Embedded Self Organizing Systems (Vol 4. No 1. 2017) (pp.2-5)

Embedded Selforganizing Systems

Issue Topic: "Embedded Systems and Its Application in Medical and Biomedical Field"

Controls of Trajectories for Targeting of Magnetic Robotics in body

Tumurbaatar Batgerel
Department of Bionanosystem Engineering,
Chonbuk National University, Korea
Power Engineering School,
Mongolian University of Science and Technology,
Ulaanbaatar, Mongolia
E-mail: batgerelt@must.edu.mn

Chan-Hee Park*
Department of Bionanosystem Engineering,
Department of Mechanical Design Engineering,
Chonbuk National University, Korea
E-mail: biochan@jbnu.ac.kr

Jun Hee Lee
Department of Mechanical Design Engineering,
Chonbuk National Univerisity, Korea
E-mail: silvlise@hanmail.net

Cheol Sang Kim
Department of Bionanosystem Engineering,
Department of Mechanical Design Engineering,
Chonbuk National University, Korea
E-mail: biochan@nate.com

Abstract[1]—This paper presents a novel method to actively control magnetic field in a region-of-interest using three pairs electromagnetic coils system referred to here as extended distributed treatment Robotics. The developed controls of trajectories for targeting of magnetic robotics in body system contains hardware, software and magnetic Robotics/nanoscale material and the in vitro manipulation in real time. In this study, we used six identical solenoids coil placed on an XYZ-axis and the electromagnet was powered by current that can generate a high-gradient magnetic field in the desired direction. Real-time video microscopy supported by the LabVIEW vision system is integrated to the developed system for real-time monitoring. Moreover, the detection of object function is done through NI Vision Assistant, tracking function is through Math Script node in the LabVIEW simulation and ROI magnetic field actual measurement is done by the real-time magnetic sensor. The motion speed and direction of the Magnetic Robotics can also be manipulated using EMM system and Joystick controller.

Keywords— Electromagnetic field (EMF); Electromagnetic manipulation (EMM) system; Magnetic Robotics; Nanoparticle;

I. INTRODUCTION

Use of Robotics for lab-on-a-chip devices has already proved to be a powerful tool. Handling small objects in very small fluid volumes for manipulating, moving, and reconfiguring components in 3D by means of Robotics make this route highly attractive. Assembly of 3D heterogeneous micro-objects, which require orientation and positional control, would be best addressed using Robotics assembly. Organ-on-a-chip applications could benefit from Robotics operations, in which complex cellular materials with 3D microscale features may need to be positioned to better recapitulate the native physiological status [1-3]. Engineered Magnetic nano/micro robotics possess unique properties and hold great potential in biomedicine and clinical applications. Their magnetic properties ability to work at the cellular and molecular level, Magnetic nano/micro-robotics have been applied both in vitro and in vivo in targeted drug delivery and imaging [4, 5]. As an alternative to existing tethered medical devices such as flexible endoscopy and catheters, mobile medical robotics could access complex and small regions of the human body such as gastrointestinal, brain, spinal cord, blood capillaries, and inside the eye while being minimally invasive and could even enable access to unprecedented submillimeter size regions inside the human body. Several groups have been proposing active, robotics capsule endoscopes within the last decade where such devices could be remotely controlled to achieve active imaging and have other medical functions [2, 6-8]. Many applications of magnetic nanoparticles rely on the use of magnetic fields to manipulate their properties, which depends on the effectiveness of the particle magnetic moment and the field gradient. Magnetic Actuation System is capable of generating a magnetic field gradient and/or uniform magnetic field, which are classified into two main categories: electromagnetic systems or rotating permanent magnetic systems [9-11]. We will discuss their advantages and application in this section. Electromagnets can be easily and simultaneously controlled by electric currents. Uniform magnetic fields and uniform magnetic gradient field can be generated by the specific configuration of electromagnets: serial and parallel connection coils. The motion of robots actuated by uniform magnetic field or uniform, magnetic gradient field can be predicted [12-15]. The electromagnets can be combined with each other in order to generate more complicated magnetic fields. This researches basic goal of this paper to electromagnetic manipulation Magnetic Robotics treatment system with precisely targeted drug release and multifunctional real-time monitoring and computer simulation in process control, in particular, the generation of the required magnetic field and magnetic force manipulation and mechanical parts of existing medical robotics devices are still relatively large and rigid to access and treat major previously inaccessible parts of the human body. This trajectory controlling device of the overall system which consists of the robotics, robot controller, monitoring, the system controller and the electromagnetic controller.

