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Development of Commercialization of IoT Healthcare Sensors Customized for 60 GHz Radar

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Abstract-The aging population, the elderly living alone, and the increase in lonely deaths are global social problems. The rising aging population due to an increase in life expectancy and decrease in fertility rates is emerging as an issue except for some developing countries with high fertility rates. According to the results of the 2015 Population and Housing Census, the elderly population aged 65 or older in 2015 was 13.2% of the total population, which is just before the aging society, and 19.8% in 2025, which is expected to be close to the super-aged society. One of the problems of an aging society is the lack of caregivers in homes for the aged because the shortage imposes increasing workloads on caregivers and leads to the deterioration of the quality of care for the elderly. Furthermore, preventive care policies are needed for healthy elderly people, who are potential care consumers who account for more than 80% of the total elderly population, before their health deteriorates in the future due to the absence of services. To solve these problems, we conducted a new type of elderly-friendly study that monitors sleep, movement, and the heart rate of the elderly using contactless radar sensors, and overcomes the limitations of existing face-to-face welfare services as a smart healthcare device that can respond quickly with related institutions in an emergency. As a result, recognition accuracy of 97.65% and an F1-Score of 92.59% were shown. If this is applied to the health and welfare service area, which has traditionally developed around face-to-face services, by combining the Internet of Things (IoT) and radar technology, personalized AI care services can be innovated through sleep and lifestyle analysis for the elderly.

Keywords*: Radar, IoT, Healthcare, Elderly, AI*

1. Introduction

The increase in the aging population, elderly living alone, and lonely deaths is a global social problem, and aging due to an increase in life expectancy and decrease in fertility rates is emerging as an issue except in some developing countries with high fertility rates. Therefore, the Korean government is operating customized care services for the elderly based on vulnerable factors in areas of physical, mental, and social participation, among basic livelihood security recipients aged 65 or older, or those who need care [1]. Among them, 10% of the total elderly can use expensive elderly care services provided by the private sector, 1% of the total elderly and 50,000 low-income seniors a year can receive national welfare benefits, and 8% of the total elderly population is eligible for long-term care insurance.

However, as of the 2015 census, preventive care policies are needed for healthy elderly people, who are potential care consumers who account for more than 80% of the total elderly population, before their health deteriorates in the future due to the absence of services [2]. In addition, one-dimensional services such as simple safety confirmation and alarms when fires are detected are currently in effect, which does not meet the needs of the elderly with chronic diseases for health care services.

Infrared light, frequently used in sensors, is used for monitoring the activities or sleep of the elderly and has the advantage of being inexpensive. However, due to poor precision, falls, which account for a large proportion of major accidents, cannot be confirmed and significant reporting is impossible. Based on these contents, this study conducted an AI service model using

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a 60 Ghz IoT laser sensor to detect or cope with the risk of abnormal symptoms not only for the elderly, but also for the general public.

2. Related studies

2.1 Sleep Disorders

Sleep disorders are an increasing problem with age. According to "Sleep disorder status of nurses in general hospitals and its influencing factors" by Yanjie Han, sleep disorders refer to physical and psychological states that trigger a series of untoward effects because of an abnormal amount of sleep or low and even poor sleep quality [3]. Sleep disorders happen to many people as they get older. Elderly adults who don't sleep well are more likely to suffer from actual aptitude to sleep. When tested for daylight despair, attention and memory problems, extreme daytime sleepiness (considered one marker of insufficient sleep), older sleepiness, and experiencing more nighttime falls. The resulting symptoms are short-term consequences of sleep disorder and include increased stress responsivity; somatic problems; reduced quality of life (QoL); emotional distress; mood disorders and other mental health problems; cognition, memory, and performance deficits; and behavior problems in otherwise healthy individuals [5] . These problems are complex for physical and mental reasons and drug use, and in old age, the nerves of the hypothalamus intersection nucleus that govern biological rhythm are lost, and the synthesis of melatonin in the pineal gland decreases, weakening the circadian rhythm. In addition, it is highly possible to have pain due to the respiratory system, digestive system, cardiovascular disease, arthritis, cancer, etc., and drugs taken are likely to cause sleep disorders. Nearly any visitor to a long-term care facility will see evidence of sleep/wake pattern disturbance among the residents. Among long-term care residents, self-reported difficulties with sleep are even more common and more severe than among older adults living at home in the community [6]. Elderly people in nursing homes are less active and are likely to lie in bed for a long time even during the day, and not being active during the day adversely affects the sleep-awakening rhythm and reduces sleep efficiency.

