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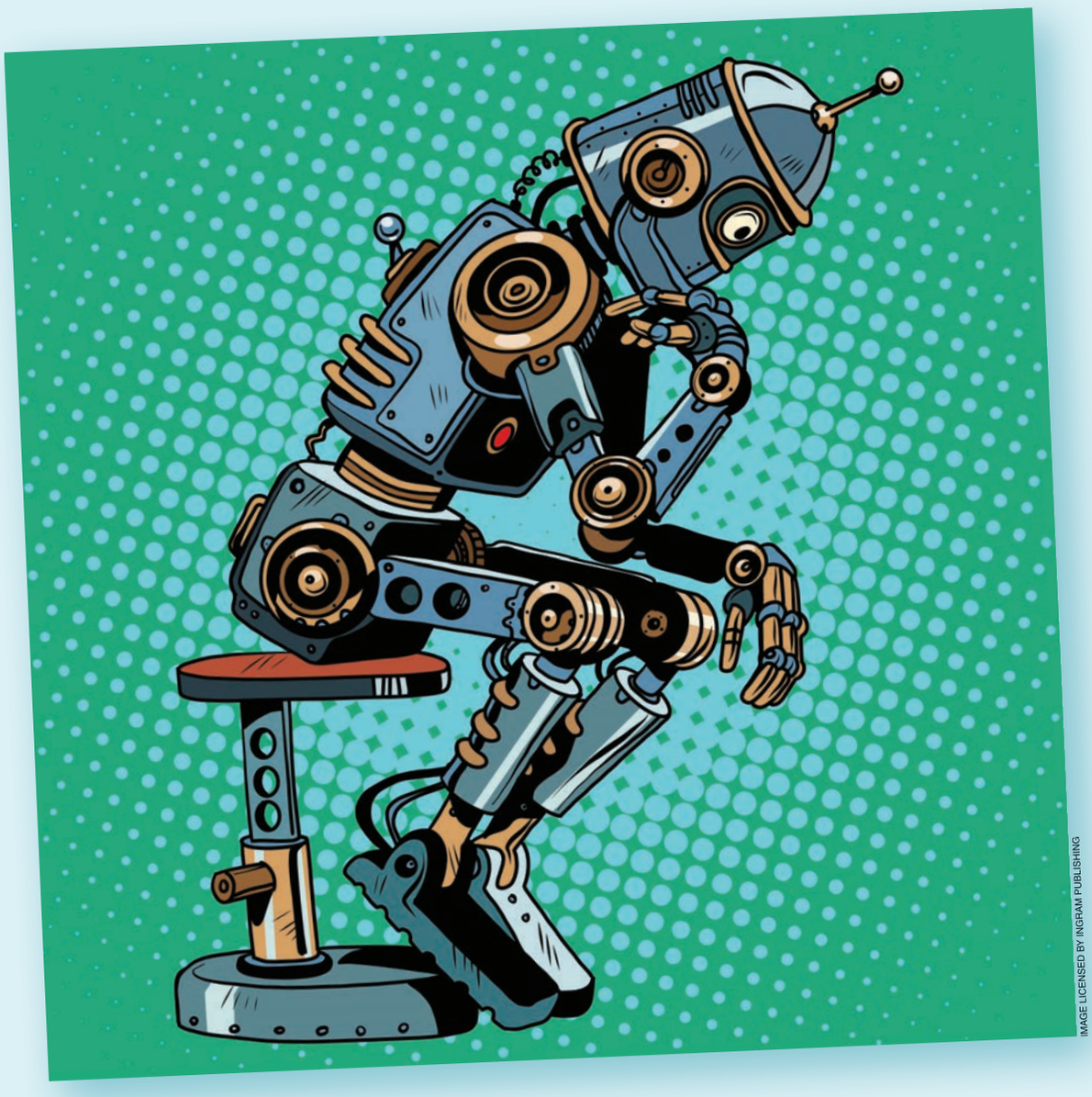
BIG DATA _REVOLUTION

The Challenges of Uncertainty

IEEE

(Computational) Intelligence

What's in a Name?



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by James C. Bezdek

This article is about the terms *intelligence*, *artificial intelligence (AI)*, and *computational intelligence (CI)*. Topics addressed here include 1) the historical evolution of the terms *AI* and *CI*; 2) the seductive semantics of terms such as *machine learning*, which owe a heavy debt to our intuitive ideas about intelligence; 3) the evolution of the IEEE Computational

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Intelligence Society; and 4) the role that buzzwords play in the lives of all researchers. I estimate that this article is roughly 40% facts, 10% anecdotes, 15% speculation, and 30% opinions. The other 5%? It's reserved for you to fill in the blank—one option would be "bull." [Parts of this article are excerpted from: J.C. Bezdek., (2015). "The History, Philosophy and Development of Computational Intelligence (How a simple tune became a Monster hit), in *Encyclopedia of Life Support Systems* (EOLSS), vol. 3, *Computational Intelligence*, Hisao Ishibuchi, Ed., pp. 1–22. Available: ieee-cis.sightworks.net/documents/History/Bezdek-eolss-CI-history.pdf.]

The Songwriters and the Stars

The previous paragraph advertises this as an article about the origin of the term *CI*. Why is this interesting? Well, Ben Goertzel, perhaps correctly, asserts that

> Yeah, terminology is ultimately a pretty boring issue. But in practice, it makes a lot more difference than it "should"…So it's mildly interesting…to look at how [a term] originates and spreads.

Since CI is often juxtaposed with the term *AI*, let's start with a tiny bit of history for this older term. Apparently John McCarthy coined the term *AI* to characterize the topics of a 1956 conference at Dartmouth that he organized with Marvin Minsky, Nathaniel Rochester, and Claude Shannon. Crevier [1, p. 50] introduces a smidgeon of doubt about this, but McCarthy stated quite unequivocally that "I came up with the term" in a c|net interview. He famously lamented that "as soon as it works, no one calls it AI anymore."

