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Functional Model of a Smart Bead Bracelet

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***Abstract*—Many smart bracelets have been developed for e-Health. However, it is difficult for the elderly to use a smart bracelet. Therefore, in this paper, we propose the Smart Bead Bracelet (SBB), which the elderly can wear naturally. The SBB is a bracelet made from smart beads. Smart beads automatically measure information for e-Health and are easily removable. The measurement information can thus be changed according to each symptom. In addition, the SBB has high affinity with traditional cultures, such as Buddhism and Feng Shui. In this paper, we define a functional model of the SBB and verify its feasibility.**

Keywords—Internet of Things, Mist architecture, Smart Bracelet, e-Health

I. Introduction

Aging is a social problem in many developed countries. In particular, increasing medical costs are a serious problem. Maintaining the health of the elderly can prevent a further increase in medical costs. Smart bracelets are suitable for health management of the elderly. There are in fact many examples of such bracelets, such as the Apple Watch. However, existing smart bracelets do not have sufficient health management functions. We propose the Smart Bead Bracelet (SBB) as a smart bracelet that has sensors customizable to the personal health conditions of the elderly. The SBS is a bracelet made of smart beads (SBs). Each SB has a different function. The SBB can be customized by combining different SBs.

In this paper, to verify the feasibility of the SBB, we implement its functional model. The SBB can be realized in the future if the mounting technology meets this specification.

The United Nations has adopted the 2015 Sustainable Development Goals [1]. There are 17 such goals, and this study relates to the third goal, “Good health and Well-being”.

Existing smart bracelets are designed to be all-in-one devices. It is difficult to change the sensor after manufacture. Health data to be recorded for the elderly depend on the medical condition of the individual. The required sensors therefore differ for each person. The SBB can be configured by combining the sensors required for each individual.

Multi-function smart bracelets include the Bangle [2] and Tangible Apps Bracelet [3]. The Bangle is a digital jewelry assistant that uses a full-scale organic light-emitting diode. The design can be changed freely, but the function cannot be changed. The Tangible Apps Bracelet is a versatile piece of smart digital jewelry. It comprises multiple pieces of jewelry having different functions. Jewelry can be selected when creating the Tangible Apps Bracelet. However, it is unclear if jewelry can be replaced after completion.

The remainder of this paper is organized as follows. Section II presents related research. Section III describes the SBB design. Section IV presents the functional model of the SBB. Section V describes the evaluation. Section VI presents conclusions and future issues.

II. Related Works

A. Low birthrate and aging population

The declining birthrate and aging population have become serious problems in developed countries. In Japan, the total fertility rate is below the population replacement level of 2.07, and the population is thus declining. Additionally, Japan is aging. The average life expectancy continues to increase moderately, and the aging rate reached 27.7% in 2018. Similar trends are seen in developed countries other than Japan.

B. e-Health

e-Health [4] refers to all forms of electronic healthcare provided through the Internet. In other words, it is an activity that improves health. e-Health has evolved from telemedicine and telehealth.

Many smart bracelets for health management have been developed with the spread of the Internet of Things.

C. Smart bracelets

Many smart bracelets, such as the Apple Watch and Fitbit Flex, have been developed. These products cannot have their sensors changed after purchase. They are thus unsuitable for our purposes. We introduce bracelet-type smart digital jewelry as examples relating to our purpose below.

The Bangle [2] is a digital jewelry assistant that uses full-scale The organic light emitting diode design can be changed freely but the functions cannot be changed.

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The Tangible Apps Bracelet [3] is versatile smart digital jewelry. It comprises multiple pieces of jewelry having different functions. Different pieces of jewelry are selected when creating the Tangible Apps Bracelet. However, it is unclear if pieces can be replaced after completion.

None of these are sufficient for personal health care.

D. Bead bracelets

A bead bracelet is made up of uniform parts called beads. Strictly speaking, although there are variations in the size of beads, the beads are easy to replace owing to their large uniformity.

Bead bracelets have various cultural backgrounds. Buddhism is widely worshiped mainly in Asian countries, such as Japan, Thailand, Myanmar, Tibet, and China. Moreover, although there is no scientific evidence, gemstones have long been considered to have mysterious powers. Spirituality is useful in human care in a broad sense. The effect of devotion is not weak. As an example, the placebo effect is well known.

