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Earphone Style Wearable Device for Automatic Guidance Service with Position Sensing

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***Abstract*—This paper describes a design of earphone style wearable device that may provide an automatic guidance service for visitors. With both position information and orientation information obtained from NFC and terrestrial magnetism sensor, a high level automatic guide service may be realized. To realize the service, a algorithm for position detection using the packet from NFC tags, and developed an algorithm to calculate the device orientation based on the data from acceleration and terrestrial magnetism sensors called as MEMS. If visitors want to know some explanation about an exhibit in front of him, what he has to do is only move to the object and stands for a moment. The identification program will automatically recognize the status based on the information from NFC and MEMS, and start playing explanation content about the exhibit. This service should be useful for improving the understanding of the exhibition items and bring more satisfactory visiting experience without less burden.

***Keywords*—Wearable device, MEMS sensor, NFC, ubiquitous computing, guide system.

I. Introduction

THERE is an increasing trend of interest in cultural tourist products in the world, and the World Tourism Organization expects that the cultural tourism market would be among the five most important segments of the tourist market in the future. There is no doubt that cultural tourism becomes more and more important form of tourism. Today's most popular tourist destinations are the ones which adjust their offer to tourist needs providing them a range of different activities and experiences. In the case, a cultural product would be a unique emotion, experience, for only sightseeing itself is not satisfactory [1]-[3], [5], [6].

Managers of the world known museums agreed that museums in the future have to make a balance between managing collections and visitors. Involving visitors into dialogue and using museums' collections creatively are now the most important tasks for museums' employees. In the future only museums that really connect with their audiences will be sustainable. Therefore, tourists should be invited to actively participate. One of the ways to realize such a thing is to accept and include some new technologies in museums exhibitions. They could be an important part of interaction between tourists and museum management side. In these years, more and more museums have tried mobile experiences and are considering to create mobile experiences in order to provide tourists more fulfilling and satisfied experiences.

In recent years, along with the spread of mobile phones, exhibition guide services using mobile phones are increasing. These services made it possible for individual commentary that tourists cannot provide with traditional paper style guidance. With the smartphone, multimedia contents can be used easily to explain the exhibition in detail or Multilanguage. This kind of service may be a great help for foreign tourists who do not know the local language. However, with such guidance using mobile phones, tourists need to operate the terminal with both hands. For example, you have to touch the screen or slide it. With their hands, they cannot do other work and become a heavy burden. Means are needed to open tourists' hands and provide tourist commentary automatically.

In recent years, wearable terminals have attracted attention rapidly. Wearable terminals of spectacle type, wristwatch type and head type were developed. The merit of the wearable terminal is that even if this device is installed, the person freely performs other work. Therefore, if a tourist can wear a device such as a wearable terminal and use the tour guide without operation, the burden on the tourist can be greatly reduced. Near Filed Communication (NFC) is a communication technology that can provide a short range communication with small power consumption. We expect to use this communication to identify the location of the tourists. MEMS (Micro Electro Mechanical Systems) can provide various sensing information, such as acceleration and terrestrial magnetism. It is very small in size and can be implemented in a small PCB area. Especially, With NFC and MEMS, we can get position information in room, as this case, the GPS is not available. In order to provide tourists such multimedia, we have developed a multimedia device for interactive guidance [2]-[4]. In the tourist facilities such as Japanese museums, this terminal and management system have already been used. Multilingual guide service is provided to tourists from the world.

Wireless charging technology is also attracting attention for mobile terminals and wearable terminals. By using wireless charging, the burden of terminal management can be greatly reduced. Currently, wireless charging for mobile phones has already been put to practical use. As representative technology, there are inductive technology such as WPC (wireless power consortium), and electromagnetic field resonance technology. Using wireless charging makes it unnecessary to connect cables, making it very easy to manage terminals.

In this paper, we developed a new earphone type wearable device and propose an approach to identify orientation and position of wearable devices by combining the position information from NFC and the orientation information from a 6 axis acceleration and terrestrial magnetism sensor, based on the previous work [7]. With the orientation and position information, the device may recognize the visitors' position

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and their orientation, and give an automatic guidance service for the exhibition object just in front of the exhibition objects. There is a wireless charging added to the device to take advantage of the convenience of wireless charging.