1.1 CONTROLS OF TRAJECTORIES MANIPULATION SYSTEM AND METHODS

This system is hardware design for manipulating the movement of nanoscale materials and robotics that have magnetic properties. Our system can work in three modes and three pair solenoids situated on the faces of the cube.

1) Parallel Coils on a serial circuit. XYZ - axis coils are controlled by three different power supplies and each parallel solenoid coils are controlled by an independent power supply.

2) Single coil on an independent power supply X-axis. The same paired coils on x-axis 1 pair coils are controlled by two independent power supply.

3) Single coil on an independent power supply Y-axis.

The same paired coils on y-axis 1 pair coils are controlled by two independent power supply. The particle represented by the circle region of interest (ROI) can be manipulated to a three dimensional degree of freedom and could follow the direction of the magnetic field intensity depending on the Power (v), Frequency (Hz) and Phase (angle) of the system. Frequency and phase, a voltage can be controlled using NI DAQ PCI-6221 board connected.

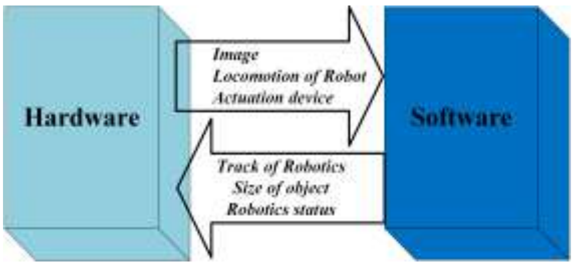

Fig. 1. Software part and Hardware part of Robotics system

Figure 1 shows the block diagram of the functional interaction between hardware and software part. Fundamentally, software part gives the communication of the robotics position and trajectory and robotics status, image processing and LabVIEW simulation. Moreover, hardware part generates the magnetic field of robotics inside a body, the locomotion force of the robotics and actuation therapy tools, NI board and Joystick control.

II. MATERIALS AND METHODS

A. *Fabrication of coil system and control power supply*

The system consists of a power supply GW-Instek APS-1102, which controlled by PCI- 6519 controllers using LabVIEW software. LabVIEW was used as a measuring instrument driver for the power supply programmable AC/DC powered source. Three power supplies were used on the EMM system. Output modes include two operation modes: alternate current (AC) and direct current (AC+DC), each of which can be combined with signal source modes internal (INT). Six identical coils (solenoids) placed on the cube faces (origin of coordinates is situated in the centre of the cube). The coil system is described in details in the article. The following coil parameters were used for calculation:

- Coil inner diameter - 100mm
- Coil outer diameter - 260.16mm
- Diameter of copper wire - 0.1001mm
- Number of turns in the coil - 1800N

The waveform and intensity of the magnetic field produced by each stimulator unit were confirmed with a LabVIEW and gauss meter.

B. *Fabrication of magnetic microbots*

In this study, alginate microsphere containing iron oxide nanoparticles (IONPs) were fabricated using the controlled centrifugation. Briefly, 2wt% sodium alginate solution was mixed with 1% IONPs and centrifuged at 1000rpm for 30sec as shown in Figure 5. The Eppendorf tube contains a 0.1M $CaCl_2$ solution and during centrifugation, the magnetic microspheres were collected on the $CaCl_2$ solution and washed three times with distilled water and denoted as Magnetic Robots (MRs) and used for further studies.

C. *Fabrication Process of Magnetic Robot:*

The electromagnetic manipulation robot was fabricated with NdFeB magnetic powder and polydimethylsiloxane (PDMS) through mould fabrication. The mold was fabricated using an engraving machine. The mold was carved on an acrylic plate. The PDMS and NdFeB magnetic powder were mixed at a weight ratio of 1:1. The mixture was stirred for 30 min. The mixture was put into the mold and the redundant mixture was removed. The robot was degassed in a vacuum box to remove bubbles and then placed in the oven to bake at 60 °C for 4 h. The size of the robot is about 5 mm, and we define the robot with the size of half centimetre small robot.

D. *Camera and Microscopy image processing*

Real time video was supported by the LabVIEW vision system. The location of the magnetic micro/nanomaterials was acquired by the vision acquisition Camera/Optical

Microscopy and sent to the main computer. Detection of the object function NI Vision Assistant, tracking function was made with Math Script node using LabVIEW software.

