Editorial

Artificial-intelligence-augmented systems

1. Artificial intelligence (AI)

Today, AI is an established and widely recognized field in its own right, that traversed the research and teaching circles of universities and eventually entered the production centers of industries. The field of AI is considered to have been born at a 2-month workshop held in Dartmouth College, Hanover, NH, USA, in the summer of 1956. The workshop was organized by Marvin Minsky and John McCarthy; the name 'artificial intelligence' was coined by McCarthy [5,11]. Now, after more than 45 years of research and development in the areas of *natural language understanding*, *problem solving and search*, *knowledge representation and reasoning*, *learning*, *vision* and *robotics*, we find the developed AI methods being applied everywhere. They range from everyday consumer products, such as washing machines, cameras and automobiles, to complex intelligent systems in the manufacturing, telecommunications and space exploration industries. In addition to the numerous branches of industry, AI-based software components are found in education, law, art and music and—last but not least—in medicine.

Let us now attempt to define AI in general. I would like to present two definitions:

Definition 1. AI is a field of science and engineering concerned with the computational understanding of what is commonly called intelligent behavior, and with the creation of artifacts that exhibit such behavior ([11], p. 54).

The term 'AI' is defined as applying the notion of 'intelligent behavior', which, in itself, needs explanation. This sort of infinite recursion introduced into the definition of AI may be resolved by specifying 'intelligent behavior'. We all do have a common sense under-standing of what is meant by intelligent behavior. However, 'intelligent behavior' is a rather comprehensive, even holistic term, embracing nearly all human actions and responses to stimulation. Such a broad term defies precise definition.

Moreover, the goal of creating artifacts that behave intelligently seems to be a complex and even unmanageable task, at least at the present time. The creation of an artificial unity with intelligent behavior still belongs to the realm of science fiction. This is illustrated in the recent motion picture *A. I. Artificial Intelligence*, directed by Steven Spielberg [1]. An android boy is imprinted with a sequence of verbal instructions to love "his" human mother who lost her human son and whom the android is supposed to replace. A machine is taught love, an emotion we usually consider one of the deepest of human feelings and that is part of our intelligence as humans. An artificially intelligent being endowed with rational

and somatic, social and emotional intelligence is far beyond our present reach (surprisingly enough, the robot boy is finally the only individual who is able to report on humans and humanity to alien visitors).

I prefer a less far-reaching definition of AI, which is much more expressive of AI in medicine.

Definition 2. AI is the science of the artificial simulation of human thought processes with computers ([3], backcover).

Definition 2 avoids the infinite recursion introduced in the first one. Instead, it focuses on human thought processes, a broad but more concrete term. It allows for the artificial simulation of *separate* human thought processes singled out from complex intelligent behavior and of *any* human thought process as long as it contributes to what we consider intelligence. Thus, intelligent behavior need not be exhibited by an artifact as a whole and with all its facets simultaneously, but may occur as a single constituent of a larger whole and be active with one of its intelligent facets at a specific point in time.

It is the decomposition of entire thought processes and their separate artificial simulation—also of simple instances of "thought"—that make the task of AI manageable. Basically, there is no principal reason such as a law of nature to assume that AI systems with extended intelligent behavior will not be part of our future. But, by adopting definition 2, a functionality-driven science of AI that extends humans through computers and computer programs step by step can be immediately established. Based on these considerations, it may be investigated whether a certain confined "intelligent" functionality, a modest or an ambitious one, can be realized and, if yes, implemented in a computer system. Such a system is then an AI-augmented system. This has already been accomplished by adding AI-based functionality such as *speech recognition*, *schedule optimization*, *differential diagnosis*, *competitive learning*, *pattern recognition* or *autonomous robot transportation* and many, many more solutions to our present computer systems and thus establish systems with patterns of intelligent behavior.

We should, therefore, abandon the Imitation Game introduced by Alan Turing in 1950 [12]—also known as the Turing Test—as a measure of the success of traditional AI. The Imitation Game, in which a machine is said to exhibit intelligent behavior when its responses to questions are indistinguishable from the responses of a human being, only accepts human-like artifacts in their entirety as being AI. Decomposed single instances of intelligent behavior would not pass. As opposed to this, the goal of making artificial humans who can replace us should be replaced by the objective of making intelligent artifacts that artificially simulate human thought processes and thus amplify and support our own cognitive abilities [4].

