URSI GASS 2020, Rome, Italy, 29 August - 5 September 2020

EM Technology for Healthcare and Rehabilitation Applications

Wenwei Yu [(1)]
(1) Center for Frontier Medical Engineering, Chiba University, Chiba, 263-8522, Japan, http:// www.tms.chiba-u.jp/~yu

Abstract

Population aging urgently demands innovation in healthcare and rehabilitation. Electromagnetics (EM) technology, both traditional and emerging ones, could be the source of the innovation, because not only it provides a fundamental understanding of the interaction between human body and its environment, but also its underlying processes act constantly on this interaction in real world. In this paper, several R&D cases for EM technology in healthcare and rehabilitation, categorized into EM for monitoring human functions, and EM as driving mechanisms for human functions, will be given, as well as a prospective view on their future trends.

1 Introduction

The size of aging population is increasing quickly, which raises big challenges to healthcare and rehabilitation. One of the challenges is the lack of caregiving personnel, especially, monitoring and guiding older people at home urgently need technology aid. Electromagnetic waves, which are transparent energy yet can interact with substances have become popular in this sector.

Although shallow penetration depth prevents the real rehabilitation and healthcare applications from reaching the targeted site, exploring in a wider spectrum of different EM parameters introduces possibility of solving the problem. Intensive research for applying EM to healthcare and rehabilitation has been carrying out from the past decade. In this paper, examples on monitoring and rehabilitation will be presented.

2 EM for Monitoring Human functions

The far field and near field of EM radiations have been used for monitoring. For far field, EM has been applied for home monitoring of older people, whose safety at home are needed to be ensured. Millimeter-wave (MM wave) radar system has been applied to detect falling and tag-less localization [1] and respiration [2]. In [1], radar, wireless communications, and data processing techniques are combined for detection. For the detection of respiration and heat beat rate, amplitude probability of the outputs of a compact microwave radar was employed. Figure 1 shows the block diagram of the system proposed in [2].

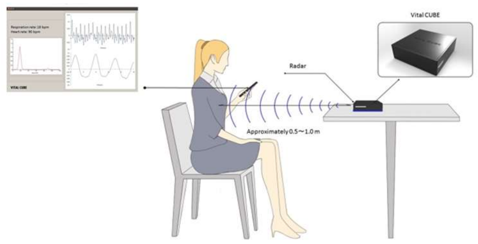
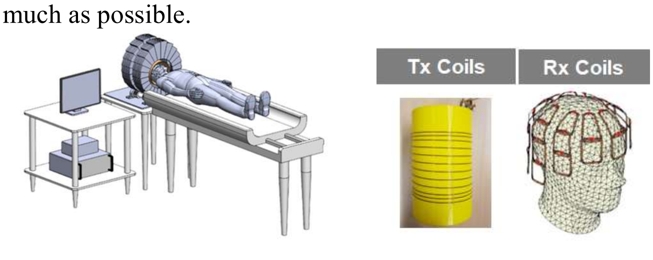


Figure 1. Measurement of respiration and heartbeat signals using radar [2]

For near field, EM waves play a crucial role in the development of portable MRI devices [3]. A portable MRI (head-only and permanent-magnet-array (PMA) based), as shown in Figure 2 (a), can offer routine scans, enabling more continuous monitoring of human body parts. The PMA in Figure 2 (a) is an irregular inward-outward ring pair array that offers a longitudinal magnetic field with a monotonic pattern [4-5].

Although a PMA-based system does not require power or cooling systems, it has a relatively low field strength and thus low signal-to-noise ratio (SNR). To compensate for it, novel radiofrequency (RF) coils are designed to excite and receive the signals from the human body under scan for imaging. Figure 2 (b) shows a solenoid transmit (Tx) coil with irregular pitches that has strong and homogeneous fields [6], and surface receive (Rx) coils that are conformal and designed to be close to the head as much as possible.



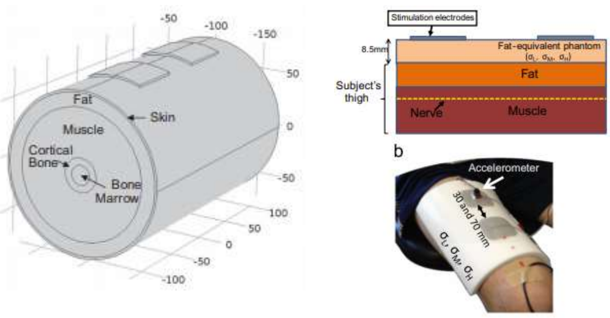
(a) A head-only portable MRI system [3, 4, 5] (b) RF coils in [6]

Figure 2. System configuration and RF coils of a Permanent Magnet Array based portable MRI system

3 EM as Driving Mechanisms for Human Functions

EM has been applied as a driving mechanism for rehabilitation. In [7], a magnet-based device has been proposed for hand rehabilitation. A wearable part is composed of permanent magnet cylinders and they are controlled by an electromagnet at the bottom. Compared with soft-robotics approach for the same rehabilitation purpose, it is a truly remote assistive device.