E. Controller Joystick

Supported by LabVIEW- NI DAQ PCI-6221 and CB-68LP input/output connector block, basic input parameters controls the phase (angle) and power (voltage) other frequency (hertz) and on/off switch. This modified configuration provides users with the ability to read positions by measuring the voltage from the middle Pin of the potentiometer. As potentiometer moves from one end to the other, the voltage measured at output would change from 0 to 5Volts. Pin V_{cc} and Pin GND on the joystick ports are connected to power supply of 5Volts output and GND.

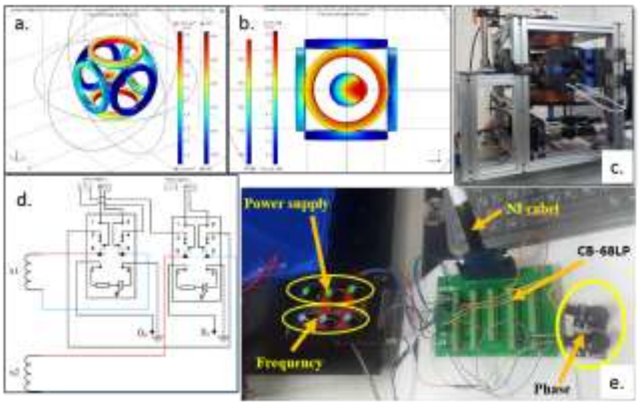

Fig. 2. Electromagnetic system design. (a) 3D coil design of COMSOL Multiphysics. (b) 2d coil design of COMSOL Multiphysics. (C) Coils real configuration. (d) Relay circuits and power mode switching system schematic. (e) Schematic of Joystick controller.

III. Results and Discussion

3.1 Result of COMSOL Multiphysics Simulation part

As a ROI at the cancer model, a circle shaped containing fluid used and particle movement due to the drug force and a magnetic force was tracked using COMSOL Multiphysics. These plots show that the model can calculate the magnetic field accurately.

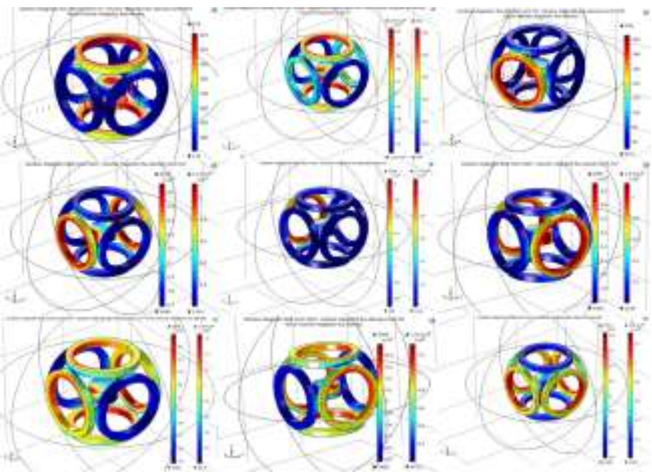

Fig.3. Robotics trajectory in the calculated magnetic field in different views. The colors show the particle velocity. Shows of the nine combinations.

TABLE I. DEFINITION INPUT PARAMETERS

Name	Expression	Value	Description
Imax	2.8(A)	2.8000 A	Coil current
Imin	0.2(A)	0.2000A	Coil current
Umax	200(V)	200.00 V	Coil Voltage
Umin	1(V)	1.0000 V	Coil Voltage
Fmax	550(Hz)	550.00 Hz	Coil Frequency
Fmin	1(Hz)	1.0000 Hz	Coil Frequency

Sample 3D and surface plots for magnetic field simulation of the setup and robotics trajectories for different excitation/direction types is shown in Figure.3. Start from the center point to direct right and left or up and down. For hyperthermia in cancer treatment, the treatment temperature should be within the acceptable range in clinical practice. For our model frequency, the magnetic field strength is 5518 A/m.

3.2 Result of real time working

The figure 4 image depicts a frame of the magnetic core attached MRs as observed by optical microscopy. Direction settings of 90 degrees, time is 10 sec, line size 58 mm. Using the same technique, the Robotics can climb up and down a vertical (line) wall. Several examinations were performed to investigate the controllability of the Robotics trajectory by changing the current of the coils. The results approved that it is possible to align the Robotics movement to all desire direction simply by changing the current of the coils. The coils assigned joystick control for different excitation types.

