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Control method and analysis of potential application based on memristor

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Abstract. Memristors have many advantages, such as small size, fast speed, and low power consumption. If the cross array is used as the memristor, a structure similar to the matrix can be obtained, which can store data and do calculation. Based on the characteristics of memristor, the realization of various control functions has a wide range of application prospects and advantages. The memristor matrix supply can be used to achieve relevant control, so that the control becomes simple and efficient. At the same time, memristor has outstanding advantages in arithmetic calculation, neural network, and artificial intelligence. This article introduces memristor and shows the theory needed to apply memristor to the control of robot arm, improve MAC calculation by memristor and the application in neural network. There is no doubt that the research in this paper will contribute to the further exploration of the control method of memristor and lay a solid foundation for its practical potential application theory in the future.

Keywords: memristor, matrix, cross array, neural network, MAC.

1. Introduction

In 1917, Chua developed a fourth circuit component, the memristor, which is parallel with the resistance, capacitance and inductance, based on the completeness of the circuit [1]. In May 2008, Hewlett Packard (HP) laboratory first carried out physical implementation of memristor [2]. This set off a flurry of research of the memristor worldwide. As a new circuit element, memristor shows great application prospect in nonvolatile storage, artificial neural network, and nonlinear circuit. In second section, the principle of how memristor works and the advantage of using memristor in some cases. In third section, the specific usages of memristor will be illustrated, including the ideal application of memristor array.

2. Basic knowledge and advantages of memristor

2.1. Basic knowledge

Memristor can be used as a resistor, which has the same dimension as resistance, can be recognized as a physical quantity which follows Kirchhoff's law and Ohm law. The resistance of a memristor to t0 at a given moment depends on the time integral of the current passing through it from $t=-\infty$ to t=t0, which shows its temporal memory characteristic. When the graph of φ-Q is a straight line, relevantly, M(Q)=R, memristor shows its linearly time-invariant. It's going to be V/I numerically. At any moment,

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the value of M depends on the total charge q which flowing through the device in the past (The magnetic flux φ is affected by the cumulative charge Q), in other words, the current flowing through the memristor is determined by the integration of the past time. Therefore, memristor is a non-linear resistance which has charge memory function [3]. The memristor which is decided by total charge q is called charge controlled ideal memristor.

2.2. Advantage of memristor

The simplest application of memristor is being a resistance random access memory (RRAM). The biggest difficulty with current dynamic RAM is that, when you turn of PC power supply, the dynamic RAM will forget what has been stored before. So that people need to sit here until all the things needed to run the computer being downloaded to dynamic RAM again when they turn on the computer next time. But with RRAM, this process will be in a flash, and your PC will back to the same status as you turn it off [4].

Researchers say that memristor can allow mobile phones to be used for weeks or more without needing to be recharged, and laptops to retain information long after the battery has run down. It is also expected to challenge the flash memory commonly used in digital devices because of the ability of storing information long after the battery has run down [5]. Using the chip made from this invention, it can store information more quickly than flash memory, consume less electrical energy and occupy less space.

Memristor can also make computer understand by searching data, which is similar to the pattern of human brains gathers and makes sense of a series of events. It makes computers smarter at finding out what data they save [6]. For example, according to the information collected before, the memristor circuit can tell a microwave oven how long to heat different foods. Nowadays, many researchers are trying to edit the code which can be operated on standard machine to simulate the function of human brain. They use a variety of machine which have huge ability of processing data, but it can only simulate very few parts of human brain. Researchers say that they can do it in a different way than writing computer programs to simulate human brain or a particular function of human brain, which is relied on the construction of a hardware based on the function of simulated brain of memristor [7]. The principle is to use almost all states in different shades of grey instead of 1 and 0. This type of computer can do lot of things which digital computer are not good at, such as making decisions, judging one object is bigger than another, even learning. This type of hardware can be used to improve the technology of recognition of facial recognition technology, which is thousands to millions of times faster than running programs on a digital computer.

3. Analysis of potential application

3.1. The concrete scheme in robot arm controller

Robot arm is a device which is widely used in industrial production. It completes heavy, high-risk, repetitive operations instead of human beings. In terms of robotic arm control, the most widely used system at present is PLC+servo motor drive system, to realize the multi axis motion of robot arm. For example, palletizing robot can rely on ‘arthroses to realize the motion of ‘front and back’, ‘left and right/rotation’, ‘up and down’ [8]. These motions are according to the established trajectory and speed. Therefore, the track of these motions is circulating. The memristor array can be constructed to realize the calculation of speed of each axis, which can be formed as a pattern of memristor array+servo motor drive system to realize the chipping and intensification of robot arm control.

