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Design and Implementation of Physical Computing Education Content based on Augmented Reality

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Abstract

Along with a variety of coding education, physical computing education for controlling various sensors is being actively conducted for elementary, middle, and high school students in line with the era of the fourth industrial revolution. A problem with physical computing education using Arduino is pin connection errors between Arduino and various sensors. Most of the students who come into contact with the Arduino for the first time often do not know the purpose of the Arduino pin and the connection position of the pin. Also, hardware built with incorrect pin connections to the Arduino board often does not work properly. If this case continues, students will lose interest in coding education. Therefore, in this paper, we implemented an augmented reality application that informs the connection process of the Arduino board and the sensor during physical computing coding education using Arduino, and designed and implemented educational content for the Arduino pin position and connection process. First, we explain the role of the Arduino board and the sensor and the location of the pins. After that, the students run the educational augmented reality educational content using their smartphones and check the correct pin connection process between the Arduino and the sensor. In the physical computing education, augmented reality content is used to increase the understanding and immersion of the class. It is expected that the educational effect will also increase by inducing fun and interest in physical computing coding education.

Keywords: *AR (Augmented Reality), Educational Content, Physical Computing, 3D animation*

1. Introduction

The 4th industrial era is a next-generation industrial revolution that combines information and communication technology (ICT) with various fields such as IOT, artificial intelligence, big data, smart factories, autonomous vehicles, and AR/VR. Coding education has become an essential course for young people who have to live in such times. Among the various tools, this paper aims to improve the problems that may appear during physical coding education using Arduino. Arduino is currently the most popular tool for

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teaching physical computing coding.

Physical computing using Arduino is the process of making hardware using various sensors compatible with Arduino, coding and uploading programs, and learning the principles and concepts of coding through the operation results. Creativity and problem-solving skills can be improved through this process. Physical computing coding education using Arduino can understand the product driving process by making various smart IOT products that can be touched in real life. Among the domestic Internet portal sites, Naver operates a program called 'Let's play with software'[1], distributes Arduino free online training and learning materials. Samsung Junior Software Academy is actively using Arduino for education[2][3]. There are various making processes that can be carried out using Arduino.

However, most first-time Arduino students tend to find the process of connecting the Arduino board and sensors very difficult. The current physical computing curriculum is as follows. After explaining the theoretical background of Arduino, the description of each pin of the Arduino board, the function of the hardware that needs to be built, the necessary sensors and the connection pins of the sensors that connect to the Arduino board, we will build the actual hardware. In the case of online learning, the learning progresses while watching the position of the connection pin through the camera.

The position of the pins connected to the sensor and the Arduino board must be correct for the hardware to move as intended. There are students who cannot connect to the correct location during class, and it is necessary to check the Arduino of each student. If the process is repeated because the hardware is not properly connected due to the inability to connect correctly, students feel difficulties in learning and their interest and concentration in learning decrease. Therefore, in this paper, in order to solve the difficulties that may appear during physical computing coding education, we will create an augmented reality that provides accurate connection information between the Arduino board and the sensor, and use it for physical computing coding education. The augmented reality-based physical computing coding education and learning process is as follows. For students who are new to physical computing, use an Arduino board and an RGB LED sensor to explain the educational content of the connection process in a PPT. Using a smart device to illuminate a prepared marker, learn the process of connecting an Arduino board and an RGB LED sensor through augmented reality.

Using augmented reality as a reference, I want to build accurate hardware for physical computing education through the process of connecting the actual Arduino board and RGB LED sensor, and increase the interest and immersion in coding education. Here are the design stages for Augmented Reality (AR)-based physical computing coding training content. The first is to build an Arduino board and RGB LED sensor in 3D format using the 3D MAX program. The second presents the code that implements the program in C language that runs the Arduino board and the RGB LED sensor. The third describes the Arduino board and the RGB LED sensor connection pins. The fourth implements the location information connecting the connection pins of the Arduino and the RGB LED in augmented reality. The Augmented Reality (AR)-based physical computing coding educational content presented in this paper uses a smartphone to check the exact pin position after running an Augmented Reality (AR) app. By adding such virtual information, we hope to prevent Arduino pin connection errors that may occur in Arduino-powered physical computing coding training and increase the interest in physical computing learning. The structure of this paper is as follows. In Chapter 2, the related research on the use of augmented reality-based educational contents, which is the basic theory of this thesis, is described. In Chapter 3, augmented reality-based physical computing SW education contents were designed. And in Chapter 4, the implementation results are presented, and in Chapter 5, conclusions are drawn.

