Monitoring system development for driving condition of a Ventricular assist device by using mobile phone

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Abstract

Small-sized implantable ventricular assist device is developed for treat end stage of cardiovascular disease. Implantation of ventricular assist device allow patient to go out. However, monitoring of device driving condition and patient health condition is necessary. In this context, adoption rate of mobile phone is increasing drastically and performance is also increased rapidly. Therefore, a monitoring system for driving condition of a ventricular assist device by using mobile phone is proposed. Moreover, a concept of monitoring system of driving and health condition and mobile phone application for interactive communication with implanted device is discussed. In addition, a concept of connection to the local area network is also discussed.

Keywords: Ventricular assist device; mobile phone; e-JIKEI Network

1. Introduction

An estimated 80,000,000 American adults (approximately 1 in 3) have 1 or more types of Cardiovascular Disease. Especially, 16,800,000 cases are diagnosed as Coronary heart disease (Myocardial infarction: 7,900,000, Angina pectoris: 9,800,000) and 5,700,000 cases as Heart failure. However, in 2007, only 2210 heart transplantations were performed in the United States (American Heart Association, 2009).

Therefore, the use of mechanical device therapy to treat cardiovascular disease is increasing. Ventricular assist devices can be used as bridge to heart transplant, recovery, or a destination alternative. The latter support strategy requires a device with increased mechanical durability/lifetime. Several techniques have been developed to improve device lifetime, such as complete magnetic suspension (Masuzawa, 2003; Okada, 2003) and passive hydrodynamic suspension (Watterson, 2001). These devices eliminate contact wear and reduce the number of moving components.

Resulting small-sized and long-lifetime device allow implantation. Implantation of ventricular assist device reduces the risk of infection disease, moreover, allow patient to go out from hospital and improve a quality of life.

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When patients, who implanted assist device, perform activities at out of intensive care unit, high reliability of a device is important. In addition, it is very important to stay in control of device driving condition and patient health condition (Kosaka, 2001; Hendry, 2001).

Meanwhile, adoption rate of mobile phone is increasing drastically in Japan (Ministry of Internal Affairs and Communications, 2009) and performance is also increased rapidly. Therefore, this paper proposes a monitoring system for driving condition of a ventricular assist device by using mobile phone.

2. Monitoring system

2.1. Bi-Ventricular assist device

Almost all ventricular assist devices which are developed by many research groups have one impeller and one set of inlet/outlet. Thus, a device is designed to support only left ventricular or right ventricular. However, right ventricular heart failure may develop in up to 40% of patients receiving left ventricular assistance (Koen, 2004; Radovancevic B, 2003). Hence, bi-ventricular assist systems require the use of two devices, which increases implantation size as well as the cost of the therapy. Therefore, authors are focused on developing a single rotary bi-ventricular assist device (BiVAD) suitably sized for implantation (Kurita, 2008). Proposed BiVAD, shown in Figure 1, includes a set of left and right vanes positioned on rotating hub to form a double-sided centrifugal impeller. Active impeller suspension is achieved with an axial magnetic bearing and rotation via an AC motor.

This BiVAD have eddy current type displacement sensor to detect rotor axial position. In order to monitor device driving condition and patient health condition, additional sensors and measurement instrument should be installed such as rotational speed sensor, pressure sensor, flow sensor and hematological sensors. And measured information by these sensors will be transmitted to the patient’s mobile phone via close range wireless communication device such as infrared data communication and Bluetooth.

2.2. Condition monitoring by mobile phone

In Japan, adoption rate of mobile phone is about 85.4% (nationwide average) and is 136% in Tokyo area (Ministry of Internal Affairs and Communications, 2009). Additionally, the performance is also increasing swiftly. Even though an average mobile phone, it is a standard equipment that global positioning system, still/moving image capture function, internet access (include email and short messaging service) and digital cash function. In addition,
user can program a mobile phone application freely by using Java program language. As is well known, multitudes of free development environment of Java program are prepared. Moreover, close range wireless communication device such as infrared data communication and Bluetooth is also equipped with.

Wherein, pairing a BiVAD with additional sensors and a mobile phone by Bluetooth communication, shown in Figure 2. And a programmed mobile application monitors device and health condition in order to give warning depending on degree of risk as following.

- Level 1: Patient can solve the problem by him/herself. (Blood pressure elevation by exercise, low battery etc.)
- Level 2: Patient can solve the problem by doctor’s instruction. (No need to go hospital)
  Mobile application sends E-mail to doctor in order to get doctor’s instruction.
- Level 3: Emergency case.
  Mobile application calls ambulance, sends current position and calls for help to local communication.

2.3. Connection to e-JIKEI Network

When device and health condition becomes risk of level 3, mobile application calls ambulance, sends current position by using global positioning system. Furthermore, mobile application takes advantage of internet connected e-JIKEI Network (Fujii, 2005) in order to call for help. Figure 3 shows the concept of the e-JIKEI Network. The basic concept is that a community will have a strong ability to prevent crime only if some residents keep watch on what happens around their houses. Thus, community safety would be realized by the voluntary cooperation and altruism of ordinary citizens. The concept intends to re-create the mutual watching system, which had usually functioned in old communities, in a much more powerful and flexible form with the aid of the information technology. In this concept, ordinary individual persons install, possess, and operate a security system consisting of their PC, cheap cameras and free software. The system is placed in each house and networked via the Internet or human communication. Call for help works to early detection of patients, in likewise a security camera becomes the first finder of crime.

3. Discussion

A number of patients who diagnosed heart failure tend to increase every year. While, a number of donor organs are limited. Therefore, a ventricular assist device will be researched widely and increasingly. Heart failure patient will go out from intensive-care unit with implantable ventricular assist device in near future. Whereat, a mobile phone can be used as a high performance remote monitoring system by take advantage of its function, such as internet connection, global positioning system, Bluetooth communication and Java based mobile application. Proposed monitoring system will be realized very cheaply. Because only using general mobile phone and mobile phone application. Moreover, connection mobile phone application to e-JIKEI Network will have a high degree of probability to early detection of patient who needs help, as well as early detection of crime.
4. Conclusion

The basic concept of remote monitoring system for driving condition of ventricular assist device and health condition of patient by using general mobile phone is proposed. And indicate possibility to take advantage of local community network in order to early detection of patient who calls for help. Proposed concept can be used not only for ventricular assist device but also almost all artificial organs.

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