The interplay between AI and CI is, in some sense, just an offshoot of never-ending arguments about the meaning of the root word *intelligence*, which takes a front seat on this excursion into the jungle of technical buzzwords. For starters, I will note that Legg and Hutter [2] compiled a list of more than 70 definitions of the word intelligence—it's fun to read and provides a nice backdrop for this article. From McCarthy's starting point for AI, there have been a number of spinoffs—not unlike your favorite TV procedural (e.g., *Law and Order*, 456 episodes) or movie franchise (e.g., *James Bond*, 23 movies). Terminology in AI is similar. For example, there is *strong AI*, attributed to Ray Kurzweil by Ben Goertzel, and there is Goertzel's own term *artificial general intelligence* (*AGI*), the story of which can be found at the website http://wp.goertzel.org/who-coined-the-term-agi/. Interestingly, and very pertinent to the present tale, Goertzel writes:

> In the last few years I've been asked increasingly often if I invented the term "AGI"—the answer is "not quite!" I am indeed the one responsible for spreading the term around the world…and I did sort of commission its creation! But I didn't actually coin the phrase.

As this story unfolds, you will see that I am in exactly the same situation with respect to the term *CI*—I didn't invent it, but I spread it around. How? Well, (I think) I wrote the first paper that defined—in a sort of rough-and-tumble, nontechnical way—the term *CI* [3]. Subsequently, I suggested attaching the term to several activities related to the IEEE Computational Intelligence Society (CIS), which began its life as the IEEE Neural Networks Council (which was itself an offspring of sorts of the IEEE Systems, Man, and Cybernetics Society). The most important event in this regard was (and still is) the World Congress on Computational Intelligence (WCCI), first held in Orlando, Florida, in 1994.

Later you will see that the current name of the CIS also had its roots in my suggestion. But, as I have been careful to point out many times, the term *CI* itself was around for at least seven years before I wrote that 1992 paper. What follows here is an abbreviated account of my understanding of the history of the term, the evolution of the IEEE CIS, its significant events, and the current state of the art of the field. Along the way, there will be much discussion about the interplay between computational, artificial, and biological intelligence (BI).

Let me start this expedition into the past with a seemingly unrelated but soon to be understood word association game about popular music. Suppose I name the song "Like a Rolling Stone," which the magazine *Rolling Stone* lists as the greatest song of all time. (You may not agree that this is the greatest song of all time, or even of any time, because of its context, language, your cultural history, your personal preferences and so on—that's okay; it will still suffice to make my point.) Many of you will know who wrote it, who performed it first, and who made it a huge hit; Bob Dylan (1965) in all three cases. But what about the song "[I'm Dreaming of a] White Christmas"? Most of you know who made it popular—Bing Crosby. Crosby spread it around by making the first, and also most popular, recording of it in 1942. [According to *The Guinness Book of World Records*, the holiday perennial "White Christmas" [(1942)] by Crosby is still the best-selling single of all time worldwide, with estimated sales of over 50 million copies.] But you probably don't know that Irving Berlin wrote the music and lyrics in 1940. It is often the case in music that the general public attributes the creation of a well-known song to the artist who made it most popular—the songwriter is often obscured by the dazzling success of the star performer who makes it a big hit. This happens in science and engineering too—a lot.

Suppose I state a technical term, name a concept, or repeat a physical law that is common in science or engineering and ask you to associate a person's name with it. For example, energy equals mass times the square of the speed of light; in symbols, $E = mc^2$. Almost everyone on planet Earth (well, okay, almost everyone among the members of the IEEE, anyway) can tell me that this

equation was discovered (created), and popularized (spread around), by Albert Einstein. But suppose I mention backpropagation in multilayered neural networks. What name leaps to your mind? This very famous and useful technique was created and reported by Paul Werbos in his Ph.D. dissertation [4], but it was, for many years, erroneously credited to David Rumelhart and James McClelland, who popularized it in their 1986 book [5]. Where does all this lead? Suppose I ask the membership of the IEEE who originated the term *CI*. Many—perhaps most—of them might say "Jim Bezdek," but they would be wrong. Just as in the case of Goertzel's term *AGI*, I probably made this term a big hit (spread it around), but I did not write the song. That piece of the story will come to light soon. But first, let's return to the music analogy, which was not my invention either!

The interplay between AI and CI is, in some sense, just an offshoot of never-ending arguments about the meaning of the root word *intelligence*.

Folk Songs and Smash Hits

There is a close parallel between the rise of (the term for) CI and the common abbreviation for the expectation-maximization (EM) algorithm. I have done a lot of work related to the theory of alternating optimization (AO), which is the scheme employed by EM when estimating the unknown parameters of a bunch of mixed probability distributions. In due course, I became very interested in trying to track down the history of AO, and my inquiries into this topic became somewhat inseparable from the history of the EM algorithm. Let me call this combined history EM/AO. It turns out that this history is, unsurprisingly, pretty cloudy. Several scholars have written quite interesting and rather comprehensive treatises about the history of various EM/AO algorithms. But the history of the term *EM* itself is pretty well known, and delightfully rendered by Meng and Van Dyk [6], who wrote (I have changed their references to the IEEE format and emphasized the crucial fact about this term in italics):