2. Related studies

2.1 Physical computing hardware

SW education is divided into coding courses and physical computing SW courses. Physical computing refers to outputting the results to monitors, various sensors, or various devices through the process of coding various hardware and hardware movements and downloading them to the built hardware. A little simplistically, it means that computers and the real world talk through data[4].

The tools used for physical computing are extremely diverse. Arduino is most commonly used for coding education [5]. The basic configuration of the Arduino board is as follows. The Arduino, an open-source based single-board microcontroller, consists of a CPU, a USB connector, 14 digital pins, 6 of which are capable of PWM output, 6 analog pins, and a reset button. Makey Makey [6] is a computer component that uses touch to create and utilize input devices. It is a board made to be used as an input device by converting electricity into a signal after connecting to a conductive object. Microbit is a small educational board measuring 4cm in width and 5cm in size developed by Lankers University, BBC, Microsoft, Samsung Electronics, and ARM for coding education [7]. Hamster robot is a software educational robot that can utilize a variety of small-sized sensors and a variety of programming languages [8]. It consists of a hamster robot body and a USB dongle, and commands can be sent to the hamster robot via Bluetooth connection.

The board most commonly used is the Arduino UNO board, and this paper also uses the Arduino UNO board. Students themselves make the hardware and upload the program after coding. After that, learning progresses in the process of checking the behavior of the hardware, and it can be confirmed that creativity and problem-solving ability improve while debugging errors that appear in this process.

2.2 Augmented Reality (AR)

Augmented reality (AR) is a field of virtual reality (VR) that synthesizes virtual images or three-dimensional virtual image information in a real environment to make it appear as if it were an object in the real environment [9][10]. Augmented reality is used in various fields. Figure 1 displays the Developed by the US Army, Tactical Augmented Reality (TAR) utilizes Augmented Reality (AR) technology to improve the situational awareness of soldiers, allowing them to see not only their own position but also the positions of allied and enemy[11].

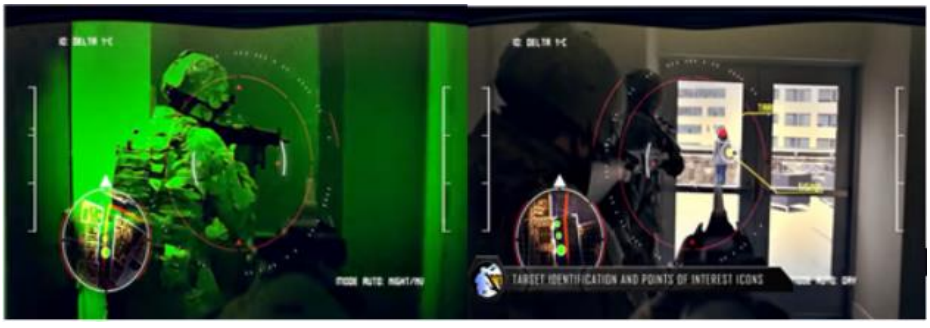


Figure 1. “Tactical Augmented Reality” developed by the U.S. Army(TAR)

Figure 2 displays the in 2015, Disney developed an augmented reality technology that allows you to create a three-dimensional character by coloring a character drawn in a coloring book. This is an example of how

augmented reality can be incorporated into everyday life[12]. Augmented reality is used to give a three-dimensional effect to the flat characters that children see through the book, thereby increasing their interest and immersion[13].

Figure 2. Augmented Reality Characters from Colored Drawings

Augmented reality-based educational content enables experiential learning that can be seen, heard, and felt with the five human senses, and supports experiential learning through a virtual learning environment that is similar to the real world[14]. In algorithm education, which is the basic concept of coding learning, augmented reality content can increase interest and immersion and improve understanding of algorithm education to help students who are new to coding education understand basic sorting algorithms[15].

3. Design of augmented reality content for physical computing

3.1 Design of Arduino education contents using AR

In this paper, we create learning contents about the process of connecting and driving the Arduino Uno board and the RGB LED sensor. Students who are new to physical computing through Arduino may find it difficult to use and concept the Arduino board. Looking at the existing coding education method, learning is conducted using 2D-centered reference materials and textbooks. Therefore, in this paper, the process of connecting the Arduino and the RGB LED sensor is produced as augmented reality content to compensate for the difficulties of sensor connection that students may feel. When a marker is lit with a smartphone, augmented reality content that informs the pin connection location of the Arduino board and the RGB LED sensor is executed. The process of connecting the pin number of the sensor and the pin number of the board is expressed in augmented reality animation. Augmented reality education contents will be used as reference materials for students' pin connection during coding education.