2.2 Global Monitoring Market for the Elderly

With aging, the health status of the elderly is becoming more dependent on receiving care or monitoring from others due to the frequent incidence of chronic senile diseases and the decline in physical and cognitive functions. One out of every two elderly people in Korea evaluates their health status as unhealthy, and in particular, two out of three people in their 80s and older are judged to be in poor health [7]. According to BCC Research's report "Technologies for Long-Term Health Care and Home Health Care," the elderly care technology market is expected to reach $13.6 billion by 2022 from $5.6 billion in 2017, while Transparency Market Research expects the global smart healthcare product market to reach $25.7 billion in 2016[8]. of the reasons for this growth include an increase in the number of elderlies, an increase in life expectancy, a surge in medical expenses, a lack of medical experts and caregivers, and the preference of the elderly who want to lead an independent and active life.

3. Experiment

3.1 IoT Radar Healthcare Sensor

Healthcare using low-cost, high-efficiency radar sensors have overcome the shortcomings of existing sensors and greatly improved detection accuracy by using radar technology, which enables more accurate detection without being affected by surrounding environmental conditions such as temperature and humidity.

Existing radar was mainly applied to large-scale targets such as vehicles, airplanes, and building security, but achieved miniaturization and lightness for use in daily life such as homes and nursing facilities, greatly increased sensor precision to detect human biorhythms (breath count, heart rate, etc.), and presented a new model for technology. The data they collect will be fed into machine learning algorithms to monitor vital signs, spot abnormalities and track treatments [9].

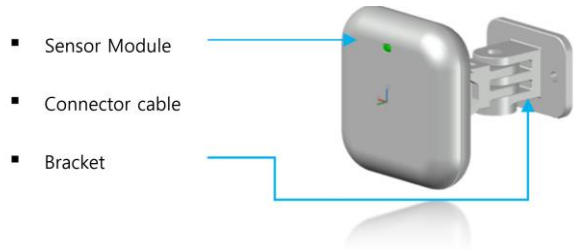

Figure 1- MOD 611 Radar module

The MOD 611 Radar module is the model that we used in this study. The specifications of the radar model above are shown in Table 1.

Table 1. Specifications of radar sensor

Category	Range
Frequency of use.	57 GHz ~ 64 GHz
Transmission output.	Max. 12 dBm
Input voltage.	7VDC ~ 14 VDC
Power consumption.	3W
Operating temperature.	-20℃ ~ +85℃

3.2 Fall Prevention Algorithm

A survey was conducted on the occurrence of falls and the behavior of the elderly after occurrence with nurses, etc., confirming that a fall off the edge of the bed occurred. Based on the algorithm in Figure 2, the fall detection function is activated after "fall prevention detection is possible" when the elderly person moves to the edge of the bed, and if there is no movement for about 10 seconds while the distance increases, it is designed to be judged as a fall.