> **How EM Became a Monster Hit**
>
> Who First Developed the EM Algorithm? With the ever-growing popularity of the EM algorithm, especially with its various deterministic and stochastic extensions (e.g. the data augmentation algorithm of Tanner and Wong [7]), those of us who do research in this area find ourselves being asked more frequently the question who first developed the EM algorithm? Although it is easy for us to direct the inquirer to Dempster et al. [8], *where the term EM appeared for the first time*, the question is really not easy to answer. In fact, the issue of the origin of the EM method was raised by several discussants of [8]. For example, Hartley opened his contribution with
>
> I felt like the old minstrel who has been singing his song for 18 years and now finds, with considerable satisfaction, that his folklore is the theme of an overpowering symphony.
>
> Hartley's folk-song analogy is indeed appropriate for describing the development of this powerful method. Just as a folk-song typically evolves many years before its tune is well recognized, various EM-type methods or ideas which precede Dempster et al., and in fact precede Hartley by many years, can be found in the literature.
>
> Although we shall perhaps never be able to find out who really sang the first musical note of the EM algorithm, *we all agree that it was Dempster et al. who brought it into the all-time top 10 of statistics* (see Stigler [9]). They made (at least) two contributions that popularized the song. First, they gave it an informative title identifying the key stanzas—the expectation step and the maximization step. Second, they demonstrated how it could be sung at many different occasions, some of which had not previously been thought to be related to the EM algorithm (e.g. viewing latent variables as missing data). Since then, we all have sung or heard it being sung many times, sometimes with abusive or even unbearable tones. [6]

My point is that this type of confusion—who initiated a term versus who spread it around—is quite common in both the arts and in the sciences. There is, more or less a direct connection between the music analogy I made previously and the popularization of the terms *EM* and *CI*. The history lesson offered by Meng and Van Dyk adapts remarkably well to the history of evolution of the term *CI*. But CI is not quite semantically equivalent to EM, because EM refers to several real AO algorithms, whereas CI is simply a broad-brush term that is used to describe—what? Well, that's the point of this treatise, isn't it?

Computational Intelligence Begins

The appearance of the term *CI* in published form goes back to at least 1983, for that is when the *International Journal of Computational Intelligence* (*IJCI*) was floated as the title of a new Canadian journal by its founding editors, Nick Cercone and Gordon McCalla. Nick and Gordon both responded to my request for some information on their use of the term. Here is what each of them wrote to me in e-mail communications.

The Origin of CI as Described by Cercone

Back in 1983, my colleague Gordon McCalla and I were the executives for the Canadian Society for Computational Studies of Intelligence (CSCSI), the oldest national AI society in the world, which began in 1974. We decided to start an AI journal to focus on pragmatic issues and AI systems and approached the Canadian National Research Council (NRC), which published journals. We decided that Computational Intelligence was a more fitting term than Artificial Intelligence after much debate; it seemed to describe our field more accurately. We thought AI was a bit of a misnomer. After satisfying their do-diligence and name searchers our NRC decided to publish *IJCI*. Gordon and I edited CI for 20 years and made the transition from NRC to Blackwell's (which bought it from NRC) which subsequently became Wiley-Blackwells. The logo is still the one drawn by a Quebec artist for the original NRC CI. The CSCSI has undergone a name change to CAIAC (Canadian Artificial Intelligence Association/Association pour l'intelligence artificielle au Canada). There have been many other journals and organizations since. [10]

> My point is that this type of confusion—who initiated a term versus who spread it around—is quite common in both the arts and in the sciences.

Subsequent to Nick Cercone's e-mail to me, Gordon McCalla added the following comments.

The Origin of CI as Described by McCalla

Nick has the history down fairly well. The term "computational intelligence" was drawn from the name of our national AI society (Canadian Society for Computational Studies of Intelligence), which had been devised at the time of the society's founding around 1973–1974. We were further encouraged by Alan Mackworth, a well known computer vision and constraints scholar, who had used the term "computational vision" for the vision area way back in the 1970s, and felt, as Nick has mentioned, that the name "computational intelligence" was a more appropriate name for our field than "artificial intelligence."

The journal is still being published by Wiley-Blackwell, as Nick says, currently moving into volume 28. Its first issue appeared in February 1985…All volumes are available from the Wiley site, and you can see the journal's evolution in content, some of which would currently still be called "computational intelligence," over the years (decades!!). [11]

I think this accurately accounts for the beginning of the (published) term *CI*. Until I discover an earlier reference, I will take this as a correct description of the origin of this particular folk song. Perhaps amusingly, and certainly related to this history, Peter Cheeseman published a very interesting argument supporting probabilistic models as the only reasonable way to represent uncertainty in science and engineering in exactly this journal, *IJCI*, in 1988 [12]. His attack (for that is certainly what it was) on fuzzy sets, complete with 22 commentaries and replies from arbiters of fuzzy models who responded to his challenge, was one of the signature papers of the early and ongoing battles between supporters of the two approaches to reasoning under uncertainty. Beyond this, things went along at a steady and relatively quiet pace from 1985 to 1992. And then…

1992—The Horizon Expands

As noted previously, my use of the term *CI* first appeared in a paper that was published in the *International Journal of Approximate Reasoning* in 1992 [3]. Below is the abstract.

Intelligence in a Nutshell

This paper concerns the relationship between neural-like computational networks, numerical pattern recognition and intelligence. Extensive research that proposes the use of neural models for a wide variety of applications has been conducted in the past few years. Sometimes the justification for investigating the potential of neural nets (NNs) is obvious. On the other hand, current enthusiasm for this approach has also led to the use of neural models when the apparent rationale for their use has been justified by what is best described as "feeding frenzy." In this latter instance there is at times a concomitant lack of concern about many "side issues" connected with algorithms (e.g., complexity, convergence, stability, robustness and performance validation) that need attention before any computational model becomes part of an operational system. These issues are examined with a view towards guessing how best to integrate and exploit the promise of the neural approach with other efforts aimed at advancing the art and science of pattern recognition and its applications in fielded systems in the next decade. A further purpose of the present paper is to characterize the notions of computational, artificial and biological intelligence; our hope is that a careful discussion of the relationship between systems that exhibit each of these properties will serve to guide rational expectations and development of models that exhibit or mimic "human behavior." [3]

