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Machines that Dream: a New Challenge in Behavioral-Basic Robotics

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Abstract

The digital revolution is transforming contemporary society. Connective intelligence is an emerging property deriving from the embedding of intelligence into the connected data, concepts, applications, and people. Furthermore, the progress in behavioral-basic robotics opens new fields of innovative investigation.

In this challenging context, might it make sense to provide machines with dreaming-like functions? Indeed, machine inactivity can be assimilated to the sleep state of living beings. Furthermore, when dreaming, we can interact with what we take to be other individuals and things and, in certain respects, the same happens in the virtual world.

This paper highlights some new directions that have emerged in the field of Artificial Intelligence, focusing on the total Turing test and dreaming machines.

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1. Introduction

In the 1990s it was argued that software configurable hardware and software that accelerates the simulation of digital devices could be used to build, in the near future, machines that are capable of evolution[1].

Indeed, in those years, various forms of machine-simulated evolution were proposed, although doubts were also expressed as to their adequacy for real life contexts[2].

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At the time, Calvin, an American theoretical neurophysiologist, suggested the implementation of an autonomous robot, the Darwin machine. In his short essay "The brain as a Darwin Machine"[3] Calvin argued that parallel computer simulation of human brain activity suggested that human beings would have a better claim on the title Homo seriatim than Homo sapiens, also due to the fact that humans are more consistently serial than wise. In accordance with this presumption, he hypothesized a machine that would have the capacity to chain together stochastic sequences of data following the analogous ways of Darwinian evolutionary biology. This machine was supposed by Calvin to be able to shape thoughts in milliseconds rather than millennia, using innocuous remembered environments rather than noxious real life ones.

Nowadays, the growth of information systems, and of the internet in particular, continues to inspire the parallel between the human brain and computer-based artificial systems[4,5]. Despite the fact that the market is currently oriented towards artificial systems that are still based on Newtonian physics and on the assumption that every element obeys simple and static rules, it has been observed that the experience of the internet and the progress made in robotics suggests a different way of designing the next-generation of information systems and robots[6,7,8]. Indeed, new information systems and robots might not be controlled but be self-organized as the result of autonomous and self-determining software or firmware agents.

This paper focuses on two issues related to the new wave of intelligent systems. The first concerns the Turing test and its revision in the light of the perspective of so-called Android science. The second reports on dreaming machines, an emerging research field that can stimulate new investigative perspectives, either in Artificial Intelligence (AI) or in cognitive and behavioural psychology.

2. Old and new intelligent systems

In the early 1960s, in an article illustrating the state of art of AI at the time, Minsky, the American cognitive scientist and co-founder of the Massachusetts Institute of Technology's AI laboratory, highlighted the lack of a generally accepted theory of intelligence[9].

Fifty years later, the definition of intelligence continues to be controversial[10], although considerable advances have been made in the cognitive sciences and in the five areas of AI that Minsky examined in his article: Search, Pattern-Recognition, Learning, Planning, and Induction.

However, something has changed in AI research over the past decades[11], particularly in the last few years[12]. Nowadays, the most current research focuses on specific scientific and engineering problems, and maintains a distance from the idea of performing the full range of human cognitive abilities. Furthermore, the research focuses on the interaction of programs and machines with the environment and with people.

Only a small number of researchers are now involved in so-called General Artificial Intelligence (AGI), whose aim is the development of programs and machines that can successfully perform any intellectual task that a human being can.

Recently, AI applications, notably in the form of neural networks and expert systems, can be found all around us. They are widely used in the fields of medicine, robotics, law, stock trading, etc., while intelligent programs are employed by the military, as well as in factories and homes. Moreover, experts forecast that, in the near future, speech recognition systems will be able to communicate with humans, both by text and voice, in unstructured English.

Due to the diffusion of the internet, a relatively new but expanding sector of current AI research is that of the Semantic Web. This will provide an infrastructure for allowing Web data to be used by a computer, making new powerful forms of information retrieval possible, as well as strengthening the fast-growing area of data mining, which is part of a process called Knowledge Discovery in Databases (KDD) that includes data selection, data cleaning, pre-processing of data, and data transformation.

