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A review of human systems of magnetic microcomputers for biomedical applications

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Abstract

Wireless controlled microrobot has attracted much attention because of its great potential in biomedical field. its small size, wireless magnetic drive and control properties make it suitable for small and closed in vitro and in vivo environments, such as chip labs and human blood vessels, for micromanipulation, micro noninvasive theory, and diagnostic applications, respectively. In recent years, magnetic field driven micro robots have been widely used in dry and wet environments for their good controllability and motion performance. and they are almost harmless under magnetic drive and control, which makes them particularly suitable for biomedical applications. In this paper, the research status of human system of magnetic microcomputer is reviewed, including related knowledge and theory, design of magnetic microrobot and magnetic navigation system. In order to understand, several types of magnetic microcomputer human system are introduced. Finally, some applications of magnetic microcomputer human system are introduced, and their great potential is demonstrated. However, for further development, many obstacles still need to be addressed.

Keywords

Magnetic; Microcomputer; Biology; Medicine.

1. Introduction

In recent years, wireless controlled micro robots have attracted wide attention because of their great potential in biomedical field. in fact, because of their small size and unlimited performance, these microrobots are well suited for closed and narrow working environments in vivo and in vitro, such as minimal/non-invasive targeted diagnosis and treatment in humans, and moving within chip laboratories for transport, classification, particle detection. With the rapid development of advanced technologies such as integrated circuits, electronic and mechanical parts have been greatly miniaturized. however, conventional power-driven modules are still not possible to minimize at the microscopic level, thus unable to drive microrobots from the macroscopic level. In recent years, scientists have implemented several on-board power supply methods by using bacteria. although they all exhibit good motor performance, bacterial motors cannot be controlled alone without the help of magnetic microtubules. the main problem with chemical methods is the toxicity and contamination of heavy metals deployed in harsh conditions in the presence of corrosive hydrogen peroxide. Another feasible solution is to use external power transmission and control, such as electrostatic method, dielectric swimming method, optical tweezers and magnetic control. Magnetic control has good performance. It has good controllability, fast speed and almost no harm, and is very suitable for biomedical applications in vivo and in vitro, especially for the treatment of living animals. Because of these characteristics, it has become a hot spot and has received more and more attention [1].

In recent years, with the development of science and technology, more and more kinds of magnetic micro robots have been invented. From the point of view of hardware, this paper reviews the current situation of magnetic microrobot (MMR) system. The conclusion on MMR control work has been well arranged in Xu et al [2].

2. Overview of Magnetic Microrobot (MMR) Systems

Ferromagnetic materials (such as iron, nickel, cobalt and their alloys and some rare earth metal alloys) are most commonly used in metal magnetoresistance because of their strong magnetic properties. And they have χ, maximum susceptibility but the inevitable lag effect. M–H curves show the dependence of magnetization M external magnetic field H for ferromagnetic materials. When an applied magnetic field acts on a ferromagnetic material, M follow the initial magnetization curve. The curve began to grow rapidly, and then reach an asymptote called magnetic saturation Ms. If the magnetic field decreases monotonically now, M will follow another curve. At zero magnetic field intensity, magnetization shifts from the origin a quantity called remanent Mr. That is to say, these materials can be magnetized. This means that after removing the external magnetic field, they will retain partial magnetism. To demagnetize it, an opposite magnetic field called intrinsic coercivity is required. If the H–M relationship plots the intensity of all applied magnetic fields, result is a hysteresis loop called a M–H curve. According to coercivity, Ferromagnetic materials can be further divided into NdFeB and Ni and other soft magnetic materials. The former has great coercivity, Large remanence. Once magnetized, they keep magnetizing the external magnetic field, which allows the material to be made into permanent magnets. Soft magnetic material has the characteristics of low coercivity. they are easily magnetized and demagnetized by external magnetic fields. Paramagnetic materials are also subjected to magnetic fields and also used in manufacturing MMR. Unlike ferromagnetic materials, they have no hysteresis. Because when the applied magnetic field is removed, they don't retain magnetism, thus minimizing the potential negative effects on microorganisms in biological applications. However, compared with ferromagnetic materials, paramagnetic materials have little sensitivity to the magnetic field. Therefore, they are much less attractive to the same magnetic field, not suitable for application. When a ferromagnet or ferromagnet is small enough (as Fe3O4, ferrite), it behaves like a single magnetic spin affected by Brownian motion. Its response to the magnetic field is similar in nature to that of paramagnetic materials, but more magnetic, called superparamagnetic. This solves the disadvantage of paramagnetism [3].

3. MMR systems

For better understanding in this section, we study several types of MMR systems.