Many elderly people are pious, and it seems that they are less likely to wear beads. In Japan, a spiritual boom is creating a trend of wearing fashionable prayer beads among young people.

E. Mist architecture

We are proposing the Mist architecture for the efficient development of Internet-of-Things devices [5]. The Mist architecture allows the linking of multiple Internet-of-Things devices in the cloud.

The Mist architecture comprises three elements.

(1) The cloud connects to a wide area network and bundles Mist.

(2) Mist connects to a field area network and local area network and bundles Droplets. Even if the local area network is separated from the wide area network by a firewall, network address translation traversal is possible [6].

(3) A Droplet is an end sensor device that connects to the field area network.

Managed network blocks have been developed as an example based on the Mist architecture [7]. The SBB system comprises an SBB and smart charm. The SBB plays the role of a Droplet while the smart charm plays the role of Mist.

F. Metabolic architecture

We have proposed a metabolic architecture for the realization of renewable computing [8][9][10]. The metabolic architecture achieves homeostasis through the active exchange of components before they fail. We also propose a ring architecture [11]. The ring architecture is similar to the SBB.

In addition, we have proposed an ARM-based cloud using the metabolic architecture and its network OpenFlow Mesh [12][13]. The OpenFlow Mesh realizes self-recognition. Self-recognition is an understanding of one's composition. The SBB understands the sequence of beads.

G. Sports Cloud

Elderly people can maintain their health through proper exercise. Sports thus help maintain the health of old people. The Sports Cloud manages sports information for athletes. In particular, the Sports Mental Cloud manages the psychological information of athletes. We have implemented the Sports Mental Cloud [14][15]. Although the SBB cannot obtain psychological information, it can obtain exercise information. The Sports Cloud can aggregate e-Health information collected by the SBB.

H. Summary

A bead bracelet is a bracelet with replaceable beads. Smart beads allow customized health care.

III. System Design

A. Requirements

We here describe requirements that the SBB system must satisfy.

(R1) Multi-purpose: The SBB has multiple beads. The individual beads are different sensors that serve different purposes. Additionally, one bead can be used for different purposes. Versatility thus has the two meanings: (1) to use multiple sensors for one purpose and (2) to use one sensor for multiple purposes. The measurement depends on the hardware whereas the purpose relates to the software.

(R2) Personalization: The SBB changes the connection of beads according to the purpose of the individual. The SBB can record different health data for each individual.

(R3) Reconfigurability: SBB beads can be exchanged freely. The bead composition is automatically recognized during the replacement of beads and the restarting of the SBB after the replacement of beads.

(R4) Extensibility: The SBB can have new beads added. The SBB downloads and installs new bead device drivers from the cloud.

B. System Architecture

The SBB system inherits the concepts of the Mist architecture and Metabolic architecture. The SBB system comprises the cloud, a smart charm, and an SBB (see Fig. 1).

The cloud, smart charm, and SBB respectively correspond to the cloud, mist, and droplet in Mist architecture. The SBB is a sensor device. A smart charm is a device that operates the SBB interactively and mediates between the SBB and cloud. The cloud stores data and works with various services.

Owing to its size, the SBB has insufficient input/output functions. A smart charm is a smart pendant that has the shape of a traditional charm and complements the functionality that the SBB lacks. A discussion of smart charms is beyond the scope of this paper.

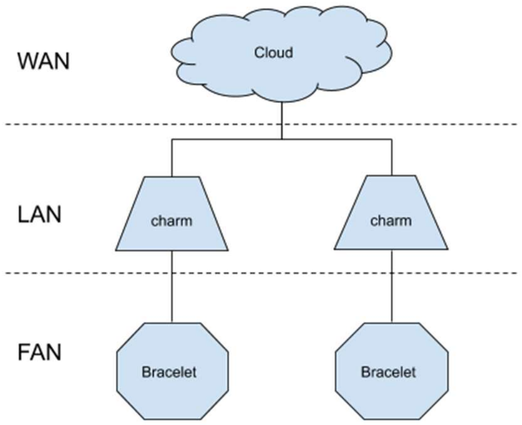

Fig. 1. Mist-based SBB and charm

C. Package Design

Beads are more difficult to implement when they are of smaller diameter. Beads of a traditional bracelet (having perhaps 18 beads) have a diameter of about 20 mm. However, even the smallest Arduino compatible microcomputer PICO [16] requires a board with dimensions of 15 mm square and a diameter of about 25 mm. A coin-type CR2032 lithium-ion battery has a diameter of 20 mm. A bead diameter of 25 mm is thus appropriate. We therefore reduce the number of beads on the bracelet to eight.