Finally, the main changes in AI concern robotics and the attempt to simulate human social attitudes[13,14]. In traditional Artificial Intelligence, robot brains were conceived as serial processing units. The keystone was a Cartesian approach based on:

- Hierarchical organization of knowledge
- Symbolic manipulation
- Automatic reasoning
- Planning as problem-solving

- Model Building
- Functional Decomposition strategies

Conversely, the approach to robotics taken recently is quite different. It is behaviour-based, and presumes that “intelligence” is the result of interaction among an asynchronous set of behaviours and the environment. The keystone concepts behind the behaviour-based approach are (see Fig. 1):

- Embodiment
- Situatedness (social behaviour and interactions in a given physical environment populated by humans, animals, objects)
- Emergent complexity (capability to operate in an environment forming more complex behaviours as a collective action of different agents)
- No planning

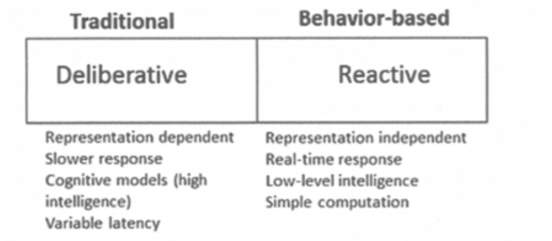

Fig. 1. Traditional vs. behaviour-based robots.

In the behaviour-based view, a physical robot is:

> […] a machine that is able to interact physically with its environment and perform some sequence of behaviours, either autonomously or by remote control[15].

Despite the alarm of many researchers concerning the possible impact of super-intelligent machines[16], the creation of a machine with equal or superior intelligence to human beings doesn’t seem to be a possibility, at least in the foreseeable future.

Nevertheless, after more than 60 years, the Turing test continues to attract the interest of researchers[17], and some elements of integration have been proposed for adapting it to the new perspectives of robotics.

3. The Turing test and Android science

In 1950, Turing suggested the Imitation Game to replace the, for him, too ambiguous question “can machines think?”[18].

Turing proposed that a human player (the interrogator or evaluator) would interrogate two other, hidden, players, a computer and a human, using written questions and receiving written responses in natural language. The task of the evaluator would be to determine which of the players was the computer and which was the human. Turing predicted that by the year 2000, technological progress would produce a computer extraordinarily powerful enough that a program would be able to fool the average evaluator for 5 minutes on about 70% of occasions.

Following this, other scientists have varied Turing’s original idea, and various similar tests have been proposed. The most widely known of these are:

- The Coffee Test[19]. A machine is given the task of going into an average American home and figuring out how to make coffee. It has to find the coffee machine, find the coffee, add water, find a mug, and brew the coffee by pushing the proper buttons
- The Robot College Student Test[20]. A machine is given the task of enrolling in a university, taking and passing the same classes that humans would, and obtaining a degree
- The Employment Test[21]. We have to test whether or not we have the capability to automate a specific job.

Turing's test deliberately avoided any direct physical interaction between the interrogator and the computer, since Turing deemed that the physical simulation of a human was unnecessary for intelligence.

3.1. The Turing total test

Recently, as a result of research in the field of Android Science, a new version of the Turing test, the so-called total Turing Test, has been formulated. In the early 2000s, Ishiguro coined the term "Android Science" to designate the interdisciplinary framework that encompasses two complementary approaches: the use of cognitive science to build very humanlike robots, and the use of robots for verifying hypotheses to understand humans[22].

Ishiguro suggested a total Turing test that includes a video signal so that the interrogator can test the subject's perceptual abilities, as well as the capability to pass physical objects through a hatch. Accordingly, to pass the total Turing Test, the android needs to be equipped with vision tools to be able to perceive objects and movement tools to be able to move them around.

Ishiguro claimed that the original Turing test was designed to evaluate the intelligence of a computer under the assumption that mental capacities could be abstracted from embodiment, whilst "the android enables us to evaluate total intelligence" (p. 5)[22].

As with the original Turing test, Ishiguro's total Turing test involves a time competition. Using the experiment with a sample of 20 subjects, the results demonstrated that 70% of the subjects were not aware that they were dealing with an android when the android could perform micro movements.

3.2. The reversed Turing test

In accordance with Ishiguro and with regard to the recent progress made in robotics, we propose a challenging extension of the Turing total test. We hypothesize that, in the light of the future evolution of the relations between humans and robots, the roles of the machine and the human should be reversed, so that the interrogator would be a robot rather than a human. The robot's task should be to recognize the true nature of the respondents, namely, that it should determine which respondent is a machine and which is a human. This test would allow the level of efficiency of a humanlike robot to be assessed. By all means, the robot interrogator ought to be programmed in order to be able to elaborate questions autonomously. This brings us to the basic new issue of machine learning: implementing intelligent assistants that are self-modifiable.