The specific technical route is as follows. Collecting the data of speed divided by time(V/I) joint actions of each axis (X, Y, Z axis), shown in figure 1.

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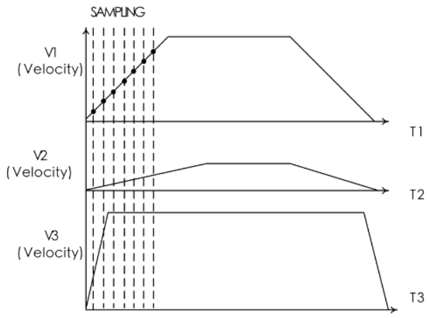

Figure 1. The data of speed divided by time(V/I) joint actions of each axis(X, Y, Z axis).

Samples are taken at regular intervals, forming 3*N array. Using current output to the servo system to realize the control of the path and the speed of robot arm.

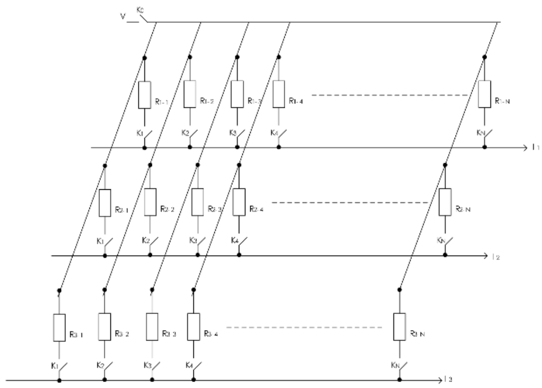

Figure 2. Three outputs of speed analog quantity(current).

In figure 2, three outputs of speed analog quantity(current), Kn is the sampling switch, the closed time is sampling time, R1-1~R1-N is the memristor array of the speed of X-axis. R2-1~R2-N is the memristor array of Y-axis. R3-1~R3-N is the memristor array of the speed of Z-axis. Each node of the wire holds a memristor device. The voltage V is the value of the voltage applied to the N column. According to ohms law and Kirchhoff's law, the value of the current of the N column can be get: I1~3=V/R1~3-N. This shows that the magnitude of current depends on the resistance value of Rij of the memristor array node. If the value of is Rij defined, the track of motion of robot arm can circulate, which makes control simpler and more efficient [9].

Take advantage of the memory principles of memristor, the simulation of the track of robot arm motion can be realized, completing the intelligent function like 'learning'. The concrete implementation method is to let robot arm to complete one motion trail, output three change analogs which represent the voltage of V1, V2 and V3. The continuously varying velocity feedback value is sampled as V11~V1N, V21~V2N, V31~V3N. The voltage of memristor V is relative to the product of current I and the memristance M, which means V(t)=M(q(t)I(t)), M(q(t)) =R(t), hence to the resistance of node R(t)=V(t)/I(t). After finishing the impedance memory, the simulation of trail of related memristor arrays can be done easily.

3.2. The calculation of memristor cross array

By mapping the numerical matrix to the simulated conductance values of each node in the memristor cross array, efficient Multiply Accumulate (MAC) can be performed in a massively parallel manner based on Ohm's law and Kirchhoff's law. Recent years, the memory computing accelerator based on the memristor has been widely concerned by academia and industry. It is not just because the

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Memristor based in-memory computing accelerator tightly integrates analog computing and memory functions to break the bottleneck of data transfer between CPU and memory in traditional von Neumann architecture. What's more, by adding some units of functions to the peripheral memristor array, the array can perform MAC calculations with a delay of one read operation, the decay time won't increase as the dimension of data increases. And MAC is widely used in various data-intensive computing tasks and becomes one of the main energy consumption operations.

MAC is one of the major operations. It is intensive in data, consuming large proportion of time and power. So, using memristor array to further complete the advantage of MAC operation will highly improve computing energy efficiency, which is expected to break Von Neumann bottleneck. The first method is recognized as soft computing because it can tolerate the device and array defects to some extent. It has described in detail that the acceleration function of memristor array in multilayer perceptron, convolutional neural network, generative adversarial network and long and short memory neural network [10]. The second method belongs to hard computing because solving data problems need higher precision appliance. The schematic diagram of multiplication summation in one step by using memristor array is shown in figure 3 [11].

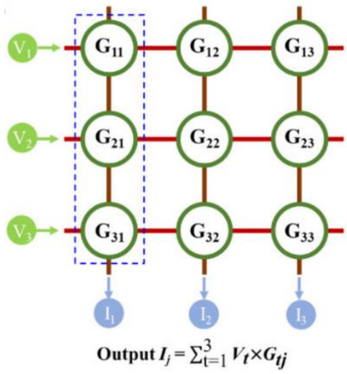

Figure 3. The schematic diagram of multiplication summation in one step by using memristor array.