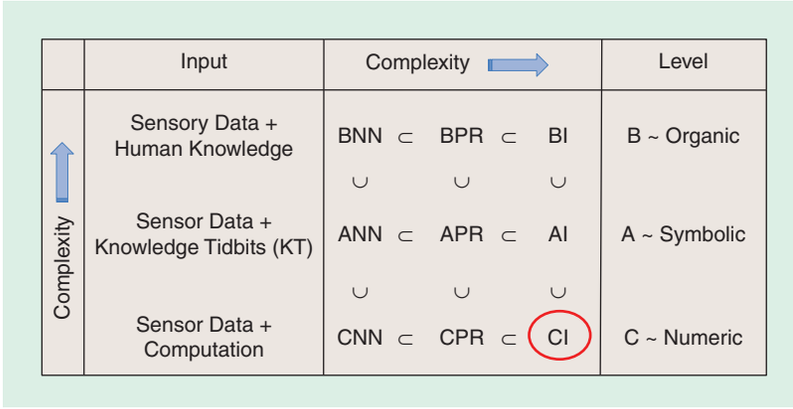

Figure 1. The ABCs: neural networks, pattern recognition, and intelligence [3].

To my knowledge, this was the first article that proposed a (somewhat loose) definition of the term *CI*. The meaning I intended for the term *CI* in [3] has been analyzed, ridiculed, supported, criticized, lionized, and so on, almost ad infinitum (or should it be ad nauseam?). See [3, Figure 1].

The abbreviations in Figure 1 are NN = neural network, PR = pattern recognition, I = intelligence. Earlier in [3] I had posted my definition of the ABCs:

- A = Artificial—nonbiological (man-made)
- B = Biological—physical + chemical + (??) = organic
- C = Computational—mathematics + man-made machines.

CPR, for example, stands here, with no pun intended, for computational pattern recognition. And so on. I meant for the inclusion symbols (both horizontally and vertically) in Figure 1 to be taken quite literally. In particular, I show CI as a SUBSET of AI. I believed this to be the case in 1992, and I still believe it today. You can see from the abstract above that my main focus was on computational neural networks (CNNs) and their relationship to AI, and more generally, to BI. I was particularly concerned about the way many writers spoke about NNs, as seen in the following quote.

Seductive Semantics in Science and Engineering

> Another objective [of the paper] concerns the use of "seductive semantics"; that is, words or phrases which convey, by being interpreted in their ordinary (non-scientific) usage, a far more profound and substantial meaning about the performance of an algorithm or computational architecture than can be readily ascertained from the available theoretical and/or empirical evidence. Examples of seductive phrases include words such as: neural, self-organizing, machine learning, adaptive, cognitive. [3]

The phraseology and semantics of computation that I was attempting to capture and discuss were exhibited in [3, Table 1] and repeated here as Table 1.

Has the debate about the relationship between NNs and (human) intelligence abated in the 20+ years since this was written? Hardly. Ray Kurzweil (the strong AI guy), Google's engineering director, recently affirmed his skepticism about what NNs can really achieve. In October 2014, commenting on research being performed at the Institute of Deep Learning in Beijing, he was quoted as saying, "There's more to human intelligence than just finding patterns" [14].

Does the term *AI* have a wider approval rating than NNs? Well, Richard Feynman had this to say about it in 1985:

> There is a great deal of work to try to develop smarter machines…This often goes under the name of artificial intelligence, but I don't like that name. Perhaps the unintelligent machines can do even better than the intelligent ones. [15]

Table 1. Defining the ABCs [3].

BNN	Hardware: The BRAIN processes your sensory inputs	Sensory data processing; how does it work?
ANN	CNN (+) KTs process sensor inputs and KTs in the style of the brain	Intermediate level processing. More than adaptivity, fault tolerance, and so forth. A human is always in the loop.
CNN	Biologically inspired models process sensor inputs in the style of the brain	Low-level sensor data processing.
BPR	Search for structure in sensory data	We are really good at it: how does it work?
APR	CPR (+) KTs	Intermediate level data processing that utilizes KTs (more than sensor data).
CPR	Search for structure in numerical data	This includes almost all NN procedures.
BI	Software: The MIND	Cognition, memory, action: how does it work?
AI	CI (+) KTs	Intermediate level cognition in the style of the mind.
CI	Low-level information analysis	Low-level cognition in the style of the mind.

Does this make you wonder if Feynman was advocating the same sort of distinction I was trying to make between AI and CI? Here's Elon Musk, Tesla founder and SpaceX CEO, warning of the dangers of artificial intelligence in 2014:

> I think we should be very careful about artificial intelligence. If I had to guess at what our biggest existential threat is, it's probably that…We are summoning the demon. [29]

It seems that any notion trifling with our beliefs about uncertainty and intelligence will always be controversial, doesn't it?

Here's Stephen Hawking as Cassandra in 2014:

> Once humans develop artificial intelligence, it would take off on its own and redesign itself…The development of full artificial intelligence could spell the end of the human race. [29]

The Musk and Hawking quotes are taken from an article written by Ray Kurzweil, "Don't Fear Artificial Intelligence" [29]. The author argues that Elon Musk and Stephen Hawking have misplaced fears. Kurzweil asserts that

> If AI becomes an existential threat, it won't be the first one. Humanity was introduced to existential risk when I was a child sitting under my desk during the civil-defense drills of the 1950s. [29]

Kurzweil seems to be saying don't worry about AI, it's not that hot! Compare these opposite-sides-of-the-fence views to the same type of controversy about fuzziness versus probability that continues to smolder and occasionally burn. It seems that any notion trifling with our beliefs about uncertainty and intelligence will always be controversial, doesn't it?

