Editorial
Intelligence: Computational Versus Artificial

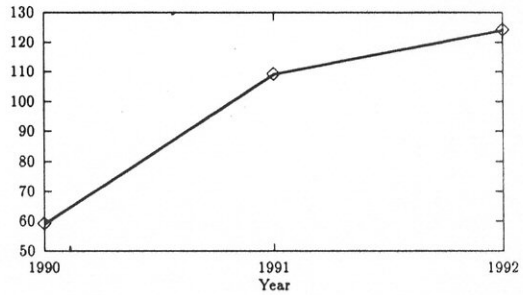

Fig. 1. Papers in the IEEE TRANSACTIONS ON NEURAL NETWORKS.

In order to distinguish *artificial intelligence* from neural networks and its sister fields, the term *computational intelligence* (CI) has been suggested.

The IEEE Neural Networks Council—the sponsors of the IEEE TRANSACTIONS ON FUZZY SYSTEMS and the IEEE TRANSACTIONS ON NEURAL NETWORKS—is sponsoring, in 1994, the first 1994 IEEE World Congress on Computational Intelligence (WCCI).* WCCI will bring together, in time and space, three premier CI technical meetings: the IEEE International Conference on Neural Networks (ICNN), the IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), and the IEEE Conference on Evolutionary Programming (EP). All WCCI participants can attend a magnificent Plenary Symposium with the theme of Computational Intelligence: Imitating Life. Some of the best known CI researchers will speak on the topic. The plenary speakers' contributions will be published as a separate book.

WCCI will be held at the Walt Disney Dolphin Hotel in Orlando, FL. The facilities are, by far, the most incredible I have ever visited. WCCI will be sharing the facilities with soccer aficionados attending the World Cup, which is being held in Orlando at the same time.

Neural networks, genetic algorithms, fuzzy systems, evolutionary programming, and artificial life are the building blocks of CI. WCCI will be an important component of the mortar.

Although others have used the phrase, the first definition of *computational intelligence* of which I am aware was offered by James C. Bezdek [1], the Editor-in-Chief of our sister journal, the IEEE TRANSACTIONS ON FUZZY SYSTEMS. In a delightful essay, he contrasts the ABC's of intelligence: *a*rtificial, *b*iological, and *c*omputational. In the strictest sense, computational intelligence "depends on numerical data supplied by manufacturers and (does) not rely on 'knowledge'." Artificial intelligence, on the other hand, uses what Bezdek calls "knowledge tidbits." Heuristically constructed AI, such as expert systems, is an example.

Even though the boundary between CI and AI is not distinct, we can, making certain assumptions, monitor the volume of research activity in each. Indeed, the separate identities of CI and AI are confirmed by inspection of the recent volume of publishing and patent activity.

The growth of CI is manifested in the volume of papers in the IEEE TRANSACTIONS ON NEURAL NETWORKS. In 1990, its first year, the IEEE TRANSACTIONS ON NEURAL NETWORKS had 59 papers (including letters). This and the paper count in subsequent years is shown in Fig. 1. This year and last, the IEEE TNN had a 10% page overrun.

A more global view comes from perusal of the Information Service for Physics and Engineering Communities (INSPEC) data base compiled by the IEE and the IEEE, and recent United States patent activity. The INSPEC data base contains titles, authors, and abstracts from over 4000 journals and is augmented with entries of books, reports, and conference records. It is focused on the fields of physics, electrical engineering, computer science, and electronics. Over one million entries have been logged into INSPEC since 1989. Contents are updated monthly. Searches for key words are performed over titles, authors, journal titles, and abstracts.

U.S. patent data was obtained from the Classification for Search Support Information System (CASSIS). Searches are also performed over titles and abstracts.

Statistics from INSPEC and CASSIS are neither the perfect nor the only measure by which to gauge the vitality of a field. They are, however, quite useful in monitoring trends and relative activity. CASSIS, in particular, is vital for monitoring applications and implementation. Patent data, though, has a

*The call for papers for WCCI, ICNN, FUZZ-IEEE, and EP are in this issue.

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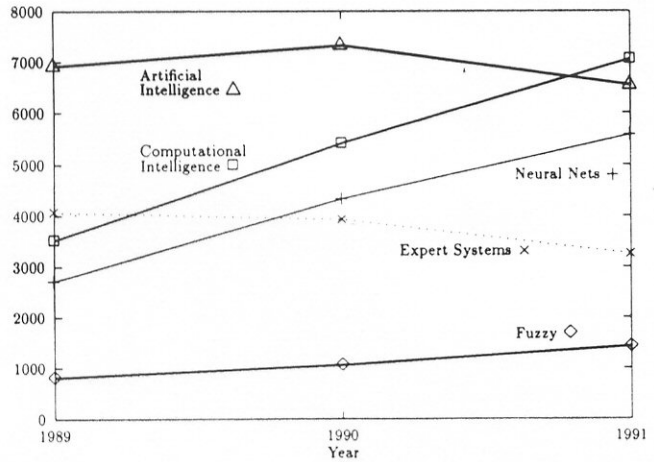

Fig. 2. Numbers of papers according to the INSPEC data base.