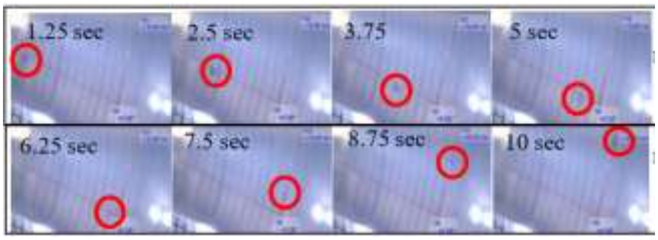

Fig.4. Robotics trajectory in the ROI field. The optical camera top-view of the precise steering of the Robotics along a 90 degree trajectory.

In placement control rotation, there is a range of magnetic field amplitude in which the robotics of these sizes changes the direction of translational motion to the opposite at some field frequency. In this frequency at which important changes of motion take place such as to stop or break of the motion direction. Thus, the modelled magnetic system can provide rotation and movement of the robotics in space by changing outer field gradient created by the magnetic coils.

	Control parameter			Current	Magnetic field (ROI)	Time	Particle trajectory Size
Model1- Step 1	Voltage (v)	Frequency (Hz)	Phase (angle)	(A)	(G)	(sec)	(mm)
	100	10	0	2.3	61	5	5
	0	0	0	0			
	100	10	0	2.3			
	Control parameter			Current	Magnetic field (ROI)	Time	Size
Model1- Step 2	Voltage (v)	Frequency (Hz)	Phase (angle)	(A)	(G)	(sec)	(mm)
	0	0	0	0	61	5	5
	100	10	0	2.3			
	100	10	0	2.3			

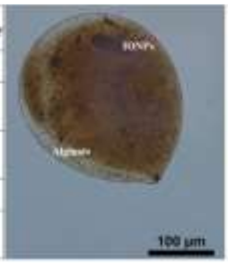

Fig.5. Magnetic particle driven parameter and microscopic image of the fabricated magnetic robotics.

To change the rolling direction, we can control the direction of the axis of spinning by adjusting the dependency power supply as shown in Figure 5. An adjustable spinning speed of the active power supply phase is more than 30 degrees in order to achieve it the frequency also increased to 3Hz. We can change the spinning direct at all axis, if the x-axis coils parameters are zero then the robotics will spin along the y-axis. In all of these excitation types, the magnetic field intensity at magnetic objects place was kept greater than the saturation intensity.

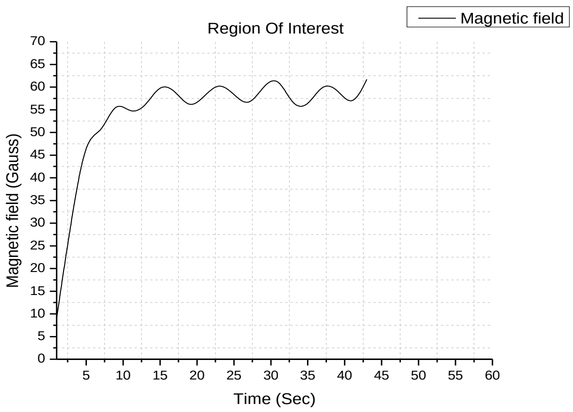

Fig.6. ROI magnetic sensor data graph

Frequency 10Hz according to our calculations using has the optimal results in manipulating magnetic robotics. At frequency 10Hz the relationship between the voltage and current follows a linear graph, also the magnetic field intensity at 10Hz shows in average 61G every 5 second time interval. Coils assigned joysticks control for different excitation types.

CONCLUSION

With the development of the magnetic robotics, they may play a role in the intravascular survey, drug delivery, and minimally invasive surgery in the near future. Practically any of the existing wireless robotics and capsules can be controlled from outside and move in the organs with the help of peristaltic motions. All control system simulation program used by LabVIEW software and COMSOL Multiphysics. The controls of trajectories for targeting of magnetic robotics system is LabVIEW NI-DAQmx, Vision Assistant, also this EMM system can be potentially used in the non-invasive treatment of diseases such as cancer with the delivery of anticancer drugs in the target area. The received numerical data are presented in the form of diagrams of field and force distribution, which affect magnetic Janus/drug loaded robotics modelled in the form of magnetic dipole along the magnetic field vector destination. Consequently, it is expected that the proposed controls of trajectories for targeting of magnetic robotics system can be used in important medical applications for cancer therapy and diagnosis.

