Ionic and Metallic Bonding Visualization Using Augmented Reality

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***Abstract*—Augmented Reality (AR) is one of the smartphone technologies that can be used to experience three-dimensional object visualization with integrated information. It can also be used as a support tool for learning different topics. One of these is chemical bonding. Thus, this study aimed to visualize ionic and metallic bonding via the use of AR in order to improve the cognitive skills of students. A marker and three-dimensional model for each chemical element were created. Each marker exhibited a unique pattern that was tracked by the application to obtain visualization. The AR engine and game engine utilized by the application include Vuforia and Unity. This research study created a framework that can be re-developed to facilitate other types of chemical bonding. However, additional rules, images, and illustrations for the application must be included in the framework.**

Keywords— augmented reality, ionic bonding, metallic bonding

I. INTRODUCTION

Many research studies have documented that augmented reality (AR) can be used to enhance the learning outcomes of students [1, 2, 3, 4, 5]. Thus, AR has been implemented in diverse fields, including education. Cai and Hsu discovered that AR improves the cognitive skills of students [1, 2]. This learning tool can be successfully integrated into existing education curricula via the use of specific frameworks and guidelines [3].

AR can be used to enrich high school students' visualization of chemical bonds [4]. The major types of chemical bonding include covalent bonding, ionic bonding, and metallic bonding. Even though some research studies have been conducted to visualize different chemical bonds, the most commonly visualized chemical bond is the covalent bond. Thus, this research study aimed to visualize ionic and metallic bonding via the use of AR in order to improve the cognitive skills of students. The framework and guidelines used to visualize covalent bonding can be used to study ionic and metallic bonding.

II. LITERATURE

A. Marker

A marker can be defined as a specific pattern that triggers the display and recognition of visual information in AR. In order to get these visual cues, the marker must be rich in detail, have a good contrast and no repetitive patterns. The marker is generated with a marker generator by Brosvision. It fulfills the aforementioned requirement because it generates the pattern randomly and has many features (sharp edge). Each marker is represented as an element printed on a 3.34 x 3.34 inch paper. This is called AR target or image target.

B. AR Engine

The various types of AR engines include Vuforia, ARToolkit, ARMedia, or Metaio. Vuforia supports 2D and 3D transformation, including multi-target configurations, cylinder targets, marker less image targets, frame markers and cloud recognition targets [6]. Vuforia is a widely used AR engine because it is the fastest, most stable, popular, and easy to use plug-in with Unity (one of the popular game engine). When the marker is moved, it tracks, recognizes and positions the image on a three-dimension model. The markers that are not fully visible (i.e. covered by objects) are recognized by the engine. The widespread use of Vuforia makes it easier to get community support.

C. Game Engine

This research used Unity version 2017.2 as the game engine. It is a cross-platform game engine that is used to develop video games for web plugins, desktop platforms, consoles, and mobile device [7]. Other alternatives include Unreal Engine or CRY Engine. Unity is designed to integrate seamlessly with Vuforia and can be easily compiled as an Android application (APK). Although Unreal Engine is more powerful, it has a complex system.

D. The Workflow of AR System

The workflow of the AR system consists of five general steps, namely, image capture, image processing, tracking, interaction handling, simulation information management, rendering, and display [8]. Image capture involves the use of a camera to capture the work scene. The AR display can be classified into three categories, namely, head-mounted display (HMD), hand-held device (HHD), and spatial display (such as desktop display and projected display). The setup for AR environment Digital image processing requires the use of computer algorithms to process the image stream captured by cameras such as open CV. In order to create interaction handling, the image must be tracked using sensor-based tracking, vision-based tracking, or hybrid tracking [9]. Interaction handling involves the use of human-computer interaction elements, namely, three-dimension input device, hand based device, or sensors. Simulation information management is then used to process the item that was visualized. Finally, the rendering step involves the visual presentation of simulation data, using OpenGL. In addition, the AR environment must be set up as a real workspace and world coordinate system with human-computer interaction functions as well as real and virtual components.

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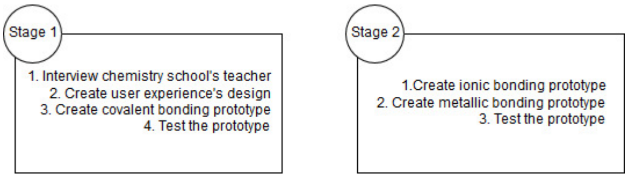

Fig. 1. Methodology of the research

E. *Ionic and Metallic Bonding*

Ionic bonding involves the transfer of electrons from one atom to another [5]. It generates two oppositely charged ions. Because of the loss/gain of a negative electron, atoms are no longer electrically neutral. When an atom gains an electron, it becomes an anion and has a negative charge. When an atom loses an electron, it becomes a cation and has a positive charge. These positive and negative ions have an electrostatic force of attraction between them that results in the formation of an ionic bond. An example is sodium chloride or NaCl. Sodium has loses its valence electron to chlorine which has seven valence electrons. This results in the stability of both atoms as they bond to form Sodium Chloride.