Finally, let me point to a very recent book written by David Gelernter titled *The Tides of Mind*: *Uncovering the Spectrum of Consciousness*. He is quoted by Von Drehle in [34]:

> As it now exists, the field of AI doesn't have anything that speaks to emotions and the physical body, so they just refuse to talk about it," ... but the question is so obvious, a child can understand it. I can run an app on any device, but can I run someone else's mind on your brain? Obviously not.

And so, the argument about what AI can and cannot do, what it is and is not, rages on. The CI community, on the other hand, seems content to simply invent and test models and algorithms that provide tools for the larger interests of the AI gang.

The IEEE Lowers Its Drawbridge for CI

Here is the e-mail that I sent to Roy Nutter, Russ Eberhart, Pat Simpson, Bob Marks, and Toshio Fukuda on 9 April 1992 that broached the term *CI* with the IEEE Neural Networks Council for the first time:

> *Thu Apr 9 12: 33: 11 1992*
> *To:* rsn@ece.wvu.wvnet.edu, rce@rti.rti.org, xm8@sdcc12.UCSD.EDU, *d43131*a@nucc.nagoya-*u.ac.jp*, *marks@blake.u.washington.edu*,
> *From:* jbezdek@trivia.coginst.uwf.edu
> *Subject: NEW name of council*
> *Status: R*
>
> I suggest the COMPUTATIONAL INTELLIGENCE COUNCIL, later to become the COMPUTATIONAL INTELLIGENCE SOCIETY.

Two months later, the name of the IEEE World Congress on Intelligent Systems was changed to the IEEE WCCI. The first WCCI, held in Orlando in 1994, combined the two major conferences of the Neural Networks Council (NNs, fuzzy systems [FSs]), with a new one on evolutionary computation (EC).

These moves by the IEEE Neural Networks Council essentially turned the term *CI* from a simple tune into a smash musical. (Readers interested in the early history of the Neural Networks Council/CIS should visit the IEEE CIS history center, where they will find a number of pdf files about events in the early years (1977–1996). There are also links to videotaped interviews with some of the important figures in the early days.) The role played by [3] in this regard is analogous to the role played by Dempster et al. [8] for the term *EM*. The main difference between the two is that [3] concentrated on the semantics of the term *CI*, while Dempster et al. not only altered the semantics of their field (by introducing the term *EM*) but also provided technical details and analyses for their intended use of the term. Channeling the words of Hartley in Meng and Dyk [6], the term *CI* became "the theme of an overpowering symphony." The next section tracks what seems to be the point of inflection for this simple tune.

Computational Intelligence Goes Viral

After the IEEE WCCI in Orlando in 1994, many people asked, what is CI? And many more simply jumped on the buzzword bandwagon and started calling it "their field," much the same way as a mathematician might say "differential geometry" in response to the question, "what field are you in?" Then the skies opened, and definitions literally flooded the planet. A number of writers began to supply their own interpretations as the heft of the term increased. Who else weighed in? Here is a representative, but by no means exhaustive, sample of comments about the definition of computational intelligence. Bob Marks summarized his view this way [16]: "Neural networks, genetic algorithms, fuzzy systems, evolutionary programming, and artificial life are the building blocks of CI." The Big 3 of NNs, FSs, and EC are shown in Figure 2. This was the

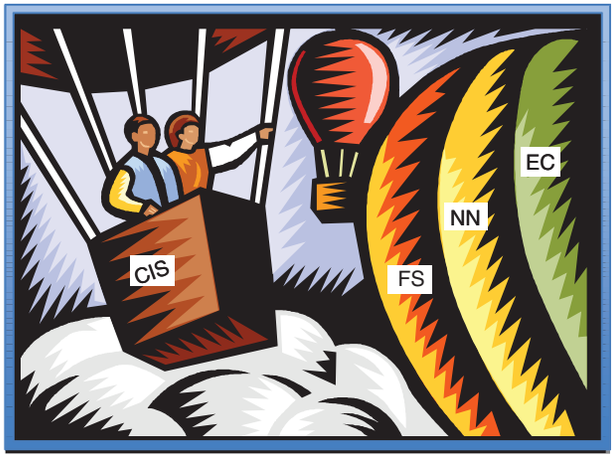

Figure 2. The Big 3 of the IEEE CIS (as the Neural Networks Council, 1993). Who are those hardy balloonists? Frank Rosenblatt and Lotfi Zadeh? Nick Cercone and Gordon McCalla? John McCarthy and Marvin Minsky? Bob Marks and Stephen Grossberg? Mickey Mouse and Daffy Duck? You decide. (Clip art image courtesy of Microsoft.)

official party line of the IEEE Neural Networks Council in 1993 for the basic disciplines making up *CI*.

I wrote a second paper for the book of invited papers associated with plenary lectures given at the 1994 WCCI [13]. There is not much in it beyond [3]. Russ Eberhart [17] offered a very different view of CI in 1995 and expanded on it in [18], where we find, "In summary, adaptation is arguably the most appropriate term for what computationally intelligent systems do. In fact, it is not too much of a stretch to say that *computational intelligence and adaptation are synonymous*." David Fogel critiqued my definition of CI in [19], and he argued that any definition that included the word *intelligence* necessitated discussion about and inclusion of the notion of (evolutionary) adaptation.

I tried one more time, in 1998, to come to grips with this term [20], but, by then, the term *CI* had acquired a life of its own. My attempt to characterize it as I had six years prior to this was summarily rejected by the discerning public (aka the academic community), who just seemed to want more from it that I could bring myself to offer.