II. Automatic Guidance System

A. System Configuration

Fig. 1 illustrates the system configuration of the earphone style wearable guide system. As shown in Fig. 1, there are two main area, one is facilities management department, another is exhibition facilities. In the facilities management department, content editor provides content creation and editing and coding, and tourist usage history analysis application aggregates the behavior of tourists, and integrated device management station is used for setting content codes to the device and charging the device and read out the history data from the device. In exhibition facilities, several PAN tags or IR tags are located in exhibition area to indicate the location of the exhibit. The wearable terminals are used to automatically play the guidance contents of the exhibition for tourists, when terminal approach an exhibition. For the wearable is equipped on the visitor's head, the Mutual position between the device and user is fixed or constrained. Therefore, the orientation of the device can be used to show the orientation of the visitor.

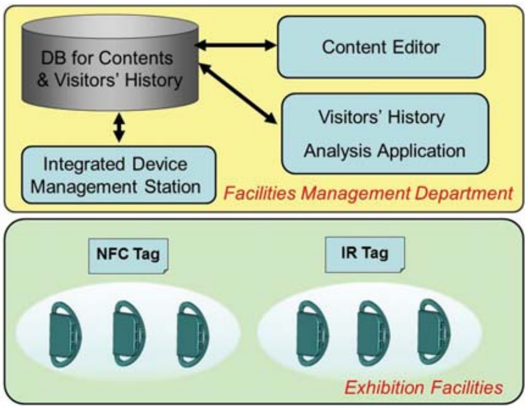

Fig. 1 The basic architecture of the guide system

For the earphone style wearable terminal is not at a regular and consists of curved surfaces in total. Therefore, it is not easy to install a connector for charging. To solve the problem, a wireless charging solution is applied in the integrated device management station. When the wearable terminal is inserted the slot in the station, the charging process will begin, while the tourist usage history information will be sent to the station with a hybrid communication which is a combination of 2.4GHz NFC and 16$Mbps$ infrared communication. We developed a very efficient approach for large capacity data transmitting to multiple terminals at the same time, and the audio guide contents are transmitted to all the wearable terminals which are inserted in the station.

B. Earphone Style Wearable Guide Device

As shown in Fig. 2, the new wearable guide device is designed as earphone style and make the two hands of visitors free. There are only three buttons for operation, two for volume adjustment and one for start or stop. In the device, we board a 6 axis acceleration and terrestrial magnetism sensor IC to obtain the information about the device orientation and attitude condition. With the NFC and a new identification algorithm, the wearable device can identify the status of the visitors and automatically start playing the related content automatically without any operation by users; therefore the device can be used by a wide range visitor from children to elder persons, for there is no necessary to master the usage of the device before using it. The only thing that the visitors should to do is putting the device on their ear as shown in Fig. 2.

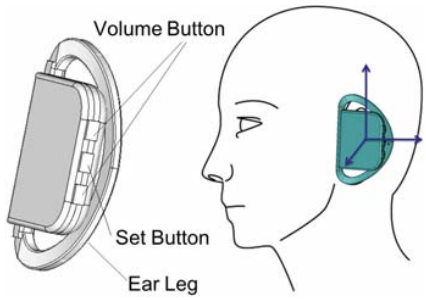

Fig. 2 The design of an earphone style wearable guide device

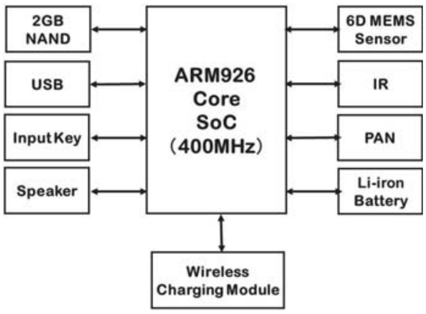

Fig. 3 The architecture of the wearable guide device

The new earphone style wearable guide device is developed with an ARM926 core SoC and a RTOS platform called ThreadX. Fig. 3 shows the main structure of the wearable guide device. As shown in Fig. 3, the wearable device is composed with a ARM926 core SoC, 6 degrees sensor IC,