Metallic bonding is the force of attraction between valence electrons and metal atoms. It is the sharing of many detached electrons between many positive ions, where the electrons act as a "glue", which gives the substance a definite structure. Most of the time, metal atoms lose electrons to non-metal atoms. This is because metal atoms have few valence (outer) electrons while non-metal atoms have almost filled valence shells. Metallic bonds are found in metals.

III. Methodology And Previous Work

The duration of this research study was two years (Fig. 1). In the first year, high school teachers were interviewed in order to obtain information about chemical bonding. This step was followed by the design of a user experience in order to create a suitable visualization (detailed explanation can be found in section IV). Based on the interview, a covalent bonding prototype was first created. Covalent bonding was chosen because many literature sources discussed the frameworks and guidelines for its development. This prototype was tested by high school chemistry teachers.

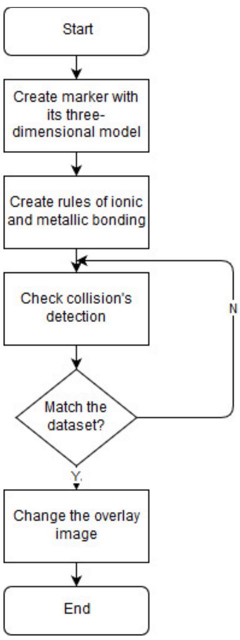

Figure 2. Application Design

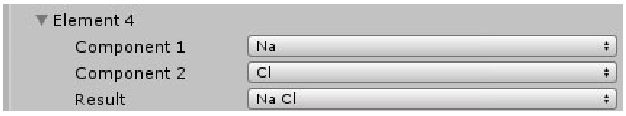

Fig. 3. Input rules in dataset

Based on the success of its development in the first year, an ionic and metallic bonding prototype was created in the second year. Although the previous framework can manage any type of chemical bonding, the three-dimensional model for ionic and metallic bonding is different. Thus, this study aimed to develop another visualization for the three-dimensional model. This prototype was also tested by high school chemistry teachers.

IV. Application Design

The workflow of the application design can be seen in Fig. 2. A marker and three-dimensional model that represent atoms such as Na, Cl, Mg, O, Ca, or Fe was created. Each time a marker was detected, an overlay image and a three-dimensional model was shown above the marker. There were three types of overlay: (1) base elements such as Na, Cl, Mg, O, Ca, or Fe had a white background, (2) incomplete and unstable compounds such as H_2, O_2, and OH had an orange background, and (3) stable compounds such as HCl, NaCl, NaOH had a green background.

This step was followed by the creation of rules for ionic and metallic bonding in compounds such as NaCl, MgO, or CaF2. These rules are documented in the dataset shown in Fig. 3.

Each marker has a three-dimension collider component with a spherical shape, marked by thin green lines (Fig. 4). When sphere colliders come in contact with each other, it triggers an event. The collision is detected and included in the dataset.

If the compound is found, the application will change the overlay image and create a three-dimension model of the marker. The steps include (1) the replacement of the second element overlay with a gray overlay (blank), (2) the replacement of the three-dimensional second element, (3) the