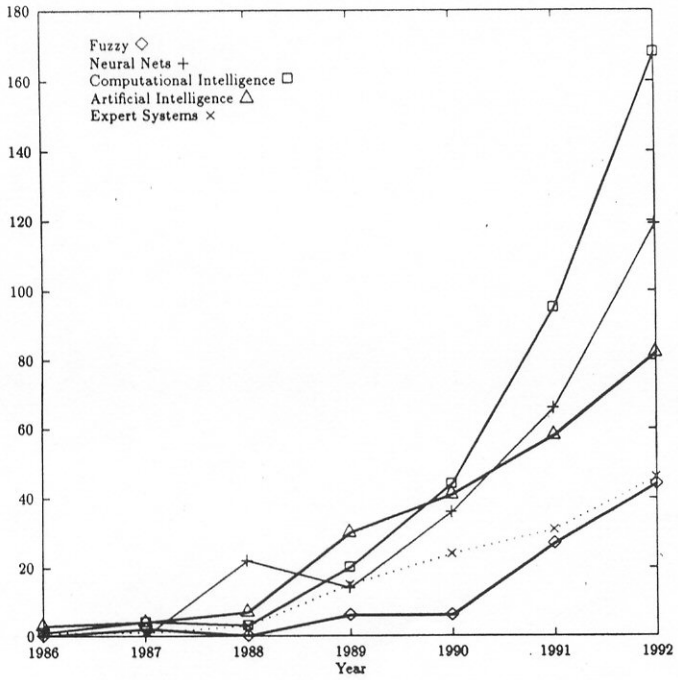

Fig. 3. Patents activity according to the CASSIS data base.

greater time delay in the measure of activity than does INSPEC data. The following are searches performed after the July 1993 INSPEC update and July 20, 1993 CASSIS update.

Since 1989, there have been an astounding 16 574 INSPEC entries logged for neural networks [2]. Almost half (7429), are associated with IEEE activities. A year-by-year breakdown (Fig. 2) reveals a trend similar to that of papers published in the IEEE TRANSACTIONS ON NEURAL NETWORKS. The data for 1992 is not complete. I have been told that entries for 1992 are received and entered into INSPEC well into 1993.

For patents, CASSIS lists 262 neural network patents since 1969. Fig. 3 shows nearly all of them have been issued in the past few years.

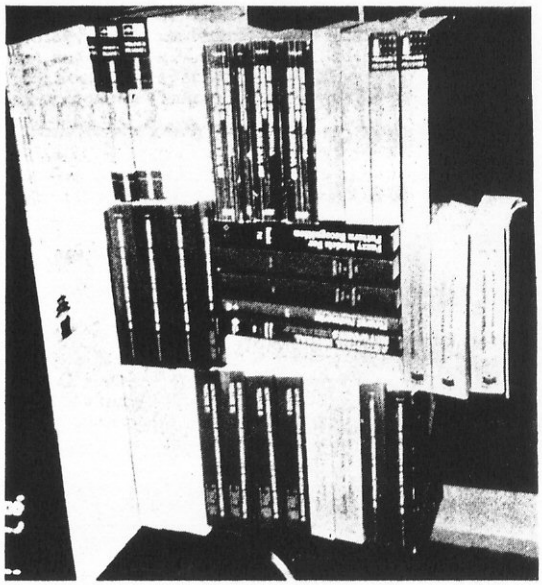

Fig. 4. CI material generated by IEEE Neural Networks Council activities dating from 1987. Included are the IEEE TRANSACTIONS ON NEURAL NETWORKS, the IEEE TRANSACTIONS ON FUZZY SYSTEMS, the *CoNNection Newsletter*, IEEE Press books, and Conference Proceedings from ICNN, FUZZ-IEEE, and IJCNN. Not shown are the fuzzy and pioneer video series and the CD ROM conference records. Almost half of the INSPEC neural network entries are associated with IEEE activities. (Photo Credit: Jeremiah J. Marks)

Only 10% of the INSPEC artificial intelligence [3] entries were also flagged as works in neural networks. As the graph in Fig. 2 shows, research activity in AI, as gauged from the number of INSPEC entries, remains quite high [4]. Cumulatively, there are 28 166 AI entries in INSPEC; 5832 are associated with IEEE activities. A total of 266 patents have been issued for AI.

Expert systems are arguably the most successful application of AI. A total of 131 expert systems patents have been issued and, as seen in Fig. 3, the volume trends upwards.The number of INSPEC entries for expert systems, on the other hand, clearly trends down in Fig. 2. There are 15 575 expert systems entries in INSPEC.

Also shown in Fig. 2 is a steadily increasing publication volume in fuzzy systems. A total of 4811 fuzzy INSPEC entries have been logged since 1989, 22% of them cross categorized in the expert system category and 12% with neural networks. Fuzzy patents total 109.

Computational intelligence [5] has experienced remarkable growth and has 21 307 INSPEC entries and 384 patents. Yearly breakdowns are shown in Figs. 2 and 3. In 1991, there were 7050 INSPEC listed works in CI and 6540 in AI. The CI patents (168) in 1992 is over double that in AI (82).

How much overlap is there between the fields of CI and AI? Judging from the numbers, not a lot. Only 14% of the INSPEC entries identified as AI were also categorized as CI. Only one third of the patents fell in both categories.

Although seeking similar goals, CI has emerged as a sovereign field whose research community is virtually distinct from AI. It will be fun to follow the evolution of both in the coming years.

References and Notes

[1] J. C. Bezdek, "On the relationship between neural networks, pattern recognition and intelligence," *Int. J. Approximate Reasoning,* vol. 6, pp. 85–107, 1992.
[2] Search words for "neural networks" used are neural net(s), neural network(s), and neurocomputer(s).
[3] Search words for "artificial intelligence" used are artificial intelligence, expert system(s), machine intelligence, and intelligent system(s).
[4] There also was a single INSPEC entry for "artificial stupidity."
[5] Search for computational intelligence included the search words used for neural networks as well as fuzzy, genetic algorithm(s), evolutionary programming, and artificial life.

Acknowledgment

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