Advanced Technology of the Fourth Industrial Revolution and Korean Ancient History*

- Study on the use of artificial intelligence to decipher Wooden Tablets and the restoration of ancient historical remains using virtual reality and augmented reality -

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Preface

The Fourth Industrial Revolution (4IR) is significant to our daily lives, with various advanced technologies ranging from artificial intelligence (AI) to virtual reality (VR) and augmented reality (AR). The 4IR is based on the digital revolution, which involved the combination of the virtual and physical realities via ubiquitous mobile technology, artificial intelligence, and machine learning.[1]

There may appear to be no relationship between Korean ancient history and the 4IR; and the term "ancient history" is not commonly associated with AI, VR, or AR.

However, advances in AI can increase the accuracy and speed of deciphering ancient texts. In particular, the number of excavation cases of

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1 Kluas Schwab, *The Fourth Industrial Revolution* (London: Penguin Press, 2017).

mokkan (a wooden tablet, 木簡) is continuously increasing; thus, comparative analyses of significant amounts of data from China and Japan is required. As a result, the quantity of the data for comparative analyses and the complexity of the required deciphering process are gradually exceeding the capabilities of humans. AI technology can be employed to increase the accuracy and speed of deciphering ancient wooden tablets.

Furthermore, there are applications for new 4IR technologies with respect to Korean ancient historical remains. Most Korean ancient historical remains are not in their original forms, and having gradually decayed into desolate ruins. Therefore, only a few ancient historical remains can be viewed by tourists and students. This problem can be solved using new technologies such as VR and AR.

In this study, the relationship between the advanced 4IR technology and the field of Korean ancient history was investigated, with a focus on the use of AI to decipher wooden tablets, and the restoration of ancient historical remains using VR and AR. First, the feasibility of using AI to decipher wooden tablets was considered, as discussed in Section 2. Section 3 presents a method of restoring ancient historical remains using VR and AR, with reference to the Anyang ruins.

Use of Artificial Intelligence in Deciphering Ancient Wooden Tablets

Mokkan (木簡) refers to texts written in *hanja* or Chinese characters on wooden tablets. They were widely used in Korea, China, and Japan. In Korea, many were excavated from the Shilla and Paekche ruins. In particular, several hundreds were excavated from Haman Sŏngsan Sansŏng. However, the deciphering of the text on wooden tablets is more complex than that of other types of inscription. The complexity of the mokkan deciphering process can better be understood from three perspectives.

The first perspective is related to the material of the text. Mokkan was made by writing with ink on wooden tablets, which are more easily con-

taminated than stone or metal. In addition, wooden tablets lose ink traces more easily. The second perspective is related to the purpose of the text. Given that Korean wooden tablets were written for various purposes beyond the scope of administrative documents, such as labels for goods in transport and handwriting practice; the characters may include abbreviations, variants, and cursive, among others, depending on the author. The third perspective is related to the content of the text. Moreover, given that the contents of wooden tablets are primarily related to daily life, they cannot be verified using literature sources, which mainly record national-level events. Therefore, the deciphering of mokkan through the comparison with other records is limited.

In previous research, infrared photography and comparative studies of Korea, China, and Japan were carried out to address the abovementioned limitations. In general, comparative studies of Korea, China, and Japan refer to material from China and Japan for the deciphering of text. Given that Japan has a significant number of excavated wooden tablets, a database was developed. The *Japanese Ancient Mokkan Dictionary* (日本古代木簡字典),[2] which is a collection of images of Japanese mokkan by character, is useful for deciphering the new mokkan text.

However, in Korea there have been limited attempts to incorporate new 4IR technology into the mokkan deciphering process. Artificial Intelligence can serve as a supplement to the existing limitations of mokkan deciphering if it can be used to decipher the text on wooden tablets with respect to specific characters.

Among the existing artificial intelligence (AI) models developed to date, some have been used for deciphering wooden tablets. For example, a model that calculates the probability of a cursive numeral representing numbers from 1 to 10 is currently in use in education. The model uses the MNIST data, which is available on the website published by the neural network scientist Yann LeCun. The data comprises cursive numeric im-

2 Nara National Research Institute for Cultural Properties, *Japanese Ancient Mokkan Dictionary* (Nara: Nara National Research Institute for Cultural Properties, 2013).

ages in various forms ranging from 1–10. It is divided into 60,000 training data points and 10,000 test data points. Each numeric image has a dimension of 28 × 28 pixels, and each pixel is represented by a number ranging from 0–255 (from pure white to the pure black color). After training the neural network-based AI using 60,000 training data points, the 10,000 test data points can be inputted to test whether the cursive numbers are accurately recognized. When an image of a specific cursive numeral is inputted into the AI training data, the probability of the number being within a range from 1–10 is calculated.[3]

This model can be similarly applied to the mokkan deciphering process. For example, 5,000 characters were extracted from Korean, Chinese, and Japanese wooden tablets; and then edited into image files with dimensions of 28 × 28 pixels. Moreover, 5,000 is an arbitrary number, which includes variants and abbreviations, among the characters in Korea, China, and Japan. By creating a minimum of 100 sample images per character, 500,000 training data points can be prepared.