The structural organization of the IEEE Neural Networks Council depicted in Figure 2 was reaffirmed at the 2 June 1996 ADCOM meeting of the Neural Networks Council by its then president, Walter Karplus, who stated that "CI substitutes intensive computation for insight into how the system works. NNs, FSs and EC were all shunned by classical system and control theorists. CI umbrellas and unifies these and other revolutionary methods." And in 2015? Visit the IEEE CIS website and read the current scope of the CIS.

Scope of the IEEE CIS

The Field of Interest of the Society shall be the theory, design, application, and development of biologically and linguistically motivated computational paradigms emphasizing neural networks, connectionist systems, genetic algorithms, evolutionary programming, fuzzy systems, and hybrid intelligent systems in which these paradigms are contained. [30]

The topics identified in this statement are not that far from the triumvirate of interests (the Big 3) seen in Figure 2 that were first publicized as CI in 1993. Indeed, if you compare the scope for 2015 to the scope of the Neural Networks Council in 1991, the changes that seem to define the basic topics defining CI are mostly cosmetic. But if we retrieve the current list of publication activities of the IEEE CIS from their website, we find a much broader set of interests.

Publications of the IEEE CIS

We currently publish three premier Transactions, the *IEEE Transactions on Neural Networks and Learning Systems*, the *IEEE Transactions on Fuzzy Systems*, and the *IEEE Transactions on Evolutionary Computation*.

Additionally, we co-sponsor the following: the *IEEE Transactions on Cognitive and Developmental Systems*, the *IEEE/ACM Transactions on Computational Biology and Bioinformatics*, the *IEEE Transactions on Computational Intelligence and AI in Games*, the *IEEE Transactions on Nanobioscience*, the *IEEE Transactions on Information Forensics and Security*, the *IEEE Transactions on Affective Computing*, and the *IEEE Transactions on Smart Grid*.

Through Councils we also support the following transactions: *IEEE Transactions on Nanotechnology* and the *IEEE Systems Journal*.

CIS publishes the high quality *Computational Intelligence Magazine* as a benefit of membership in CIS and sponsors an IEEE Press/Wiley book series on computational intelligence.

Judging from this list, the technical activities of the IEEE CIS reach far beyond its official scope. Does this list of publications affiliated with the CIS help us decide what the term *CI* means? For example, is cognitive development a subset of what people mean when they say computational intelligence? Well, not for me, and probably not for many others either. But it is interesting and provocative, for example, to see a title such as *IEEE Transactions in Computational Intelligence in AI and Games* under the IEEE CIS banner. CI in AI? This title certainly supports the assertion represented in Figure 1 that CI is a subset of AI and brings us full circle to the relationship between CI and AI. It would be impossible, in 2016, to provide you with an accurate estimate of the numbers of laboratories, books, papers, journals, institutes, degree programs, and so on that now use CI as if its essential meaning was as well understood as a term such as, for example, calculus. Well, so what? Let's press on and see what's happened since those early attempts to define CI.

Turf Wars and Buzzwords

The discourse about what CI is (or is not) has not diminished since the arguments about it began in 1992. Chapter 6 of *Encyclopedia of Life Support Systems* (*EOLSS*) volume titled *Artificial Intelligence* [21], authored by Bart Craenen and A. E. Eiben [22] in 2009, has the title—wait for it—*Computational Intelligence*! This chapter has a pretty accurate and complete recounting of the definitions of CI offered by Bezdek, Marks, Fogel, and Eberhart that I reviewed in the previous section. Below are some snippets of their discussion on this topic.

Craenen and Eiben Weigh in on CI

Although used fairly widespread, there is no commonly accepted definition of the term computational intelligence. Attempts to define, or at least to circumscribe, CI usually fall into one or more of the following categories:

- Conceptual treatment of key notions and their roles in CI
- "Relative definition" comparing CI to AI
- Listing of the (established) areas that belong to it…The relationship between computational intelligence and artificial intelligence has formed a frequently discussed issue during the development of CI. While the above quote implies they are synonyms, the huge majority of AI/CI researchers concerned with the subject sees them as different areas, where either
- CI forms an alternative to AI
- AI subsumes CI
- CI subsumes AI. [22]

If you scan the table of contents of the EOLSS volume *Artificial Intelligence* [21], you will find among its chapters these entries: "Ch. 6. Computational Intelligence"; "Ch. 7. Evolutionary Computation"; "Ch. 9. Neural Networks"; "Ch 10. Fuzzy Logic." Evidently the editor of [21] clearly felt that the presumptive Big 3 that CIS still uses as the cornerstones of CI, as well as CI itself, are subsets of AI. This is another data point arguing for the inclusion structure shown in Figure 1.

Craenen and Eiben suggest the addition of two more core topics, DNA computing (DNAC) and quantum computing (QC), to their interpretation of CI, which includes fuzzy systems computing (FSC), neural networks computing (NNC), and evolutionary computing (EC). They compare these five computational styles from three vantage points: 1) the computational medium, 2) parallelism, and 3) inspiration from nature. In terms of the computational medium, they group {FSC, NNC, EC} as silicon-based computing, while {QC, DNAC} use different environments for the actual calculations. In a somewhat more controversial opinion, they call FSC an outlier to the other four styles in terms of parallelism. In terms of natural inspiration, they state that FSC and QC do not belong to natural computation—that is, having been inspired by natural processes. I find this a bit puzzling, since the entire field of fuzzy systems is based on the idea of representing natural language computationally. Puzzling, but so what? This is a really good chapter to read, and it provokes a lot of thought about what CI is and is not. I recommend it.

On the other hand, have a look at the table of contents for the EOLSS volume *Computational Intelligence*, edited by Hisao Ichibuchi [23], in Table 2. To be sure, this volume is largely composed of topics related to the Big 3, but it would be pretty unfair to hold the CIS's hand to the fire for departing from its technical roots of 30 years ago. In the main the topics shown still represent the Big 3. For example, I regard support vector machines as a subfield of CNNs, but you may wish to call it something else. Swarm intelligence? It's a low-level optimization technique that seems to fit in the EC domain.