Figure 3 shows the overall structure of augmented reality content used in physical computing coding education. Physical computing learning consists of a total of five parts. The first explains the concept and principle of the Arduino board, and the second is designed to learn the RGB LED connection and pin usage. The third stage is to complete the hardware while watching the operation of the Arduino pin connection implemented in 3D augmented reality that connects the Arduino board and the RGB LED sensor using a smartphone. Augmented reality aids understanding of the hardware construction process by presenting the pin connections of the RGB LED sensor step by step. The Fourth, learn the code that implements the execution code of the Arduino board and the RGB LED sensor in C language. Fifth, upload the code to the Arduino board and check the execution result of the RGB LED. Through the augmented reality content presented in this paper, we hope to raise the level of understanding, interest and immersion in physical computing learning using Arduino.

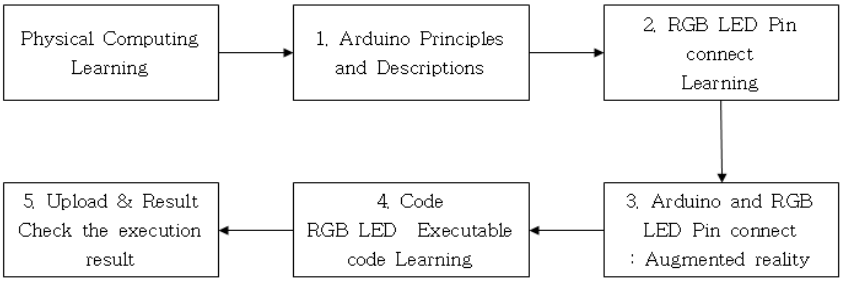


Figure 3. Structure of augmented reality-based physical computing content

3.2 Content components for learning physical computing

In Learning Physical Computing, Table 1 below defines the tools and content elements covered in Learning Physical Computing. Arduino Uno, a physical computing learning tool. RGB LED sensor. Augmented reality in the form of 3D animation is used as a reference for configuring physical computing hardware that can be referenced when configuring hardware. When connecting the pins of the Arduino Uno board and the RGB LED sensor, the pin positions of the Arduino Uno board are indicated by arrows to induce the correct pin connection, and the executable code is implemented in C language. After that, upload the code to the Arduino Uno board and check the result of running the RGB LED sensor.

Table 1. Physical computing coding training content elements

Learning tools	Contents	Media type
Arduino, RGB LED	Learn the concepts and principles of Arduino Uno board and RGB LED.	Hardware
Augmented reality contents	After modeling the Arduino board and RGB LED in 3D form, an animation indicating the position of each pin of the RGB LED sensor on the board is implemented in augmented reality.	Text, 3D Modeling, Animation
C language code	Write C-based code that runs an RGB LED sensor.	Text

Figure 4 shows the process of creating augmented reality-based physical computing coding education content.

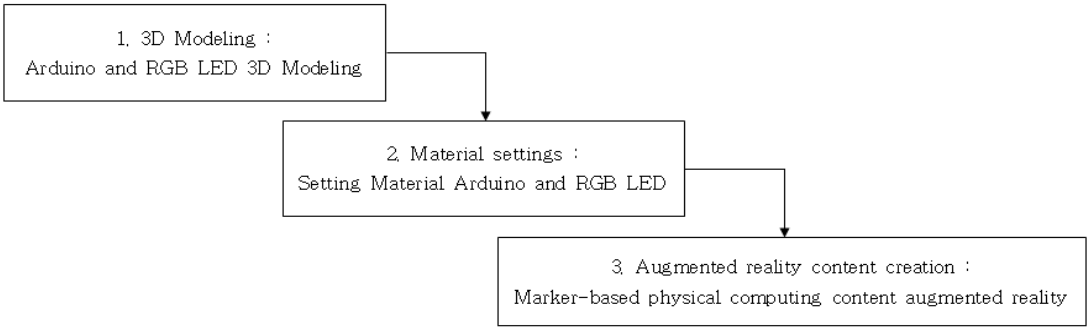


Figure 4. Process of Producing Physical Computing Content Based on Augmented Reality

First, we 3D model the Arduino Uno board and the RGB LED sensor. Second, the 3D modeled Arduino Uno board and RGB LED sensor are coated with material to look identical to the real Arduino board. Third, create an animation that

displays circles and arrows matching the color of the pins to indicate where each pin is connected. Create animations with augmented reality content. When the prepared marker is illuminated with a smartphone, the pin connection process of the RGB LED sensor on the Arduino board appears in augmented reality.