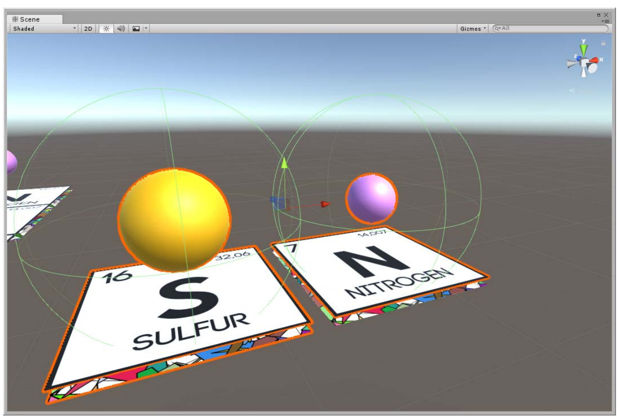

Fig. 4. Three-dimension collider component with spherical shape

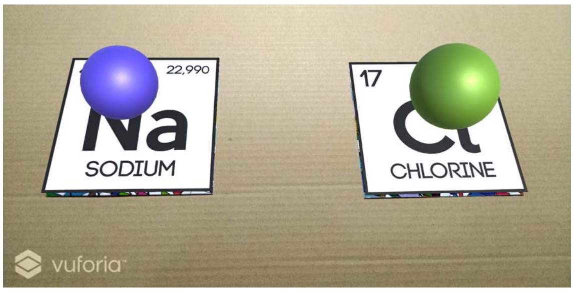

Fig. 5. Element of Na and Cl

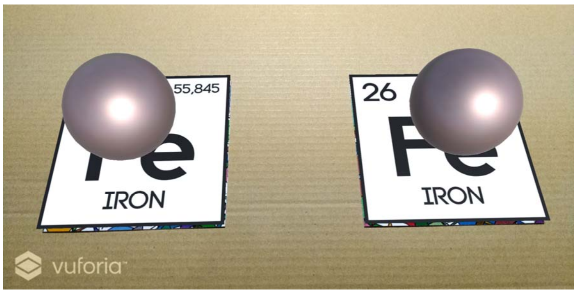

Fig. 8. Element of Fe

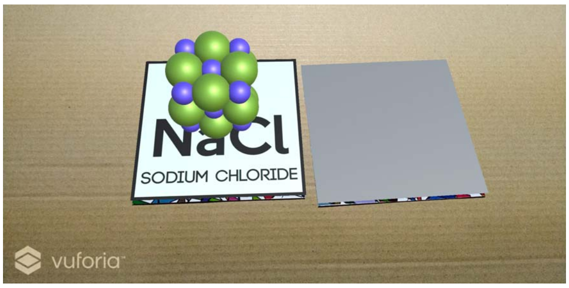

Fig. 6. NaCl compound

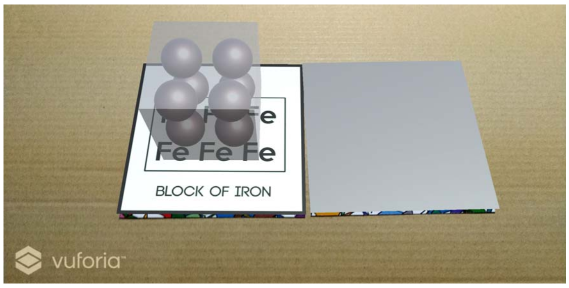

Fig. 9. Fe block compound

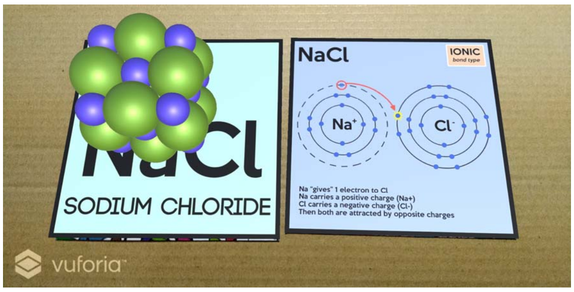

Fig. 7. NaCl information

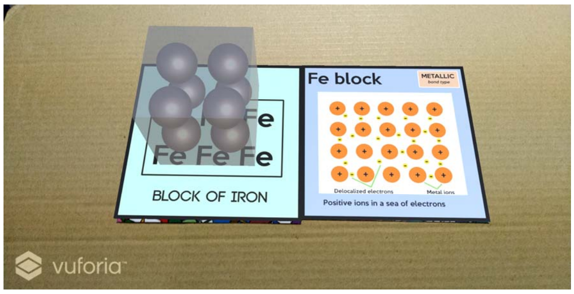

Fig. 10. Fe block information

replacement of the first element overlay (bonding result) with the bonding element overlay, and (4) the replacement of the first element three-dimensional model with the element model.

The elements can be returned to their original form by bringing them closer to the reset marker. The same principle is used for the combination of two elements that use a sphere collider. An info marker is used to view the details of the information.

V. IMPLEMENTATION

Ionic bonding was tested with Na and Cl elements (Fig. 5), which form NaCl. Na was brought close to Cl, which resulted in the formation of NaCl (Fig. 6). When NaCl compound was brought close to the info card, it displayed a detailed information of the bond formation (Fig. 7).

When the Fe element (Fig. 8) was brought close to another Fe element, the Fe block was created (Fig. 9). When the Fe block was brought close to the info card, it displayed a detailed information of the bond formation (Fig. 10).

This test was carried out with eight different devices to improve any dysfunctionality within the device. The operating system is various from Android 2.2 to Android 5.1. The implementation shows that the application works well for all devices.

VI. CONCLUSION

This research study created a framework that can be re-developed to facilitate other types of chemical bonding. The guidelines for this framework include the creation of basic elements that do not exist as a new marker, chemical bonding between elements and the use of an information card. This framework can be used to create other types of illustrations for the application must be included in the framework.

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