Lesmo, 18.8.1989

Caro Rinaldo,

di seguito hai il mio riassunto, in inglese, composto di cinque pagine.

Ti chiedo di sostituire le prime due pagine già inviate con quelle che ti mando ora perchè ho fatto qualche piccolo cambiamento.

In conclusione, le cinque pagine che seguono, costituiscono la versione finale del riassunto.

Cordiali saluti.

Marco

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CELLULAR NETWORKS, NEURAL NETWORKS, AND INFERENTIAL PROCESSORS

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The technological progress in the development of solid state digital circuits has reached new levels and new successful results of both in miniaturization and in computation speed.

Today, the topologies of the integration masks, which allow the specification of the single electrical activities taking place in a SLSI (Super Large Scale Integrated) circuit hosted in the same chip (namely the discrete token containing the largest integrated circuit), are geometrically made up with segments as short as one tenth of a micron (a micron being one millionth of a meter).

This integration technology, called submicronic, has recently allowed the design and the construction of new microcomputers, called microsupercomputers, hosted on one chip, which deliver impressive computation power.

An example of this microsupercomputers, hosted on a single chip, and based on a complex electrical circuit utilizing more than one million of transistors, is the INTEL 80860, which delivers more than the potentiality of the CRAY 1 supercomputer.

It is based on a RISC (Reduced Instruction Set Computer) approach, it is made up with three mathematical units organized in pipeline (namely a sequential exploitation of several processing units which provides parallel operation of the units), it utilizes vectorialisation (namely the computation on numbers is made by processing in parallel the various digits of the numbers involved in a mathematical operation) in numerical computation, it runs at a speed of 35 MHz (next year will be upgraded to 50 MHz), it provides up to 105 million (150 million next year) results per second, and it costs 750 dollars only

However the most promising exploitation of the availability of submicronic technology and of one-million-transistors-chips does not appear to be focused on the construction of just ONE microcomputer on ONE chip (even if a microsupercomputer).

In fact, the most interesting approaches are oriented to construct MANY systems (not necessarily computers) on ONE chip, and to conceive the CONNECTION together of a large number of these chips, thus envisaging the implementation of a NETWORK of many elements connected together, where each network is conceived to be made at least of 100.000 elements.

These new approaches are denoted with the technical term CONNESSIONISM, since they point out the dependency of the functionality of the overall artificial system (the network properly programmed) from the TOPOLOGY (a topology is the description of the articulated set of connections linking together several elements) describing the routing of the flux of information being processeed within the network.

Please do not confuse the following two topologies:

a) the topology (static network construction topology) of the network itself, which is fixed, because it describes both the fixed connections of the elements, within the same chip, and the fixed connections of the chips among themselves;

b) the topology (dynamic network exploitation topology) of the paths followed by the various items of information, using the routes available within the network, during the processing activity performed by the network itself.

It is clear that the connessionism, although technologically allowed by the submicronic-based chips, has, as well, the anthropomorphic inspiration, generally speaking, of the human brain, where it exists a complex and unexplored NATURAL NETWORK of up to 20.000.000.000 biological elements, called NEURONS.

However, the ARTIFICIAL NETWORKS of elements, embedding the connessionism, can be distinguished into two different classes, which depend from the criterion which is adopted for conceiving the NATURE OF THE ELEMENT, which constitutes the system to be connected together in large number within the network.

A first class of networks is based on the criterion of adopting as its element, a system, which is able of providing functions which are useful and appropiate toward the scope of the processing activity which is required to the network, as a whole.

This criterion, that we can call ARTIFICIAL CRITERION, has been adopted, up to now, with the selection, as element, of one of the three following systems, of different degrees of complexity:

a) a digital system, capable of specialized processing functions, though, as a whole, of more limited scope than a microcomputer (for example, a digital system able of executing a limited class of mathematical operations and associated with a local memory of reduced size);

b) a microcomputer, though limited for the size of data, of instructions, of instruction set, and of memory (for example, a computer processing data of a single bit size, with a very small limited memory);

c) a microcomputer, augmented with other dedicated digital systems and associated with a local memory of significant size (example of this augmented microcomputer is the so called transputer).

The network which adopts the artificial criterion in selecting its elements is called CELLULAR NETWORK.

It represents, therefore, a first type of connessionism, that we will call CELLULAR CONNECTIONISM.

The reference of a cellular network with the brain, namely the anthropomorphic role in the conception of a cellular network, is therefore WEAK, because this role is limited to capture, from the structure of the brain, the very high parallelism provided in the brain behaviour by the activities of the very high number of neurons.