Figure 5 is the RGB LED execution code written in C language. The integer variable red represents pin 8, the green variable represents pin 9, and the blue variable represents pin 10. The RGB LEDs on the Arduino board are defined to output through the red, green and blue variables of the RGB LEDs. When the code is uploaded to the Arduino board, it is repeatedly output in the order of red, green, and blue.

```
int red = 8;
int green = 9;
int blue = 10;


void setup() {
  pinMode(red,OUTPUT);
  pinMode(green,OUTPUT);
  pinMode(blue,OUTPUT);

}

void loop() {
  digitalWrite(red,HIGH);
  digitalWrite(green,LOW);
  digitalWrite(blue,LOW);
  delay(2000);
  digitalWrite(red,LOW);
  digitalWrite(green,HIGH);
  digitalWrite(blue,LOW);
  delay(2000);

  digitalWrite(red,LOW);
  digitalWrite(green,LOW);
  digitalWrite(blue,HIGH);
  delay(2000);

  digitalWrite(red,LOW);
  digitalWrite(green,LOW);
  digitalWrite(blue,LOW);
  delay(2000);
}
```

Figure 5. RGB LED Executable Code

4. Development of augmented reality contents for physical computing

In this paper, we utilize 3D MAX to produce 3D modeling, and In order to realize augmented reality, we created augmented reality content for physical computing learning using CoSpaces tools. 3D MAX is a 3D modeling tool used in various fields such as 3D characters and architectural interiors. CoSpaces is an augmented reality tool that can be easily implemented by elementary, middle and high school students and the general public who are new to AR production as an open source-based program among various augmented reality tools. CoSpaces tools can create various contents such as VR, 3D, and AR.

Using the Arduino board as a reference, we modeled the Arduino board's built-in processor, appearance, and RGB LED using shapes such as cylinders and squares in 3D MAX, and extracted the material using the actual picture of the Arduino board. Upload the material to the Aduino board modeled in Cospacs for augmented reality production and paint the material. Figure 6 displays the It is a screen with Arduino and RGB LED sensor with CoSpaces material. Upload Arduino and RGB LED 3D modeling data to CoSpaces for augmented reality creation. Figure 6 shows the connection arrangement of the RGB LEDs to the Arduino in the CoSpaces tool.

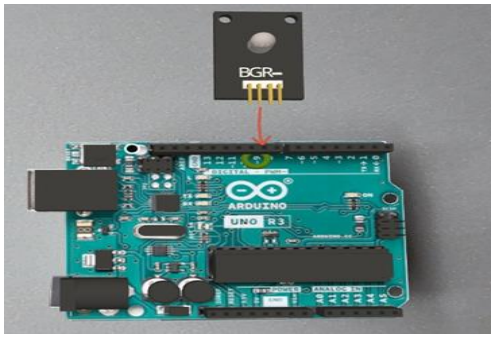
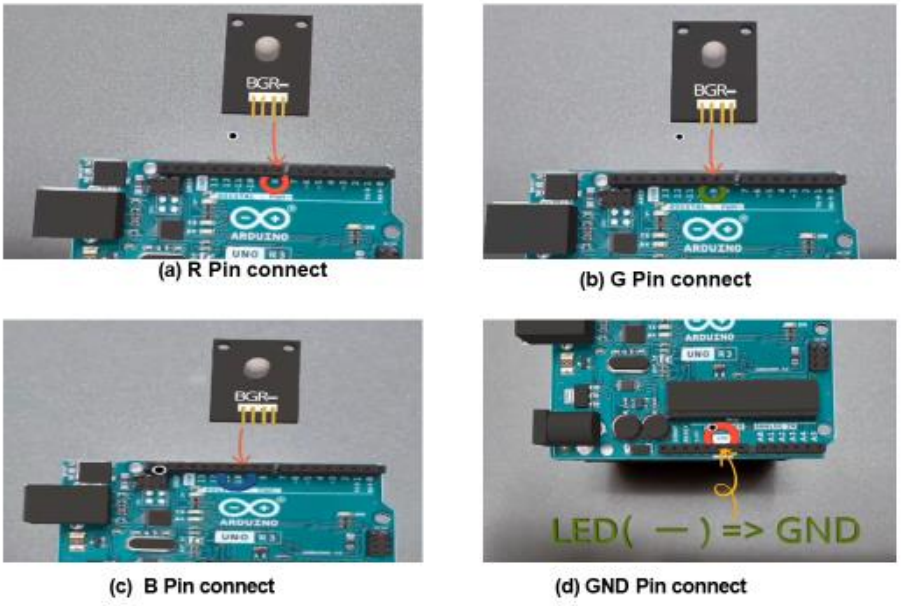