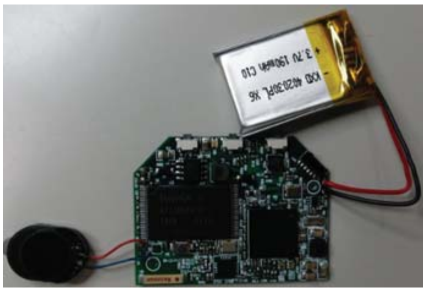

Fig. 4 The PCB module of the wearable guide device

ubiquitous communication IC, a flash memory, a mini speaker and a wireless charging module. A 200mAh Li-iron battery is used to provide the power to guarantee the device can work more than 8 hours without charging. Fig. 4 shows the PCB module of the wearable guide device. There is a coil fixed on the PCB to provide a wireless charging function. Fig. 5 shows a photo of the trial manufacture device. The weight of the device is less than $40g$, it is light enough for wearing on the ear for a long time.

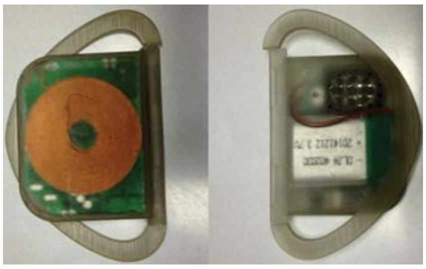

Fig. 5 The trial manufacture of the earphone style wearable guide device

As wireless communication, we developed our own communication protocol, which can reduce power consumption greatly compared with fashionable wireless communication such as Wi-Fi, Bluetooth. Therefore, the new wearable guide can provide a much longer operation time. For a guide system in exhibition facilities, it is important that the wearable guide device can provide guidance service without charging for the total opening period of tourist facilities. In the design of the wearable terminal, it has become important to extremely reduce the power consumption of the communication function and the reproduction function in order to realize long-time operation and weight saving.

C. Wireless Charging

As shown in Fig. 2, the shape of the earphone style wearable guide device is not easy to provide a direct connection for charging, so we adopt wireless charging technology in the device. In our wireless charging circuit, we adopted inductive technology for its high efficiency and low cost. To realize the wireless function, we designed a charger slot to provide wireless charging as shown in Fig. 6. The shape of the charging slot is designed according to the outer shape of the wearable terminal, and the charging distance of the charging coil can be reliably secured. With such a design, the management load of charging is greatly reduced, contributing to cost reduction of the operation side. When you want to charge the wearable device for low battery condition, the only thing you should do is putting the wearable device into the slot of the charger. The wireless charger can provide up to $250mA$ charging current, and charging time is less than three hours to charge the battery to full.

D. Structure of Unique Service by History Learning

In order to provide highly satisfactory service to those who visit sightseeing facilities like museums, it is necessary

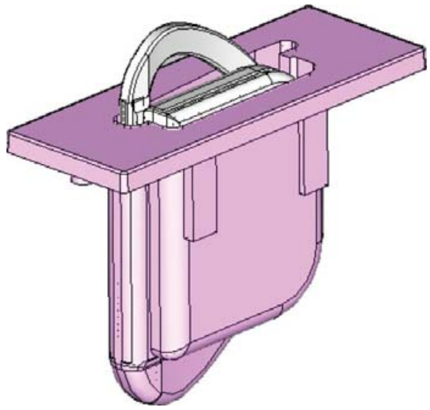

Fig. 6 The design of the wireless charger and the device

to deal with a wide range of age, hobbies and purpose. In order to realize such a service, we want to a close loop information flow by using behavior history information of tourists and modifying the contents selection condition and etc... With such concept, it is possible to realize an automatic guidance service with a flexible customized service. Fig. 7 shows the total information flow in the automatic guidance system. In the system, wearable terminals have a close cooperative connection to the integrated device management station, therefore, the behavior history information of tourists and contents can be transmitting automatically. This give a base for automatically learning processing. As shown in Fig. 7, the information flow is from the integrated device management station to the terminal by wireless communication when the device is put on the charge slot, then, based on the presetting condition, and the position and status of the tourists, the wearable terminal will start to provide a voice guidance service that is selected from the DB in the terminal. While the tourists use the wearable terminal, the terminal will record tourists' behavior history with time stamp for later analysis and behavior study at the integrated device management station. On the basis of this system structure, by adopting artificial intelligence technology etc., more advanced guide service will be possible in the future.