ACKNOWLEDGMENT

This paper was supported by grant from the Basic Science Research Program through National Research Foundation of Korea (NRF) by Ministry of Education, Science and Technology (Project no KRF 2016H1D3A1938077, Project no. 2016R1A2A2A07005160 and Project no NRF 2015R1C1A1A02036404).

This research was also partially supported by the Materials and Components Technology Development Program of MOTIE/KEIT, Republic of Korea 10076464.

REFERENCES

[1] A. Heidsieck, S. Vosen, K. Zimmermann, D. Wenzel, B. Gleich, Analysis of Trajectories for Targeting of Magnetic Nanoparticles in Blood Vessels, Molecular Pharmaceutics 9(7) (2012) 2029-2038.

[2] L. Mohammed, H.G. Gomaa, D. Ragab, J. Zhu, Magnetic nanoparticles for environmental and biomedical applications: A review, Particuology 30(Supplement C) (2017) 1-14.

[3] Y. Tu, F. Peng, D.A. Wilson, Motion Manipulation of Micro- and Nanomotors, Advanced Materials 29(39) (2017) 1701970-n/a.

[4] D. Byun, J. Choi, K. Cha, J.-o. Park, S. Park, Swimming microrobot actuated by two pairs of Helmholtz coils system, Mechatronics 21(1) (2011) 357-364.

[5] M. Fletcher, M. Biglarbegian, S. Neethirajan, Intelligent system design for bionanorobots in drug delivery, Cancer nanotechnology 4(4-5) (2013) 117-125.

[6] M. Sitti, H. Ceylan, W. Hu, J. Giltinan, M. Turan, S. Yim, E. Diller, Biomedical Applications of Untethered Mobile Milli/Microrobots, Proceedings of the IEEE. Institute of Electrical and Electronics Engineers 103(2) (2015) 205-224.

[7] O. Felfoul, J.B. Mathieu, G. Beaudoin, S. Martel, In vivo MR-tracking based on magnetic signature selective excitation, IEEE transactions on medical imaging 27(1) (2008) 28-35.

[8] J. Wang, N. Jiao, S. Tung, L. Liu, Magnetic microrobot and its application in a microfluidic system, Robotics and Biomimetics 1(1) (2014) 18.

[9] X.-Z. Chen, M. Hoop, F. Mushtaq, E. Siringil, C. Hu, B.J. Nelson, S. Pané, Recent developments in magnetically driven micro- and nanorobots, Applied Materials Today 9 (2017) 37-48.

[10] L. Agiotis, I. Theodorakos, S. Samothrakitis, S. Papazoglou, I. Zergioti, Y.S. Raptis, Magnetic manipulation of superparamagnetic nanoparticles in a microfluidic system for drug delivery applications, Journal of Magnetism and Magnetic Materials 401 (2016) 956-964.

[11] M.D. Tehrani, M.O. Kim, J. Yoon, A Novel Electromagnetic Actuation System for Magnetic Nanoparticle Guidance in Blood Vessels, IEEE Transactions on Magnetics 50(7) (2014) 1-12.

[12] F. Qiu, B.J. Nelson, Magnetic Helical Micro- and Nanorobots: Toward Their Biomedical Applications, Engineering 1(1) (2015) 021-026.

[13] X.-Z. Chen, M. Hoop, N. Shamsudhin, T. Huang, B. Özkale, Q. Li, E. Siringil, F. Mushtaq, L. Di Tizio, B.J. Nelson, S. Pané, Hybrid Magnetoelectric Nanowires for Nanorobotic Applications: Fabrication, Magnetoelectric Coupling, and Magnetically Assisted In Vitro Targeted Drug Delivery, Advanced Materials 29(8) (2017) 1605458-n/a.

[14] R.D. Smolkin, Calculation of magnetic field strength and electromagnetic ponderomotive force of separators, IEEE Transactions on Magnetics 38(3) (2002) 1528-1533.

[15] X.-Z. Chen, N. Shamsudhin, M. Hoop, R. Pieters, E. Siringil, M.S. Sakar, B.J. Nelson, S. Pane, Magnetoelectric micromachines with wirelessly controlled navigation and functionality, Materials Horizons 3(2) (2016) 113-118.