Figure 6. Upload Arduino and RGB LED to CoSpaces App

Figure 7 shows the animation of connecting the R pin of the RGB LED to pin 8 of the Arduino Uno board. In (a), the R pin is marked with an arrow and the 8th pin is marked with a red circle. (b) is an animation of connecting the Green pin of the RGB LED to pin 9 of the Arduino UNO board. The G pin is marked with an arrow and the ninth pin is marked with a green circle. (c) is an animation of connecting pin B of the RGB LED and pin 10 of the Arduino Uno board. Pin B is marked with an arrow and pin 10 is marked with a blue circle. Finally (d) is the animation of connecting the (-) pin of the RGB LED to the GND pin of the Arduino Uno board. The (-) pin of the LED is crafted with text and marked with an arrow, and the GND pin of the Arduino Uno board is marked with a red circle to implement augmented reality running animations.



(a) R Pin connect (b) G Pin connect

(c) B Pin connect (d) GND Pin connect

Figure 7. Augmented reality for RGB LED pin connection process

5. Conclusion

Arduino is one of the leading physical computing learning tools. However, a first-time Arduino student will find the Arduino and Sensor pin connection process very difficult. It's one of the most common errors in the course of real-world coding training. Wrong pin connections between the Arduino board and the sensor will not only prevent you from seeing the results of the hardware movement, but will also cause the sensor to malfunction. Students will also avoid learning physical computing if this phenomenon occurs repeatedly. Therefore, in this paper, augmented reality-based educational contents were produced to complement the process of connecting the pins between the Arduino and the sensor during physical computing coding education using Arduino. When constructing the hardware, a smartphone was used to animate the process of connecting an augmented reality-based 3D Arduino board and an RGB LED sensor. For students who are new to Arduino and do not understand the pin connection, it can be produced as a 3D animation and referenced repeatedly. The augmented reality-based physical computing coding education content proposed in this paper increases the sense of immersion and concentration during coding education compared to 2D-based education content through existing teaching materials and lesson plans, and increases class participation and it is expected that it will be useful in cultivating creative talents through the accurate making process.

Acknowledgement

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References

[1] Naver software. Let's play, https://www.playsw.or.kr/software/view/entry_arduino/634?currentTab=software_apply
[2] Samsung Junior Software Academy, http://www.juniorsw.com/
[3] K. Eom, W. Lee,"The Board Design for Physical Computing Education," Journal of the Korean Society of Computer Education's Summer Academic Press, Vol. 19, No. 3. pp. 35-28, 2015.
[4] Physical Computing, https://terms.naver.com/entry.naver?docId=3612009&cid=58598&categoryId=59316
[5] Arduino, https://www.arduino.cc
[6] Makey Makey, https://www.makeymakey.com
[7] Microbit, https://www.nise.go.kr/sedu/pt/page5_01.html
[8] Hamster Robot, https://www.nise.go.kr/sedu/pt/page4_04.html
[9] S. Cho, Y. Choi, T. Hong, "A Study on Typology of Augumented Reality Based Application Content Service," Journal of the Animation Society of Korea, pp. 62–63, 2012.
[10] Augmented Reality, https://ko.wikipedia.org/wiki/%EC%A6%9D%EA%B0%95_%ED%98%84%EC%8B%A4
[11] Tactical Augmented Reality, https://business.adobe.com/kr/resources/5-realworld-examples-of-augmented-reality-innovation.html
[12] Magnenat, Stephane & Ngo, Dat & Zund, Fabio & Ryffel, Mattia & Noris, Gioacchino & Rothlin, Gerhard & Marra, Alessia & Nitti, Maurizio & Fua, Pascal & Gross, Markus & Sumner, Robert, "Live Texturing of Augmented Reality Characters from Colored Drawings", IEEE transactions on visualization and computer graphics, vol. 21, 2015.DOI : https://doi.org/10.1109/TVCG.2015.2459871
[13] H. Cho, S. Kim, "A Study on the Edutainment Contents Elements in Augmented Reality(AR) Educational Contents Design," Journal of the Korean Society of Design Culture, Vol. 25, No. 1, pp. 441-452, 2019.DOI : https://doi.org/10.18208/ksdc.2019.25.1.441
[14] S. Han, C. Lim. "Developmental Study on Augmented Reality Based Instructional Design Principles," Journal of Educational Technology, Vol. 35, No. 2, pp. 455-489, 2019.DOI : https://doi.org/10.17232/KSET.35.2.455
[15] So-Young Kim, Heesun Kim, "Development of AR Content for Algorithm Learning", International Journal of Internet, Broadcasting and Communication, Vol. 14 No.3, pp. 292-298, 2022.DOI : https://doi.org/10.7236/IJIBC.2022.14.3.292