3.3. The application of memristor in neural network

Synapse is the key point of neural network. Because the resistance of memristor depends on the nature of its past state, which is similar to the way synapses in the brain works, can be used to stimulate the connection of synapses in human brain, it can also be used in the researchers about neurodynamic neuromorphic chips. Before the memristor, brain-like computing platform is mainly built by deep learning processor.

Traditional DNNs neural network mainly relies on software operates on CPU and GPU platforms, which consume a lot. Therefore, based on DNNs neural network, relevant researchers raised two mainly brain-like calculation platform: A dedicated processor based on deep learning theory and a neurodynamic-like neuromorphic chip. Research on the former one is relatively mature and no more detailed description [12]. This paper mainly discusses a brain like neural computing platform which supports SNNs model through memristor.

The prime problem of brain-like computing platform is the approximate circuit of synaptic structure. Several typical synaptic structure of memristor is shown in figure4, includes unidirectional, semi-bidirectional, and bidirectional synapses.

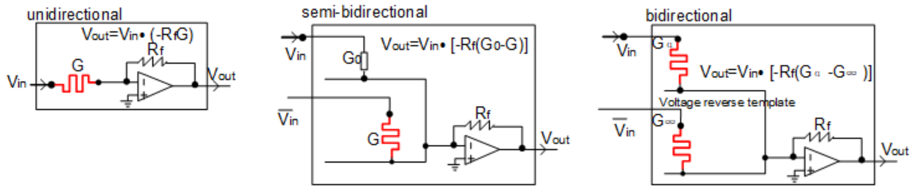

Figure 4. Realization of the synaptic structure of memristor.

All of them is using the way of connecting the memristor and feedback resistor to the operational amplifier in a closed loop to make the synaptic weight is adjusted precisely through pulse modulation.

Synapses can further form memristor array, the structure is shown in figure 5, which can get the product of the input vector and the weight vector.

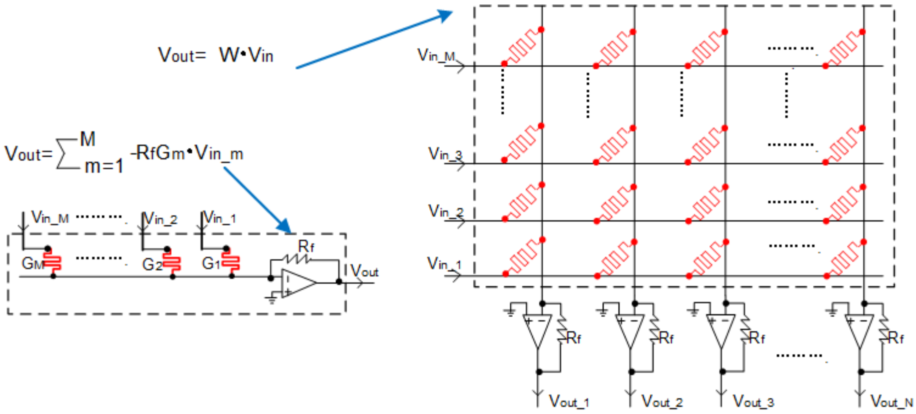

Figure 5. Memristor array.

This process mixes the storage and calculation together, providing a train of thought for the research of neuromorphic chip [13].

The specific function of storage and accounting integration put higher demands on the device characteristics on memristor. The existing devices are still non-ideal in linearity, durability, and dispersion characteristics. Therefore, in order to explore the way to increase ability of device characteristics, improve the precision of different resistance state control, decrease the pulse time required for conductance regulation, restrain conductivity drift effect, and reduce device fluctuation. At the same time, in view of the demand for miniaturization of high-density data storage and low-power data processing in "memory and computing integration" chips, it is necessary to study the design and performance optimization of new memory in nanometer size, to provide a good device basis for the development of high-performance intelligent "memory and computing integration" brain chips in the future. In conclusion, the development of memristor has a deep driving effect on the high-quality development of artificial intelligence.

4. Conclusion

Memristor is a breakthrough discovery in the field of modern basic electronics and advanced electronics. Its appearance will improve the reliability and computing power of computer systems and reduce the power consumption. But at the same time, the complex physics principle in the memristor structure is still not clear, its large-scale array integration technology is still under study. What's more, in the most promising application of cross bar structure memristor system, the phenomenon that resistance distribute unevenly on the Structure often happens. Therefore, how to manufacture high performance cross bar memristor array with nano size is the crucial and difficult point for future research. The difficulties mentioned above leads to the failure of manufacturing and applying memristor in a large scale. As a result, researchers should explore more in the materials, principles, and structure of memristor in the future.

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