3.1. Magnetic navigation systems

H–M MNS is a system of Helmholtz coils and Maxwell coils, use their generated uniform magnetic field and uniform gradient field to control magnetorheological changes. In the direction of this magnetic field, the magnetic induction coil is coaxial, Automatic feedback from a 5 mm magnetic field to an automatic control of a silicon surface. In this system, First activate the Helmholtz coil to produce a uniform magnetic field in a predetermined direction, to align the magnetoresistance with the flux line. Then activate the Maxwell coil to produce a uniform gradient field, pushing the magnetorheological movement along this direction. Then, Relevant researchers have proposed an improved structure, with a fixed X direction a magnetic field degree of freedom around the Y axis and rotating magnetic field degrees of freedom for 3d motion control of mm magnets in vascular models. In 2010, A new MNS, is proposed It has three fixed orthogonal Helmholtz coils, a stationary Maxwell coil and a rotatable Maxwell coil. With the exception of continuously controlling the three-dimensional motion of mm cylindrical permanent magnet 1 mm×1 in a vascular model, three static Helmholtz coils can also produce

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a rotating uniform magnetic field, drive the ball to drill, provide a potential and effective treatment for vascular occlusive disease [4].

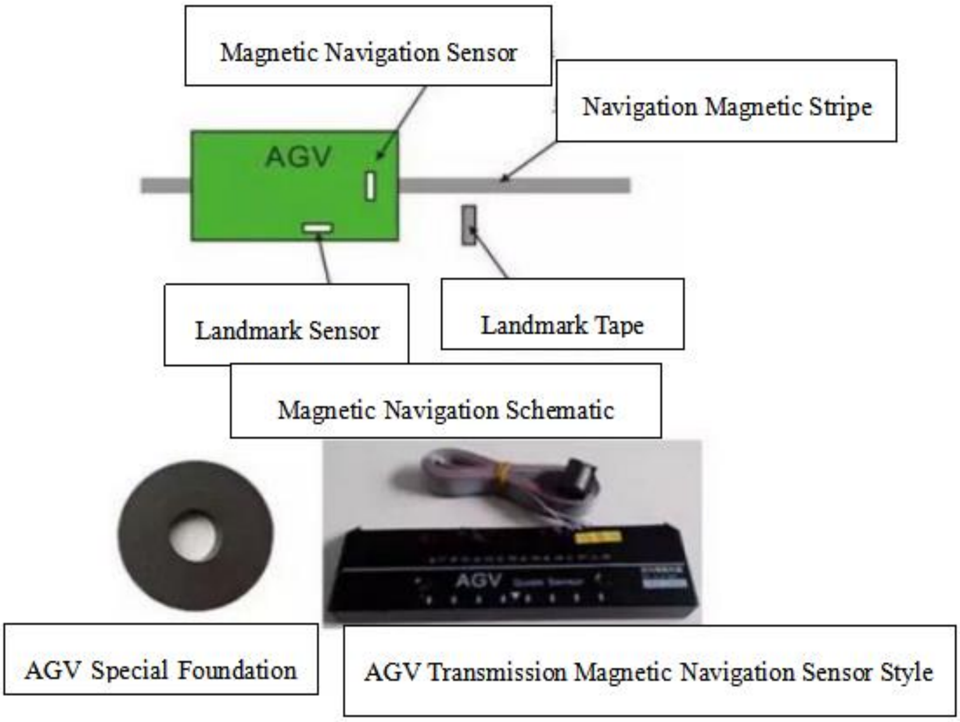

Figure 1: Magnetic navigation system diagram

3.2. MR imaging system based

Because of its great application in tumor therapy, the use of commercial magnetic resonance imaging (MRI) systems to control magnetic particles has attracted great interest. as a widely used clinical imaging instrument, it is readily available and enables patients to lie inside. three orthogonal slice selection and signal-encoded gradient coils can be used to control unconstrained magnetic devices as well as to locate them while working in the human body. First, scholars have proposed an automatic navigation of 1.5 mm ferromagnetic spheres in the carotid artery of living pigs. Then, this paper also introduces a method of real-time two-dimensional straight-line navigation of 1.5 mm ferromagnetic spheres using clinical MRI system. Although magnetic resonance imaging systems can produce very high static uniform fields (10 T and above), the controlled magnet can be magnetized to its saturation magnetization intensity Ms. However, gradient fields themselves can produce very low (0.01–0.05 T/m), which greatly limits the applied the magnetic force, reducing the flexibility of three-dimensional control and navigation of small magnetic particles in human blood vessels. To solve this problem, Researchers installed a special Maxwell coil in a magnetic resonance imaging tunnel, generate sufficient gradient field by input high current. Placing μm 10.82 iron oxide particles in a two-dimensional Y tunnel, the success rate is 60. Then, they rolled out the upgraded gradient coil, Improved performance to 99 per cent