We may view, therefore, a cellular network, as an artificial network of cells which intends to emulate, with respect with the brain, considered as a natural network of neurons, the very high parallel structure, which is assumed to be a promising architectural approach, in the scope of improving the performances of the network, intended as an artificial system to be devoted to the brain emulating task of information processing.

An example of cellular network, which has been disigned and constructed, is the CONNECTION MACHINE, which is a cellular network which has a static network construction topology of n-cube (namely, as in an ordinary cube, of three dimensional geometry, that we will call 3-cube, each vertex is connected with 3 other verteces and there are a total number 8 verteces, where 8 is equal to 2 to the power of 3, in an n-cube, conceivable in an n-dimension geometry, each vertex is connected with n other verteces and there are a total number of 2 to the power of n verteces).

The connection machine, which has been developed by the company Thinking Machine, of Cambridge, Massachusetts, USA, has a topology of n-cube with n equal 16 (at the end of the year, a new connection machine will be available, with an n-cube with n equal 20), and, therefore, each vertex is connected with 16 (20 at the end of the year) verteces and there are a total number of 2 to the 16 equal 65.536 verteces (2 to the power of 20 equal

1.048.576 verteces at the end of the year).

In the connection machine each vertex is represented by a cell which consists of a single bit computer with 4.000 bit of local memory.

A second class of networks is based on the criterion of adopting as its element, a system, which is able of emulating the observable behaviour of the neuron, as it can be described within a given modelization of the biological neuron, with the underlying assumption that this effort, of a more narrow reproduction of the brain structure, should result as a very promising one in enhancing the information processing capabilities of the network.

This criterion, that we can call ANTHROPOMORPHIC CRITERION, has been adopted, up to now, with the selection, as element, of various models of the neuron, of lesser or greater accuracy in the effort of emulating the biological neuron.

Therefore, the element of the network is constituted by an ARTIFICIAL NEURON providing functions which are useful and appropiate toward the scope of the processing activity which is required to the network, as a whole.

The network which adopts the anthropomorphic criterion in selecting its elements is called NEURAL NETWORK.

It represents, therefore, a second type of connessionism, that we will call NEURAL CONNECTIONISM.

The reference of a neural network with the brain, namely the anthropomorphic role in the conception of a neural network, is therefore STRONG, because this role, besides capturing the very high parallel structure of the brain, as it is the case of the cellular network as well, is focused to reproduce in the element of the network the same behaviour, as more closely as possible, that can be observed and precisely described in examining the biological neuron.

We may view, therefore, a neural network, as an artificial network of artificial neurons which intends to emulate, with respect with the brain, considered as a natural network of neurons, the very high parallel structure of the brain together with the functions provided by the network elements, considered as artificial neurons, closely emulating the biological neurons, in the scope of improving the performances of the network, intended as an artificial system to be devoted to the brain emulating task of information processing.

The neural networks, up to now, have not yet been constructed, but have been simulated, by means of a network compiler, in large computers.

In the last two years, the author of this paper, together with Giovanni Manzini, of the Scuola Normale di Pisa, has designed a dynamic network exploitation topology, for the connection machine, which has enabled to define the architecture of an inferential processor (this definition of the dynamic network exploitation topology is called SUBSYMBOLIC PROGRAMMING of the cellular network, thus been upgraded at the level of an inference processor).

We recall that the inferential processor is an information processing machine whose task is not the execution of algorithms, as it is the case in usual computers, but is the solution of problems.

Positive experimental results have been in fact obtained in utilising the connection machine of the MIT Artificial Intelligence Laboratory, with 65.536 processors.

The ability of constructing an inferential processor, that we can call as well a problem solving machine, has been therefore illustrated as feasible, by adopting a powerful example of cellular network.

In conclusion it is argued that a more ambitious emulation of human intelligence, as it is provided by the research results of artificial intelligence, dedicated to the conception and design of inference processors, can be obtained by utilising the artificial connectionism approach, based on the use of cellular networks, such as the connection machine, which, as an embedding environment, provides a WEAK and not a STRONG emulation of the brain structure.

It is therefore significant to assess that an advanced emulation of human intelligence, intended as an high functionality observable in human mind, can be better performed by utilizing, as mean (namely technology) for constructing the emulating environment, the type of networks, namely the cellular networks, that try to emulate in a weak way the human brain structure.

This clarifies, in an interesting way, that the scope of artificial intelligence is not only limited to design artificial systems, namely information processing machines (computers) and robots, which reproduce SOME AND NOT ALL the performances observable in human mind, namely the intelligent and perceptive behaviour, but that it assumes to perform only AN EMULATION AND NOT A SIMULATION of physiological behaviours.

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