There are also some fields represented by publications under the IEEE CIS banner that don't have a sufficiently large current support set to warrant inclusion in [23]: virtual reality, financial engineering, autonomous mental development, game theory, bioinformatics, information forensics, and so forth. That's fine—topics come and go just like buzzwords, or cuisines. We see additional topics that reflect technological evolution in both AI and CI. For example, Chapter 8 in [21]

Table 2. The table of contents for the book *Computational Intelligence* [23].

1. History of Computational Intelligence (this article, long form, somewhat dated now)
2. History and Philosophy of Neural Networks
3. Recurrent Neural Networks
4. Adaptive Dynamic Programming and Reinforcement Learning
5. Associative Learning
6. Kernel Models and Support Vector Machines
7. The Genesis of Fuzzy Sets and Systems—Aspects in Science and Philosophy
8. Design and Tuning of Fuzzy Systems
9. Fuzzy Data Analysis
10. Introduction to Interval Type-2 Fuzzy Logic Systems
11. Rough Set Approximations—A Concept Analysis Point of View
12. Evaluating the Evolutionary Algorithms—Classical Perspectives and Recent Trends
13. General Framework of Evolutionary Computation
14. Evolutionary Multiobjective Optimization
15. Memetic Algorithms
16. Swarm Intelligence
17. Artificial Immune Algorithms in Learning and Optimisation
18. Hybrid Computational Intelligence
19. Computational Intelligence and Medical Applications
20. Computational Intelligence and Smart Grids
21. Computational Intelligence and Computational Systems Biology
22. Computational Neuroscience
23. Neuromorphic Engineering
24. Brain-Machine Interface

bears the title "Quantum Computing." Chapter 15 in [23] is titled "Memetic Algorithms." These topics are at once fields, but they are also fully formed buzzwords. Let's turn to that idea now.

Buzzwords Are One Coin of the Realm

Why has the term *CI*, and discussions about its presumptive meaning, become so popular and pervasive? Well, first and foremost perhaps, it's a turf war of sorts between (people who say they are "in") CI and AI. Looking back, you might wonder, for example, why the song "White Christmas" is a monster hit that has been covered by hundreds of performers and continues to sell millions of records (including buyers and listeners who have never even seen snow), while "Jingle Bell Rock" is relegated to a bit of airtime on oldies stations every December? Everyone has his or her own theory about stuff like this, so here's mine.

Any Google search on "buzzwords gone bad" yields page after page of links to articles about buzzwords in fashion design, government labs, resume writing, politics, Internet marketing, and on, and on, and on.

The introductory paragraphs of the first issue of the Canadian journal *IJCI* [24] contain a sentence that I think is extremely relevant. Explaining their choice for the title of the journal, Cercone and McCalla wrote, "The name also seems short enough to be catchy." This sentence concentrates on the importance of choosing a good buzzword. Before you dismiss this as cynicism or scorn, let me reassure you that I mean absolutely no disrespect to Nick Cercone and Gordon McCalla or to the publishers of that journal. On the contrary, I admire their gumption and their foresight for admitting to their readers that catchy is important. It's important for all of us too.

Here's a different sort of example of what I mean. There is an IOS Press journal *Intelligent Data Analysis*. What kind of articles do you expect to find in it? Can you imagine doing, publishing, or reading about *un*intelligent data analysis? (Okay, we are all guilty of doing unintelligent data analysis from time to time. Correlate this with Richard Feynman's remark that "Perhaps the unintelligent machines can do even better than the intelligent ones.") This is an example of how (buzz)words like *intelligent* are easily abused.

A quick Internet search on the query "buzzwords gone bad" yields a link to a note from Jonathan Chizik dated 9 August 2011 that says, "keynote speaker here just said one of his company's tactics to succeed is to 'think intelligently'…as opposed to what, thinking stupidly?" To which, David McBride replied the next day: "They should proactively leverage their synergies by trying harder to think intelligently." [36]. Now do you see what I mean?

Any Google search on "buzzwords gone bad" yields page after page of links to articles about buzzwords in fashion design, government labs, resume writing, politics, Internet marketing, and on, and on, and on. Here's part of an article published in *Marketing Today* about the pervasive and destructive nature of buzzwords in business and industry:

> Companies claiming to create "synergies" in an effort to develop a "value-added" "paradigm" that leads to new "solutions" may want to be strategic in another way: not going overboard with cliché phrases and industry jargon…Buzzwords and industry jargon are a form of shorthand used by people within a particular company or profession, but they can be confusing or even seem exclusionary to individuals outside of that field…When these words are overused, they can lose their impact altogether. Part of the motivation to use buzzwords can be attributed to a desire to demonstrate your expertise, but this can often backfire… As society and pop culture evolve, old catchphrases die out, while new jargon is born. [32]

Note the final sentence: "As society and pop culture evolve, old catchphrases die out, while new jargon is born." Sound familiar? Do you think this is a bit harsh? The implication in this quote is that buzzwords are bad. On the other hand, an editorial written by Mark Radford in October 2004, about the use of buzzwords in the software development industry includes the following excerpt.

Buzzwords Are Useful

> Perhaps we should learn from experience with TDD [Test-Driven Development] and take stock of practices that we would like to see adopted more widely, and then sharpen our skills in coming up with buzzwords and/or buzz-phrases that are sufficiently *catchy* for the majority of developers and/or managers. Then, as what happened to TDD happens to other useful practices, maybe the "Buzzword Adoption Pattern" will start to emerge. [25]

There are two interesting points about this quote. First, Radford uses the word *catchy* (which I have made italic for emphasis) as a desirable quality for good buzzwords, just as the founding editors of *IJCI* did. And second, Radford does not dismiss the buzzword as an annoying artifact of bad speaking and writing. Instead,

he advocates an almost formal approach to the adoption of useful buzzwords. Ask yourself right now: is computational intelligence catchy? Maybe a little less so than 20 years ago, right?