The diameter of a bracelet is generally on the order of 50 mm. Figure 2 shows beads placed on such a bracelet. Here, a hemispherical ball is placed on a square pedestal. This allows a uniform, repositionable shape to be achieved. The pedestal stabilizes the direction of the beads. It also makes sensing easy. A large sensor, such as a Global Positioning System (GPS) unit, or organic light-emitting diode can be realized by bundling multiple beads.

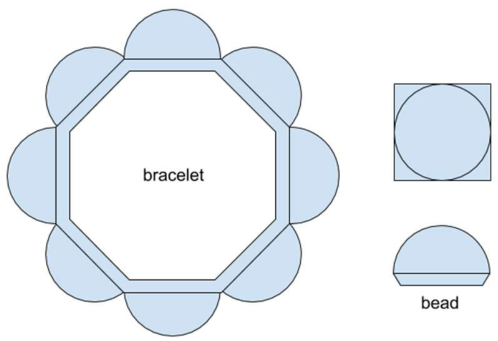

Fig. 2. Package design of the SBB

D. Beads

The SBB has multiple SBs with different functions. The different types of SB are as follows.

(B1) Core (micro-controller)

(B2) Battery (or button cell)

(B3) MicroSD card

(B4) Spacer

(B5) Dummy

(B6) RGB light-emitting diode

(B7) Rotary encoder (click wheel)

(B8) Body temperature

(B9) Pulse sensor

(B10) GPS unit

The microcomputer can connect to the Internet via Wi-Fi and Bluetooth Low Energy (BLE). The microcomputer and sensor are driven by batteries. A MicroSD card saves data even if the SBB is offline. A spacer adjusts the inner diameter of the bracelet. Dummy beads have no sensor. A rotary encoder and RGB light-emitting diode respectively enable minimum input and output. The rotary encoder performs selection and determination operations by rotating and pressing respectively. The body temperature sensor detects a medical condition such as a fever. The pulse sensor measures the heartbeat and detects stress. The GPS unit helps in the search for wandering elderly people.

None of the SBB beads display much information. Large display devices cannot be installed owing to the restricted bead size. A smart charm solves this problem. It is possible to operate the SBB from a smartphone via the cloud because the SBB is based on the Mist architecture.

Construction of the SBB requires the number of beads to be limited to eight. Sensor beads can be exchanged and used under this limitation.

An SB is connected via an Inter-Integrated Circuit (I2C) [17]. The SB has an I2C address indicating the bead type. Beads of the same type have the same I2C address. I2C cannot recognize devices with duplicate addresses. It is therefore necessary to have a function for distinguishing devices of the same type.

IV. FUNCTIONAL MODELS

The previous section described functions of the SBB. This section describes a functional model that realizes these functions.

A. Functional Model of the SBB

The functional model realizes functions of the product. Specifications other than the function may differ from those of the product. Specifically, beads designed to satisfy the package constraint are mounted independently of the package size.

In this paper, we mainly verify reconfigurability using a functional model. The SBB must be reconfigurable. At the same time, the SBB must be able to recognize itself. Here, self-recognition means automatically detecting the positions of the beads. The beads are replaceable with a few exceptions. The SBB is totally reconstituted when the beads are replaced. It is necessary to understand the SBB functions after reconfiguration.

We believe that core beads can be realized with a PICO microcontroller. However, development using a PICO microcontroller is not always easy. Therefore, in this paper, we prototype a functional model of the SBB using an M5Stack board [18]. The functional model may be of any size. M5Stack, M5StickC, and M5Atom are members of the M5 core product family.

M5Stack adopts an ESP32 microcontroller, like a PICO controller. The EPS32 has Wi-Fi and BLE connectivity. M5Stack can therefore communicate with a smart charm (i.e., another M5Stack) through Wi-Fi or BLE.