Compared to services provided by smartphones and tablet terminal products, automatic guidance for low-cost operation for a long period of time can be made without burdening visitors, automatically tracking fluctuations in the needs of tourists, and to meet the needs of tourists Provide matching intellectual tourist information service.

III. Identification of Position and Status

In order to provide tourists with correct guidance at the right time, it is important to accurately identify the location, orientation and movement of tourists in real time.

Here, regarding the position information, a packet transmitted from the NFC tag installed in the exhibit or its vicinity is used. In the method of obtaining position information using a tag such as a beacon, a method using the reception strength of radio waves becomes mainstream.

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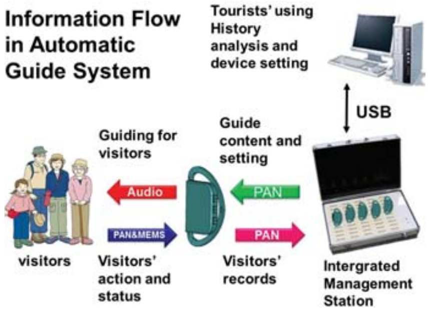

Fig. 7 The total information flow in the guidance system

However, in reality, the radio field strength is enlarged to the movement of the surroundings, the change of the exhibition arrangement, the change of the weather, etc., and seems to be problematic in practical terms.

A. Identification of Position Approach

When there are a plurality of exhibits in the exhibition space, it is necessary to use a plurality of wireless tags to indicate the position of each exhibit, so that the wearable terminal sometimes receives wireless signals from a plurality of tags at the same time.

In the location-specific application using the wireless beacon, there is a method of measuring the signal strength of the wireless tag. Since this signal intensity varies greatly due to changes in the environment, sufficient accuracy can not be expected. Here, without using the signal strength of the tag, we use a method to locate by tag packet only. Since signal strength can not be used, we reduce the signal effective distance of the tag and cover a small area with one tag. As a result, this area can be specified when a wireless packet of a tag is received. However, if there is overlap in the vicinity of the boundary of these areas, the wearable terminal sometimes receives signals from other areas evenly. Generally, upon receiving a tag packet, processing corresponding to the area indicating this tag is performed. Then, when the signal from the tag in another area is received occasionally, it immediately switches to the processing of the area, resulting in malfunction.

In order to accurately estimate the position, we realized to improve the accuracy of position estimation by integrating tag reception times. Instead of the received tag signal strength, we defined the index B_{ID_i} representing the number or frequency of received tag signals ID_i. When a tag packet of ID is recevied, for all i, B_{ID_i} is modified by

$$B_{ID_i}^{k+1} = \begin{cases} f(B_{ID_i}^k + \beta - \delta(t_{k+1} - t_k)) & ID_i = ID \\ f(B_{ID_i}^k - \beta - \delta(t_{k+1} - t_k)) & ID_i \neq ID \end{cases} \quad (1)$$

where, $f(\cdot)$ is a function defined as

$$f(x) = \begin{cases} \mu & (x > \mu) \\ x & (0 \leq x \leq \mu) \\ 0 & x < 0 \end{cases}$$

In (1), δ reflects the elapsed effect of time. Figs. 8 and 9 give the flow chart of the ID receiving frequency counting implementation. There are two threads for monitoring the tag receiving process. In the counting process thread, the tag signal frequency will be modified when a new tag signal is received. The parameter μ is a saturation upper limit to avoid the too large value of the signal frequency.