2. AI in medicine

When Kazem Sadegh-Zadeh, a professor of the theory of medicine in Münster, Germany, founded the journal *Artificial Intelligence in Medicine* in 1989, he wrote the following in his editorial for the inaugural issue:

. . . AI may be viewed as a useful aid that might help physicians utilize available scientific knowledge and thereby enhance their expert performance for the patient's and societies' good ([6], p. 3).

The editorial was entitled *Machine over Mind*, an allusion to *Mind over Machine*, a book written by Hubert and Stuart Dreyfus in 1986 [2]. The Dreyfus brothers postulate that a computer will never be able to match the human mind and human expertise. Sadegh-Zadeh not only rejects the Dreyfus thesis—as well as the arguments concerning the Chinese Room example introduced by John Searle [10], where Searle rejects any possible 'understanding' on the part of computers or computer programs—but also explains his theory of an ongoing technical revolution that leads (or has already led) to a Machina sapiens [8]. Machina sapiens is a global megamachine, a non-biological machine mind that is both qualitatively and quantitatively different from the human mind. He postulates a biosphere/technosphere hypercycle, where machines are continuously introduced into the cycle as catalysts. He states that knowing this contributes to a better awareness of what we are doing when we research medical AI.

After transferring the journal *Artificial Intelligence in Medicine* from the German Burgverlag to the international publishing company Elsevier Science Publishers B.V., Sadegh-Zadeh wrote in his second editorial for the journal:

To remain naturally unintelligent or to become artificially intelligent? This is the question, and in dubio pro aegro, *the answer* ([7], p. 2).

Although quite provocative, what Sadegh-Zadeh says is that medicine should *be able to overcome the idiosyncratic modes of physician performance and expertise that have been characteristic of medicine for millennia* ([7], p. 1). Furthermore, he writes in ([9], p. IX) *that one should avoid the mistake of viewing AI in patient care as a mere application of formal methods, methodologies and theories to standard medical subjects and domains, for AI in patient care research and technology is not an applied science, but a novel and original engineering science of clinical practice.*

The above-mentioned convictions of Sadegh-Zadeh served as the impetus to introduce the journal *Artificial Intelligence in Medicine* (to the best of my knowledge) and also urged him to serve as its chief editor for the last 13 years. He, together with the associate editors—here most notably Elpida Keravnou-Papailiou—(I was also one for some time) made it a widely accepted scientific journal with a high international reputation.

Along with those who work in or are interested in the field of AI in medicine, I would like to thank Professor Kazem Sadegh-Zadeh and his associate editors for their excellent work for introducing this fascinating journal and for nurturing it with care and expertise for all these years.

I sincerely hope that the coming period under the new editorship will carry forward the magnificent work done by Kazem Sadegh-Zadeh, the associate, assistant, and book review editors and the members of the advisory board.

Through recent advances in science and technology, there will be a slight extension of the intended aims and the scope of the *Artificial Intelligence in Medicine* journal. The aim is to publish original articles from a variety of interdisciplinary perspectives concerning the theory and practice of AI in theoretical and clinical medicine, in human biology, biomedicine and bioinformatics and in health care, health and medical technology.

The areas that are of particular theoretical interest include *knowledge representation*, *automated reasoning*, *intelligent communication*, *computational theories of learning*, as well as *signal*, *image*, *speech* and *natural language understanding*. The theory, engineering and practice of *computational*, *knowledge-based* and *agent-based intelligent systems* in clinical medicine, biomedicine and health care and of *software intelligence* built into medical instruments, equipment, robotic or prosthetic devices are of special practical interest. Further topics are methodological, philosophical, ethical, psychological and social aspects of medical AI.

The journal features original research contributions, tutorials on new methods, research area reviews and bibliographies, editorials, book reviews and letters to the editor.

In summary, this should be the overall objective under which research reports are published in the international journal *Artificial Intelligence in Medicine*:

> To publish research results—*either* sound theoretical *or* promising practical results from which lessons can be learned—on AI methods developed for or applied in the large body of medicine.

Let's work together to make this objective a reality!

References

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