There are three major variations of M5Stack. M5Stack Basic is the most basic variation and has a liquid-crystal display (LCD), three buttons, a battery, Wi-Fi functionality, BLE functionality, and a Grove (compatible with I2C) terminal. M5Stack Gray has an inertial measurement unit in addition to the features of M5Stack Basic. M5Stack Fire has three types of Grove interface (A, B, C) in addition to the features of M5Stack Gray. Port A is an I2C port, Port B is an I/O port, and Port C is an UART port. M5Stack Gray stacks the PLUS module and can use three ports like Fire. In addition, a rotary encoder can be used.

M5 Stick has only an I2C network. Beads are realized as I2C devices. I2C sensors, such as a pulse sensor, body temperature sensor, and GPS unit, are connected via the I2C network.

M5 Atom is the smallest of the M5 Core family, having dimensions of 24 mm × 24 mm × 10 mm. Bead requirements except that of the thickness are thus met. However, M5 Atom has no LCD and only one RGB light-emitting diode.

The development environment of M5Stack includes Arduino IDE and UIFlow. Arduino IDE is an Arduino-compatible IDE that uses the Processing IDE. UIFlow is a Web-based IDE using Blockly. For UIFlow, developers can connect M5Stack to a Wi-Fi network and code on site (http://flow.m5stack.com/).

According to the above consideration, a PLUS module is added to M5Stack Gray to realize a functional model. The LCD of M5Stack emulates the operation of a smart charm. In the functional model adopted in this paper, the communication between the SBB and smart charm is omitted because the SBB system is realized by M5Stack alone. The different types of SB are as follows.

(B1-3,6-7) M5Stack + PLUS module + Port A I2C hub

(B8) No Contact Infra-Red ray (NCIR) unit

(B9) Mini Heart Rate Unit

(B10) Qwiic GPS + Qwiic-Grobe adapter

Here, Qwiic is a specification for smaller wiring that is compatible with Grove. The width of the M5Stack I2C sensor unit is about 25 mm. Therefore, the width is the only dimension equal to that in actual implementation. Discussion of the implementation of B8-10 is beyond the scope of this paper.

B. I2C Network in the SBB

The SBB requires a self-recognition function. Here, self-recognition means automatically detecting the position of a sensor. The position of the sensor cannot be identified when connecting with a normal Grove hub unit.

In OpenFlow Mesh, the switch position can be identified from the switch connection status. To this end, Port A hub units are connected hierarchically and linearly. A Port A hub unit realizes six port switches using the TCA9548A I2C multiplexer. However, each Port A hub has the same address and cannot identify itself. This is because the addresses of all I2C devices on the path must be unique. A Port A hub cannot be accessed after the second Port A hub because it has the same address.

A Port A hub unit distinguishes beads with the same address by port. The position of the sensor can be identified even if the sensor is connected to one Port A hub. However, this method requires the use of many wires. Specifically, the Grove cable comprises four lines: the VCC (Voltage Collector), GND (Ground), SDA (Serial Data Line), and SCL (Serial Clock Line). The VCC and GND can be shared but the SDA and SCL cannot. Therefore, for eight beads, 2 + 8 × 2 = 18 wires are needed. A band is therefore used as a base on which the beads are fitted. The positions of the terminals are designated in advance on the band and are wired on the board. In this method, the device located at the prepared place is recognized. It is therefore difficult to increase the number of devices. A Port A hub implements up to six ports only. However, the TCA9548A used in the Port A hub unit is an eight-port I2C multiplexer. Therefore, in principle, up to eight beads can be connected.

Figure 3 shows the wiring of the base bracelet unit. The base bracelet unit is the base of one bead. Eight such pieces form a bracelet. The wiring shifts each time it passes through the unit. As an example, the first bead connects to the SCL and SDA of Port 0. Here, the SCL and SDA of Port n are denoted SCLn and SDAn. SCL0/SDA0 are not wired to the next base unit. SCL1/SDA1 are wired in the same place as SCL0/SDA0. In this way, each bead uses the highlighted terminal.

Using a double-sided flexible printed circuit board, it can be reduced to eight on one side. In this case, the terminal pitch is 2.54 mm. A hole for the sensor is drilled in the center of the base. The hole is not shown in the figure. The wiring within the unit is diverted to avoid the hole.