4. Can a machine dream?

The Ishiguro experiment showed both the importance of micro movements for the appearance of humanlike qualities, and the significant possibilities that exist for interdisciplinary studies between engineering and cognitive science.

In this regard, might the idea of the Darwin machine still be topical? This question suggests another question: if machine inactivity can be assimilated to the sleep state of living beings, does it make sense to implement a software for machine dreaming inspired by the principle of the Darwin machine? Of course, by a machine that dreams, we intend a machine that, when inactive, elaborates its own knowledge autonomously.

At the moment, the literature concerning machines that dream is scarce. Although some experiments have been made on Memory Association Machines and some theoretical proposals have been advanced on Dreaming Machines[23,24] no one has yet, as far we know, programmed a computer to dream.

Thus, we believe that studying dream activity and machine behaviour together can open new investigation perspectives. To this end, Google has recently released the source code for its DeepDream software (https://github.com/google/deepdream)[25].

DeepDream is a computer vision program that uses a convolutional neural network to find and enhance patterns in images via algorithmic pareidolia, simulating the psychological phenomenon of recognition patterns, shapes, and familiar objects as a result of a vague and sometimes random stimulus (see Fig. 2). Instead of precisely prescribing something, DeepDream allows one to simply feed the network on an arbitrary image or photo and leave the network to analyze the picture. This process has been named inceptionism, from the science-fiction movie Inception (2010), and people have compared the images produced by the program to hallucinogenic nightmares.

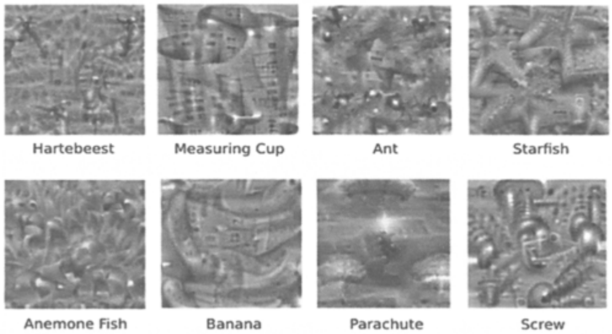

Fig. 2. Some examples from Google DeepDream.

It has also been argued that investigations into visual aspects of external perception, mental imagery, and visual mentation can lead to new interesting findings, for example stimulatingly innovative ideas on creativity and creative process that could be useful either in machine learning or in pedagogic fields[26,27].

Indeed, several philosophers, psychologists, and neuroscientists have recently characterized dreaming in terms of virtual reality, immersive spatiotemporal simulation, or realistic and useful world simulation. Some authors have studied dreams in terms of aspects that can stimulate computer-based applications[28,29], for example the passive attention supposed in dreams is simulated by computer. Furthermore, new interesting suggestions for research can derive from the study of social interaction in dreams, which forms a new investigation field of quantitative study of dream content[30]. For example, is there a relationship between an individual's behavior on the Web and the content of their dreams? Studying social relations in dreams and comparing them, not only with those that take place in real life but also on the Web, can allow investigation into the possible correlation between an individual's virtual identity/identities and the social content of their dreams.

Finally, an integrative theory has recently been proposed to unify human mental imagery, mind wondering, and dreaming[31]. This theory has formed the foundations for a computational model and artwork Dreaming Machine[32]. The computational model is a working system that learns from its visual perceptual experience during the day and generates hypothetical (simulated) images constructed from collected perceptual material while dreaming at night. Currently the computational model is limited to the construction of visual images, but we can hypothesize an additional module that could analyze the objects autonomously generated by an inactive machine, and assess their usefulness in its active status. Indeed any creative act needs to be assessed and accepted by the creator, as even the Bible states: God called the dry land Earth, and the waters that were gathered together he called Seas. And God saw that it was good (Genesis, I, 10).

5. Conclusion

Artificial Intelligence (AI) is a broad area that is continuously in progress: some of the first AI applications, such as automatic translation and optical character recognition, have become a routine technology today. Furthermore, the digital revolution is transforming contemporary society. Connective intelligence is an emerging property resulting from the embedding of intelligence into the connected data, concepts, applications, and people[33]. On this purpose, we are persuaded that reflecting on human behaviour, including dreaming activity, at the light of the current technologies can contribute to the implementation of the so-called new-generation of intelligent systems.

In this paper we have highlighted some aspects and new investigations in AI suggesting some challenging issues. We have also tried to show how research in the field of quantitative analysis of dream content, as well as that in Android science, leads to the same conclusion: the opportunity for the integration, in the field of AI, between cognitive and behavioural approaches.

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