EM plays a key role in deep brain/tissue stimulation. In [8], a low frequency envelope (0.01 KHz), formed by two interferential waves, was applied to increase the penetration depth of a stimulation from scalp to deep brain. Moreover, in terms of the increase in the penetration depth of stimulation to the nerve in a leg, it is found that reducing tissue impedance is a possible mechanism to generate muscle activation with less energy [9]. Figure 3 (a) and (b) shows a cylindrical model and the experimental setup for this study.



(a) Cylindrical model in [9]

(b) Experimental setup of human-phantom coupling in [9]

Figure 3. Models for investigating the variation of dielectric properties of biological tissues [9]

For tissue impedance, i.e. electrical properties (permittivity ε_r and conductivity σ), the new magnetic resonance imaging (MRI) contrast, MR electrical property tomography (MREPT) [10], offers a promising approach to measure them in vivo. This approach is based on data from MRI measurement (B1-). Machine learning that was initially proposed in [10] shed the light to solve the existing problems of MREPT, namely noise sensitivity and boundary inaccuracy.

4 Conclusion

This paper demonstrates a few innovative applications of EM to monitoring and rehabilitation, including both the research in the literature and those from joint research projects between our research group in Chiba University and our collaborators. It have been shown that, owing to the nature of EM waves, some constrains of the applications due to the requirement to the contact of human-machine interaction, can be removed, bringing people convenience.

Alternatively, re-designs by exploring different spectrum of frequency/electrical properties have proven to revolutionize the corresponding applications. Because of the wide spectrum and invisible power EM offers, more EM-related applications are expected in the near future to tackle the difficulties of aging-related problems.

5 Acknowledgements

Authors wish to thank all the collaborators in our past and current projects.

6 References

1. M. Mercuri, et al, "Analysis of an Indoor Biomedical Radar-Based System for Health Monitoring", IEEE T-MTT, Vol 61, No. 5, 2013

2. Guanghao Sun, Shinji Gotoh, Zijun Zhao, Seokjin Kim,Satoshi Suzuki, Nevrez Imamoglu, Wenwei Yu, and Takemi Matsui, "Vital-CUBE: A Non-contact Vital Sign Monitoring System Using Medical Radar for Ubiquitous Home Healthcare", Journal of Medical Imaging and Health Informatics, 4, 863-867 (2014)

3. Z. H. Ren, et al, "A Low-field Portable Magnetic Resonance Imaging System for Head Imaging", Progress in Electromagnetics Research Symposium 2017 in Singapore, 19-22 Nov. 2017

4. Z. H. Ren, W. C. Mu, and S.Y.Huang, "Design and Optimization of a Ring-Pair Permanent Magnet Array for Head Imaging in a Low-field Portable MRI System", IEEE Transactions on Magnetics, Volume 55, Issue 1, Jan. 2019

5. Z. H. Ren, J Gong, and S.Y.Huang, "An Irregular-shaped Ring-Pair Magnet Array with a Linear Field Gradient for 2D Head Imaging in Low-field Portable MRI", IEEE Access 7, 48715-48724, 2019

6. Z. H. Ren, and S. Y. Huang, "The Design of A Short Solenoid with Homogeneous B1 for A Low-field Portable MRI Scanner Using Genetic Algorithm", poster, ISMRM 26th Annual Meeting & Exhibition, Paris, France, 16-21 June 2018

7. I. C. Baek, M. S. Kim, and S. H. Kim, "A Novel Non-mechanical Finger Rehabilitation System Based on Magnetic Force Control," Journal of Magnetics, vol. 22, no. 1, pp. 155–161, 2017.

8. N. Grossman, et al, "Noninvasive Deep Brain Stimulation via Temporally Interfering Electric Fields", Cell 169, 1029–1041, June 1, 2017

9. J. Gomez-Tames et al, "A human-phantom coupling experiment and a dispersive simulation model for investigating the variation of dielectric properties of biological tissues", Computers in Biology and Medicine, pp. 144–149, 61, 2015

10. A. J. Garcia, W. Yu, and S. Y. Huang, "Region-specific regularization of convection-reaction Magnetic Resonance Electrical Property Tomography (MREPT) for improving the accuracy and noise-tolerance of EP reconstruction", poster, ISMRM 26th Annual Meeting & Exhibition, Paris, France, 16-21 June 2018