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Dedicated to my parents and teachers.

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Introduction

In ancient times, the Vedic said, “Words mean nothing”. The world-famous Chinese teacher Confucius noted in the “Analects of Confucius”: “If language be not in accordance with the truth of a thing, affairs cannot be carried on to success”. Modern Indian teacher Shri Shri Ravi Shankar, in his “Celebrating Silence”, wrote: “Knowledge is untruth if it is only words”.

Artificial Intelligence (AI) models have two semantics: verbal and wordless. The former is created by data, symbols, schemas, logic, images, and words; the latter includes non-verbal free will, inspiration, imagination, emotions, and thoughts. Currently, knowledge is accumulated verbally in the environment of digital computers. In modern AI, words, image processing, deep learning, and generative language models are mainly digitally realised.

However, the possibilities of the digital environment are limited: the number of machine learning parameters is constantly growing and already exceeds trillions, and it is challenging to make digital semiconductor elements more minor than the size of an atom. At the same time, it is becoming increasingly clear that human cognitive processes reflected through AI are as digital (discrete) as analogue (continuous).

Discreteness (digital) is a heritage of the radio lamp era of computer construction. The radio lamp processed the analogue signal unsteadily, but it switched well between 1 and 0. It was convenient to realise these switches with the digital computer while solving various tasks because the theory of discrete mathematics worked quite clearly. The Nyquist–Shannon–Kotelnikov sampling theorem guaranteed the growing accuracy of the discrete calculations with decreasing sampling intervals. However, such an increasing accuracy cannot continue to the ideal level digitally.

AI cannot feel pleasant memories and emotional experiences like humans, transporting them like a “time machine” into the past. Signals in the surrounding reality have a digital and continuous (analogue) form. A person perceives these signals mainly in analogue form. For example, the primary layers of eye receptors work in an analogue way, as well as the endings of nerve fibres that cause muscles to move. Signals only for transmitting data through the body are converted into discrete (pulse) ones. Due to this transformation, the discrete signal speed of movement through the body decreases significantly, and the reliability of transmission increases.

The wordless semantics have an analogue nature and should be processed in an analogue way by a computer without sampling. For this, not all signals coming into the computer from the environment must be reduced to values at the points of reference in time (pulses) and space (pixels) on the curves of continuous signals, as is now done in digital computers. For example, continuous signal processing can be carried out through light, waves, and chemical effects. The depth of feelings, the chaos of thought, cognitive activity, and the transcendental states of the human mind have to be brought from behind the curtain of AI digital restrictions to the analogue way.

With the help of laser beams, it is already possible to perform addition and multiplication operations, which are carried out considering phase characteristics since wave amplitudes are added up, not intensities. Analogue processes of inverting and scaling, Fourier transform, matrix multiplication, and function convolution are performed at light speed.

Advanced (general, strong) AI must help to solve many complex problems. For example, the Big Bang model describes the birth and development of the Universe well, but not from its beginning, and this model is not the only one that describes the Universe's development. The issues with dark matter and dark energy are hanging. Investigations with the help of the James Webb Space Telescope (JWST) give rise to some doubts about the prevailing views on the Universe's history. There are still many mysterious gaps in science, and advanced AI should support their resolution in future. For example, there is no doubt that the second law of thermodynamics on the increase of entropy of a closed system cannot be violated. However, many scientific laws are only sometimes omnipresent—laws of conservation of energy, momentum, and momentum of the amount of motion are the result of various symmetries, and they should be considered absolute; however, the law of conservation of the baryon number operates only within the accuracy of a modern experiment.

It is becoming increasingly apparent that its hitherto imperishable classical digital paradigm should be supplemented with an analogue one on a fundamental level to resolve such scientific problems. AI models that reflect the knowledge of reality are different from reality itself. As philosopher G. Husserl said, there is an abyss of meaning is lying between knowledge and reality. A bridge over this abyss cannot be built rationally. This bridge has only one support—in the present. It is being built on both sides, often in unrelated places, from time to time. A person simultaneously solves direct and inverse problems: from the present to the future and vice versa. Rationality and computer digitalisation help to support this cognitive process.

However, the meaning of things is not entirely formalisable; it is only sometimes friendly with logic and is often the fruit of paradoxes. It originates at the moment of the appearance of two somethings: atoms, things, words, thoughts, events, etc. Only the meeting of two something can generate meaningfulness. To make sense, we act. Actions create changes and changes—differences. With the differences, new meanings are found, which support moving towards the anticipated goal.

The meaning search resembles the effect of optical interference when the diffraction of rays generates a new image reflecting the features of light sources. This book addresses an attempt to advance AI systems considering non-formalisable cognitive

semantics using analogue data processing methods. The development of analogue AI systems may rely on achievements in analogue-like disruptive photonic computing, quantum computing, biocomputing, and neuromorphic computing.

This book addresses the *analogue way* of creating photonic AI (PAI), considering that light is most different from the natural structure of the body structure and the human neurosystem. The term "analogue" is used in this book in two senses. Firstly, it means a continuous change of parameters at each point in space. Secondly, it means the object is all points of continuous coordinates, not a discrete (point, digital) representation of information. The modern digital computer paradigm for knowledge management in AI systems must be revised so that the analogue information model considers wordless semantics.

The idea of using light in computing machines appeared simultaneously with the invention of lasers. For several decades, separate nodes of computing systems have been successfully created using optical technologies. The field nature of light determines the numerous advantages of optical technologies for transmitting, recording, processing, and storing information. Photons have a variety of degrees of freedom representing different quantum states such as polarisation, path, time-bin, and frequency. They can utilise high-dimensional or continuous variables. Photons are not subject to decoherence. Photons form electromagnetic waves. They are stable, but the material for image recording is unstable relative to the photon. Many light beams can pass through the same space area, intersect, and not affect each other due to the lack of an electric charge for photons. Using two-dimensional and three-dimensional characteristics of light allows for high density and speed of information transmission. Well-developed technologies exist for generating, manipulating, and measuring photons in space, fibre, and chips.

The book tries to solve the scientific-technical challenge of the continuous representation of reality in AI systems. This makes it possible to practically reset the time of training of AI systems to zero and break the vicious circle, in which time and energy tend to be infinite, to ensure absolute accuracy of calculations in digital computers. The continuous representation of entropy and the signals in the PAI system also allow for overcoming the visible ahead impasse with the performance raising of digital computers.

There are many challenges to creating PAI, including the synthesis of new materials, the control of optical processes, and the building of effective interfaces between discrete and analogue computing.

The book's structure aims to consistently create PAI with enriched cognitive semantics of models described in our previous book [1]. From the beginning of the book, a conceptual formulation of the problem is made. Then, the architecture details of the PAI system's components and a description of photonic materials for rewritable 3D holographic memory are given.

Reference

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