Apparently buzzwords come in two flavors: good buzzwords and bad buzzwords. A quote from the website About.com/Grammar and Composition supports this explicitly:

> The Fortune 500 communications professionals surveyed for this stylebook are split down the middle when it comes to the use of buzzwords in business writing. Approximately half disdain buzzwords of any kind while the other half think some buzzwords are effective (for instance, bottom line, globalize, incentivize, leverage, paradigm shift, proactive, robust, synergy and value-added). As a general rule, use buzzwords judiciously, always keeping the readers in mind. "If a buzzword is lively and capable of injecting some spunk into a dull sentence (and it does not alienate the readers), then use it. (Cunningham and Greene, 2002)" [33]

Ask yourself another question: is computational intelligence lively? Does it spark your interest? Does it spark the interest of your students and colleagues? And super importantly perhaps—does it catch the eye and tickle the fancy of a dean or program director who might fund your research? I believe that good buzzwords are an integral part of science and engineering! Below is the explanation I offered for the phenomenal growth of the term CI in 1998.

> **Bezdek Weighs in on CI—Again!??**
>
> Why [is CI so popular]? Well, I'm not really sure. But I suspect that there are two main reasons. First, the technical community is somewhat disenchanted with (perceptions, anyway, of) the basis of AI research. I will argue here that AI tackles really hard problems, and that goals may have been set unrealistically high in the early days of AI. And second, scientists and engineers have a certain hunger—maybe even a justifiable need—for new terms that will spark interest and help sell papers, grant proposals, research and development programs and even products. These are the defining characteristics of the so-called buzzword, of which CI is currently a prime example. After all, computational neural networks in their best-known form have been around since 1943 [26], evolutionary computation since 1954 [27], and fuzzy sets since 1965 [28]. Funding entities and journal editors get tired of the same old terms. Is my attitude about this a little too cynical? Probably. But I think it's pretty accurate. [20]

CI has in fact become a fairly high-level term that encompasses lots of technical activities, much like the terms mathematics or physics.

Have things changed in 2016? I don't think so. It would be trivial for me to dismiss CI as just a good buzzword, but certainly that's a large part of its appeal and a logical explanation for its astonishing growth. But when Prof. X tells you that he or she has worked in the area of computational intelligence for over 35 years, it makes you wonder how people outside of our technical community will interpret such a statement. After all, if I tell you that Prof. Y is an English professor, you may wonder in what specialty—poetry, Yeats, science fiction, novellas, American literature, grammatical construction—but you will certainly have a pretty good general idea about what Prof. Y must do. Would you have the same understanding about Prof. X? I am guessing no.

Where Are We Today?

I think the debate about CI versus AI, including questions such as "Is it CI or AI?" or "Does one of these areas include the other, do they overlap?" and so on are really pretty moot today. I agree with Craenen and Eiben, who remark in [22] that the boundary between CI and AI has diminishing borders. They point out the symbiosis of these two areas by noting that topics such as EC, FS, and NN are frequently given a broad treatment in AI textbooks, while core publications such as the *International Journal of Computational Intelligence and Applications* consider symbolic AI as one of the areas integrated into CI.

CI has in fact become a fairly high-level term that encompasses lots of technical activities, much like the terms *mathematics* or *physics*, both of which can be divided into finer sets of more specialized areas. For example, just as in mathematics, there are differential equations, ordinary differential equations, and linear ordinary differential equations, we can break down each branch of CI, e.g., EC genetic algorithms, mutation, and so on. And in the vernacular of the day, when we say we work in CI, it's a branding (of us) by this term. I find no harm in this, nor should I take offense if others disagree. After all, most of us don't care whether the Houston Astros baseball team play their games in Astro Field, Enron Field, or Minute Maid Park, do we? It's still baseball; only the name of the playing field has changed over the years. For that matter, the Houston Astros began as the Colt 45s, but

that was when Armstrong and Aldrin landed on the moon. And the rest, as they say, is history.

At the end of the day, I don't think it's very important to categorize the meaning of this term anyway. The term itself has become a monster hit even if it doesn't suit your taste. And after all, what I say or think CI means is nothing more than my opinion. But I'm happy to have one, because as (I recall), Herb Caen said many years ago in the *San Francisco Chronicle*, "any clod can have the facts—having an opinion is an art" [35]. So, now you have mine, and the fat lady can sing.

About the Author

James C. Bezdek (jcbezdek@gmail.com) earned his B.S.C.E. degree in civil engineering from the University of Nevada, Reno, in 1969 and his Ph.D. degree in applied mathematics from Cornell University in 1973. He is a past president of the North American Fuzzy Information Processing Society, the International Fuzzy Systems Association (IFSA), and the IEEE Computational Intelligence Society [(CIS) when it was the Neural Networks Council]; the founding editor of the *International Journal of Approximate Reasoning* and *IEEE Transactions on Fuzzy Systems;* a Life Fellow of the IEEE and IFSA; and a recipient of the IEEE Third Millennium medal, the IEEE CIS Fuzzy Systems Pioneer Award, the IEEE CIS Rosenblatt Award, and the Information Processing and Management of Uncertainty Kampé de Fériet Award. He is also with the Department of Computing and Information Systems, University of Melbourne, Parkville, Victoria, Australia. His interests include woodworking, optimization, grandchildren (14), clustering in big data, cigars, cluster validity, fishing, feature analysis, blues music, poker, and visual clustering. Retired in 2007, he will be coming to a university near you soon.

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