3.3. Magnetic drive torque

This magnetorheological is driven by the magnetic torque generated by a uniform magnetic field. The uniform field of rotation and oscillation forces the magnetic resonance to rotate and oscillate synchronously. MMR rotation and oscillation are then converted into thrust by artificial flagella. this MMR shows good performance in a fluid environment with a low Re number. the magnetic torque is applied by several orthogonal Helmholtz coils, which can generate rotation or oscillation to obtain a uniform magnetic field by inputting appropriate current signals such as square, sine and cosine waves. unlike maxwell coils, the Helmholtz coil exhibits good magnetic field uniformity in a relatively large workspace. In the central blank area, the field is within 1% of the center value. and the magnetorheological damper driven by magnetic moment can be driven by only a weak magnetic field (several mT), and good swimming performance can be obtained. compared with the magnetorheological damper driven directly by magnetic gradient, it is more suitable for driving at micro-scale. inspired by the spiral movement of spiral-like bacterial flagella, such as e. coli, scientists have found an effective way to make MMR swim in low Reynolds number fluids. They mimic the structure of microbes and show the propeller. magnetization along the diameter direction. As a result, when a rotating uniform magnetic field is applied, the MMR will rotate synchronously with the magnetic field, and then turn its own rotation motion into a flat motion like a screw. This structure is very suitable for motion in high viscosity fluids. The conversion of the front and rear motion only needs to change the rotation direction of the magnetic field. Some scholars later proposed an artificial bacterial flagella with a diameter of 2μm、 and a length of 8.8μm (ABF). A Ni/Ti bilayer film was prepared by direct laser writing and physical vapor deposition. Under a magnetic field of 7.5 mt and 175 hz, ABF in water speeds up to 127μm/s(14.4 individual length/s)[5]。

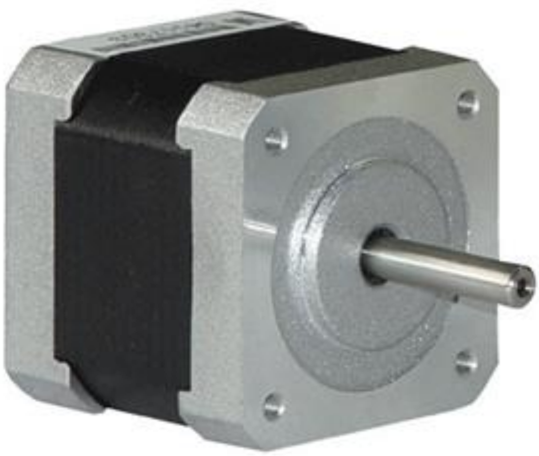

Figure 2: Magnetic drive torque

4. Application of Magnetic Microcomputer in Biomedical Field

Under the action of external electric field, the permanent magnet intervention device installed at the distal end can navigate in the complex and fine channels inside the human body, such as blood vessels and brain, and realize the minimum minimally invasive diagnosis and treatment, which cannot be achieved by the traditional interventional equipment. Compared with the capsule endoscope driven by vehicle power supply, the capsule endoscope driven by external magnetic field gets rid of the shortage of limited power supply. additionally, due to the additional axial degrees of freedom driven by the magnetic field, it can be used not only as an imaging and sensing device, but also for active diagnostic, therapeutic, or surgical functions such as transport, drug injection, and biopsies.

Magnetic control provides a suitable solution for the active control and movement of these traditional medical devices and creates more possibilities. As for those MMRs that are unconstrained and wirelessly controlled, as mentioned in the section, they are fine. These micro-robots are suitable for closed, tiny in vitro and in vivo environments such as human blood vessels, microfluidic channels and magnetic fields under control. They can achieve a distant goal that cannot be achieved by related machines and then perform tasks such as precision control and minimal/non-invasive diagnostic and therapeutic applications. In addition, unlike manual surgery and existing robot tools (position control), magnetic control devices are force controlled. This makes interaction with fine objects such as human tissues and active microorganisms safer to avoid irreparable damage.

5. Conclusion

A brief review of the research status of MMR system is presented. At present, scientists mainly focus on the study of MMRs motion control. they proposed various shapes and modes of motion MMR, some of which showed good controllability and motion performance compared to small sizes. For the movement of these magnetoresistance, scientists have adopted many novel methods to deal with the main resistance in the micro world. In order to make these tiny objects, magnetic and non-magnetic materials combine advanced manufacturing techniques such as micromachining and laser direct writing. Various types of metal nanomaterials are proposed to drive and control these metallic magnetoresistances, each of them having its advantages and disadvantages. In these systems, electromagnetic navigation systems are widely used for their good controllability and diversity. they can generate various different fields, such as gradient field/uniform field and rotation/oscillation field, by properly arranging and inputting different current signals. Some potential applications are also introduced. Although most of these methods are carried out in experimental environments and cannot represent the actual behavior in practical applications, they still show good feasibility and great potential.

To sum up, the current MMR system is still in the primary stage and is not perfect, but it still has great development potential, which will be widely used not only in the field of biomedicine, but also in many fields in the future.

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