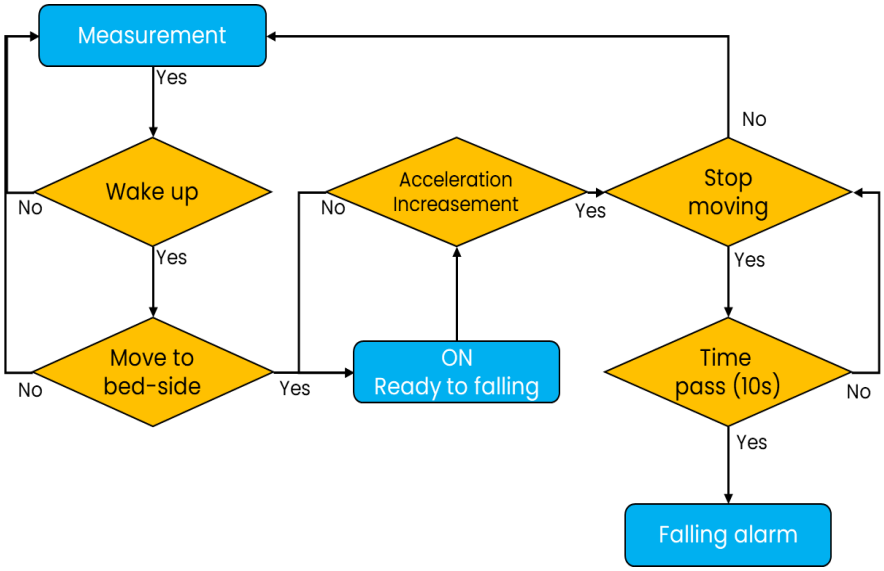

Figure 2- Fall detection algorithm

It was conducted as an empirical test for commercialization, and the scope of application was made available for analysis of general life patterns, care for the elderly in nursing facilities, and patient management systems in hospitals. The empirical data is a method of receiving and processing daily cumulative information based on movement, breathing, and room information of target patients secured from sensors installed in nursing hospitals.

Installation of a total of 80 sensors was completed, and nurses' daily reports were conducted when special matters occurred while real-time data for 80 elderly people who were hospitalized and nursing were secured.

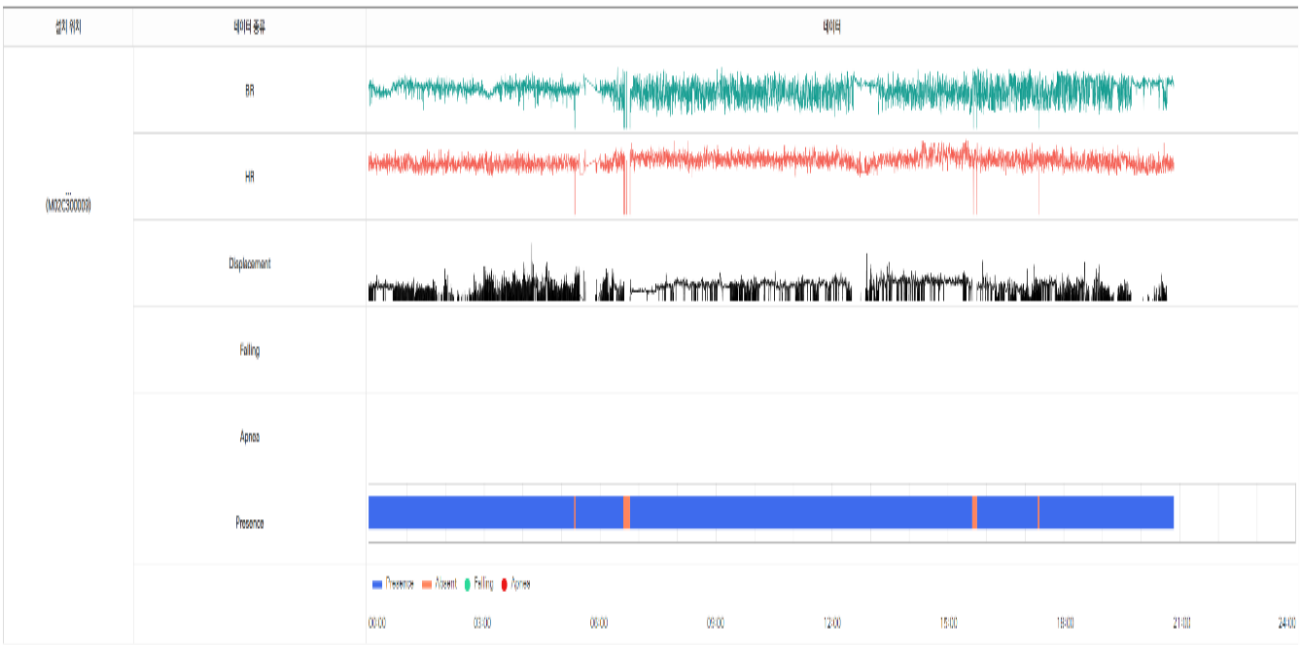

Figure 3- Data storage format

Sensor data for the 80 elderly people were stored in the server in real time. According to Figure 3, most of the elderly in nursing hospitals have difficulty moving, so it can be seen that they stay in their room almost 24 hours a