In the position area identification process thread, we will make a sort process for the frequencies in ID list buffer, and find ID with the maximum value and minimum value. For ID with minimum frequency value, we will remove the ID from the list buffer. A time reducing process is also carried out in the thread. When the maximum frequency value ID is more than a threshold $omiga$, which means the tag signal is strong enough, the ID message will be sent to the upper layer application, By actual measurement experiments, the identification accuracy of the tag area by this method has been improved from 72Due to the introduction of this index, malfunction of the guide commentary was greatly lowered, and the provision accuracy of the guide commentary was greatly improved.

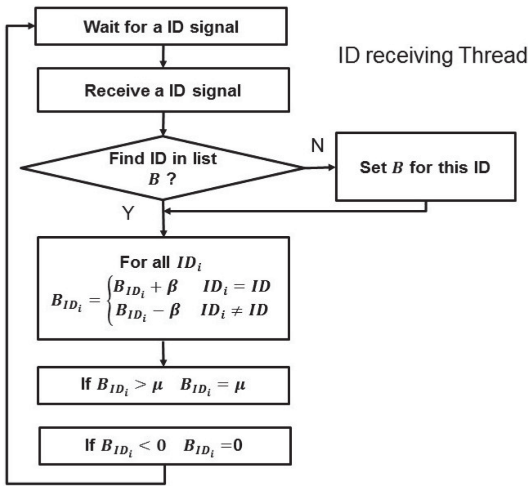

Fig. 8 The counting process thread

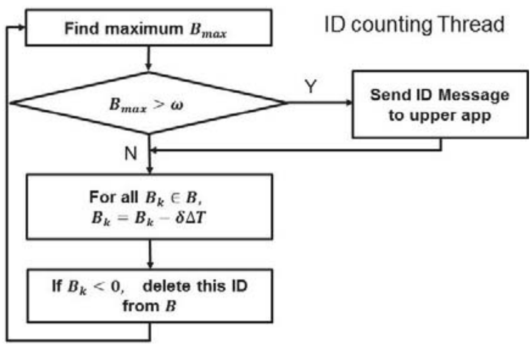

Fig. 9 The position area identification process thread

To calculate the orientation of the terminal, the algorithm proposed in the previous study [6] was adopted. If it is not a specific position, there is no need to calculate the orientation. We only calculate the orientation when the wearable terminal is on an valid area. Fig. 10 shows the process of determining the position and orientation of the wearable terminal.

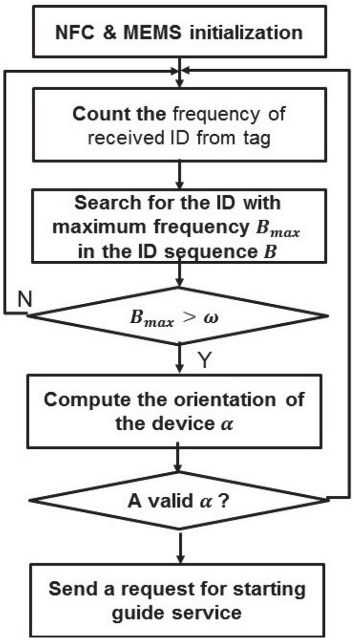

Fig. 10 The identification of the position and orientation

IV. Conclusions

In this paper, we have developed a wearable terminal that can be worn on the ear and realized to provide automatic guiding service to tourists. To identify the tourists' position and orientation, a NFC IC and a 6 axis acceleration and terrestrial magnetism sensor are used. The position measurement method using the radio wave reception intensity from the tag is liable to cause a large deviation due to environmental changes. In this research, we propose a new method using reception frequency, and this effect was confirmed by experiment. In order to reduce the burden of managing the wearable terminal, we developed wireless power transmission and power receiving circuit and successfully implemented the wireless charging function. Also, by adopting a unique charging slot designed, charging management of the terminal becomes very easy. In conjunction with a management system that aggregates the usage history of tourists, customized guidance services corresponding to the taste of tourists become possible. The wearable guidance service developed in this research can be expected to raise the satisfaction of tourists.

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