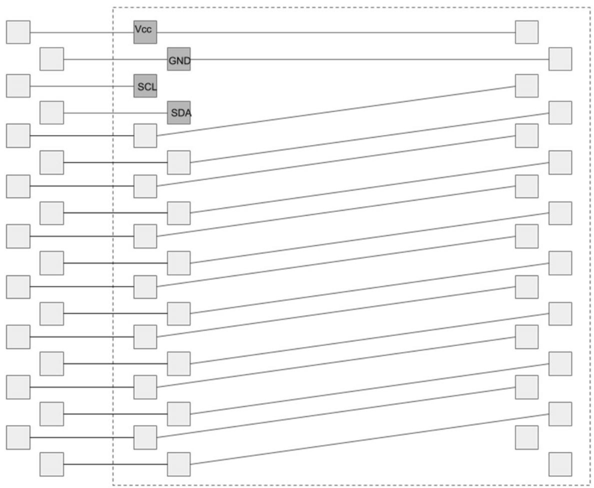

Fig. 3. Base bracelet unit

C. Functional Model of a Smart Charm

A discussion of smart charms is beyond the scope of this paper but we provide a minimal explanation of the functional model of a smart charm. A smart charm has a sufficiently large LCD and buttons or rotary encoder; i.e., it can be realized by adding a PLUS module to M5Stack.

D. Software

The SBB system checks the configuration at startup. The SBB scans the I2C and locates the beads from its port. Even multiple beads of the same type can be correctly identified.

The driver needs to be updated for new types of bead. In the case of an interpreter system, only the driver can be downloaded and installed. However, current SBB systems need to load code compiled by the Arduino IDE. It is therefore necessary to update the entire system software. This is a topic for future study.

Drivers belong to classes and can be shared by similar beads. Bead instances are created individually and stored in slots depending on the port.

Figure 4 shows the software structures of the SBB. The bead class shows the SB driver. The SB driver adopts setup, sense, and menu methods. Here, setup initializes, sense reads from the sensor, and menu displays the operation screen.

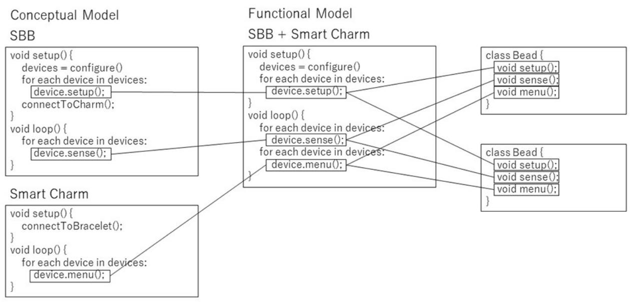

Fig. 4. SBB software structure

In the functional model, sense and menu are called from the loop function based on Arduino. The loop is called repeatedly. Here, configure recognizes the beads. The beads are identified by the I2C address and I2C port. The driver of the recognized device is loaded and set up.

The smart charm screen is operated by the menu method. Only one bead can be operated at a time. If no beads are selected, the charm's own menu is displayed. A bead is selected using buttons on the rotary encoder or M5Stack itself.

The SBB and smart charm are integrated in this functional model. However, the SBB and smart charm are separated in the original conceptual model. The menu loop transitions to smart charms when implementing the conceptual model.

V. EVALUATIONS

A functional model of the SBB was created with M5Stack and an I2C hub unit. The base bracelet unit is reproduced on a bread board.

Two NCIR units were connected to this functional model at the same time. They have the same I2C address but were identified correctly. The model worked correctly even if the configuration was changed. Reconfigurability was therefore realized.

We were able to operate each SB on the smart charm screen. Therefore, self-recognition was also realized.

VI. CONCLUSIONS

We designed a functional model of the SBB. The SBB cooperates with a smart charm to form one system. The functional model was implemented by integrating both with M5Stack. Experiments showed proper reconfigurability and self-awareness.

Future challenges are as follows. The SBB and smart charm are separated and communicate on the network in the implementation of the conceptual model. Using Mist architecture, we will operate an SBB remotely from the cloud. Additionally, SBB data will be sent to the cloud. Finally, we will create an SB as per the package design. We will create the package using a three-dimensional printer.

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