day. Their names was anonymized and encrypted, and personal information such as resident registration number, phone number, and detailed address, which are all other data that can be referred to as a specific person, was not secured. Since the quality of breathing data varies depending on the installed location of the radar, sensors were installed in various locations as follows and the data was compared.

Table 2. Data quality by radar location

Place	Relative data quality	Fall detection
Ceiling, chest top	Low	Best
Ceiling, the edge of the bed	Middle	High
Wall above head	Best	Low
Wall close to head	High	Low

According to Table 2, when a sensor is installed near the ceiling, the power level of the radar decreases as the distance increases, causing small movements (breathing) to be missed, but if it is too close, data loss occurred due to the narrowing of the radar's observation radius.
However, in order to track the fall analysis of the elderly, it is important to obtain information in a wide radius, so actual data for various cases were secured, and by comparing and analyzing each case with radar, estimation data on where the target user sits and poses were constructed. Test of development and progression (TDP) tests were conducted to secure actual test-based data on two cases of ceiling chest top and overhead wall, the best locations for fall and respiration tests, and the process of occurrence of fall events was established as the estimation system became possible.

4. Results

The test progress can be seen in Table 3.

Table 3. Test Results

No. of Subject	① Ceiling								② Wall over headboard							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
(1)							-	-						-	-	-
(2)						-	-	-						-	-	-
(3)						-	-	-							-	-
(4)						-	-	-							-	-
(5)								-						-	-	-
(1)						-	-	-							-	-
…																
(5)						-	-	-						-	-	-
(1)								-							-	-
(2)						-	-	-							-	-
(3)						-	-	-						-	-	-
(4)															-	-
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(1)						-	-	-						-	-	-
(2)						-	-	-						-	-	-
(3)						-	-	-						-	-	-
(4)							-	-						-	-	-
(5)						-	-	-							-	-

According to the results in Table 3, accuracy of 97.65% and an F1-Score of 92.59% were recorded for ceiling installation. In the case of wall installation, 90.80% accuracy and 74.58% based on F1-Score were recorded. The vicinity of the center of the overhead wall (depending on the size of the bed, but about 60 cm ± 10 cm away from a single bed) is most suitable, and to check falls in nursing hospitals, it is suitable to install it on the ceiling. Based on the above results, the acquisition of KC (Korea Certification, Legal Compulsory Certification) certification of MOD611 sensors including EMC standards was completed for the commercialization of safety and the developed radar.

5. Conclusion

Falling is one of the most common accidents in medical institutions, and according to *Patient Safety and Quality: An Evidence-Based Handbook for Nurses*, unintentional falls are the most common cause of nonfatal injuries for people older than 65 years, and up to 32 percent of community-dwelling individuals over the age of 65 fall each year in the United States [10]. The most important thing is to prevent falls, and patients/elderly with limited mobility have the best way to fundamentally prevent them when they don't have external help, but most of them tend to believe that they can walk and work by themselves. Various sensors have been used to detect falls, but the detection rate is low and there is a problem of discomfort caused by the contact system, but the fall detection system developed/advanced in this study shows that it can measure the movement of the elderly through non-contact means and does not cause privacy problems. Due to these advantages, it is believed that it can be used for fall detection of those with mobility difficulties in various medical institutions such as hospitals and nursing hospitals, and it is in progress to quickly cope with falls using sensor data for proof of concept in this study.

By introducing state-of-the-art radar technology to currently built care services, it can provide stability to the elderly, efficient services to service providers such as caregivers, and more systematic services to local governments as management subjects. To this end, a hybrid web app-based service application is being developed during this study, and after development it will provide an immediate response to the elderly who are being sensed when a fall problem occurs.

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