish a paper with errors, similar to what happened in an episode of the television show *The Big Bang Theory*, when Sheldon Cooper misread the value of a cross section to be in square meters instead of square centimeters.[11] This made his published result off by a factor of 10,000. Far worse than embarrassment would be a mistake that threatened the integrity of a structure, such as a building, a bridge, or an airframe.

Nonetheless, I believe that voice-activated personal assistants for research use will come into their own. IBM is busy developing algorithms so that its Watson can be used as such an assistant for physicians.[12] Someone will develop a voice-activated personal assistant for other researchers. The materials research laboratory of the future will be ruled by the algorithms that allow the voice-activated personal assistant to function. Instead of naming the personal assistant Alexa, perhaps it will be Igor. A voice-activated personal assistant will likely also be available for our colleagues involved in theory, modeling, and simulation.

For those of you who like a more hands-on approach and to get ahead of the curve, you may be able to make your own virtual assistant using a Raspberry Pi—a series of small, low-cost computer boards designed for teaching purposes.[13] As for me, I am not likely to tinker with this myself, but I look forward to the next generation of personal assistants that I hope will be much more capable than the current versions. If a personal lab assistant is available, I will likely take advantage of that. I also sincerely, devoutly hope that the verse at the top of the article winds up referencing only the algorithms involved in their tasks as voice-activated personal assistants, and not the "computer overlords" as stated by Ken Jennings during his competition against IBM's Watson on *Jeopardy*.[14]

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