After the AI has learned the 500,000 training data points, the text photo to be deciphered can be inputted, and then the result can be extracted. If x is a specific text photo of a mokkan character, then the training data y extracted from the Korean, Chinese, and Japanese mokkan data are '5000 (a1,2,3… 5000) × z (number of samples per letter).' The AI analyzes the inputted text photo x and classifies the color of each pixel from the pure white color to the pure black color. The learning results of the '5000z' training data points were then compared, and a probability of 5000 letters similar to x was derived. The probability of the letter that x represents was derived as follows.

Probability that x is a1: 0.001
Probability that x is a2: 0.015
…

3 Tariq Rashid, *Make Your Own Neural network*, trans. Gyo-seok Song (Seoul: Hanbit Media, 2017), 195-239.

Probability that x is a4999: 0.910
Probability that x is a5000: 0.009

Based on the results above, the letter x has a 91% probability of being read as the character a4999.

A mokkan deciphering system similar to this model was recently developed under the name MOJIZO by a joint development with the Nara National Research Institute for Cultural Properties and the Historiographical Institute of the University of Tokyo. Details on the project can be found on the MOJIZO website (http://mojizo.nabunken.go.jp/), in addition to the materials at the time of publication in 2016.[4]

Fig. 1. Input and deciphering process of MOJIZO

4 Nara National Research Institute for Cultural Properties·Historiographical Institute of the University of Tokyo, “Mokkan, Kuzushiji deciphering system – MOJIZO – a challenge of 20 percent that even experts can’t decipher(木簡・くずし字解讀システム— MOJIZO— 専門家でも解讀できない２割に挑戦)” 2016.(Press Release, https://www.nabunken.go.jp/fukyu/press.html).

The word MOJIZO, which is the name of a deciphering system for wooden tablets etc., was derived from the word *moji*, which means "character" (もじ, 文字); and the word *zo*, which means "warehouse" (ぞう, 蔵). Moreover, it is a text image search system made using the database of the Nara National Research Institute for Cultural Properties and the Historiographical Institute of the University of Tokyo as training data. When the user inputs a text image into the search system, a similar text image is produced as the result. For example, if the user inputs a specific text image of the wooden tablet, the system provide the top eight similar text images in the database of the two institutions.

The database of the Nara National Research Institute for Cultural Properties, which is included in MOJIZO, is the mokkan image database, which consists of images for each character written on mokkan excavated from Japan. It comprises approximately 1,800 characters, 14,000 wooden tablets, and 89,600-character images. The database of the Historiographical Institute of the University of Tokyo contains various images of premodern Japanese writing, with a total of approximately 6,000 written characters and 230,000-character images. These figures were made publicly accessible in 2016, and they are updated annually. This is because, with the expansion of the data, the character recognition rate increases, and the accuracy is improved.

The development of MOJIZO has helped address the issues related to the character reading processes of existing text deciphering methods. In particular, deciphering may require an extensive period of time, and it may eventually fail if carried out with dependence on a dictionary. Furthermore, existing database search systems cannot conduct searches if a query is not inputted as a character. Given that variants are difficult to input as characters, an image-based search system is generally required. Hence, the Nara National Research Institute for Cultural Properties and Historiographical Institute of the University of Tokyo provided a premodern text data database as training data, and then developed a search system by combining image processing and text recognition technology.

MOJIZO can search for numerous characters from the Nara to Edo pe-

riods, in addition to characters that cannot be inputted via computers. In addition, the user can select one of the multiple results depending on the nature and time period of the character data. This system increases the efficiency of deciphering and interpretation of the data, and it can also be used to decipher difficult-to-read text such as symbols or other non-character data.

However, given that the databases included in MOJIZO are both Japanese mokkan and ancient documents, the accuracy of the results differs when inputting text from Korean mokkan. For example, if the user inputs the characters “gam” (甘) and “ha” (下), which appear in the Haman Sŏngsan Sansŏng excavations, “gam” (甘) and “ha” (下) would be included in the results obtained from the Nara National Research Institute for Cultural Properties database. This is highly probable because these two characters have simple shapes, and the font on the wooden tablets was relatively clean. (See <Figure 2>)

Fig. 2. MOJIZO search results (“gam” (甘), “ha” (下))

However, the characters “maek (麥, 麦)”, “pae (稗)”, “mun (文)”, and “bon(本)” were not derived when searched (see <Figure 3>). This is because the searched images were not fully edited in the format required by MOJIZO.[5] According to the image preparation manual of MOJIZO, the background color is required to be as white as possible, with the excep-

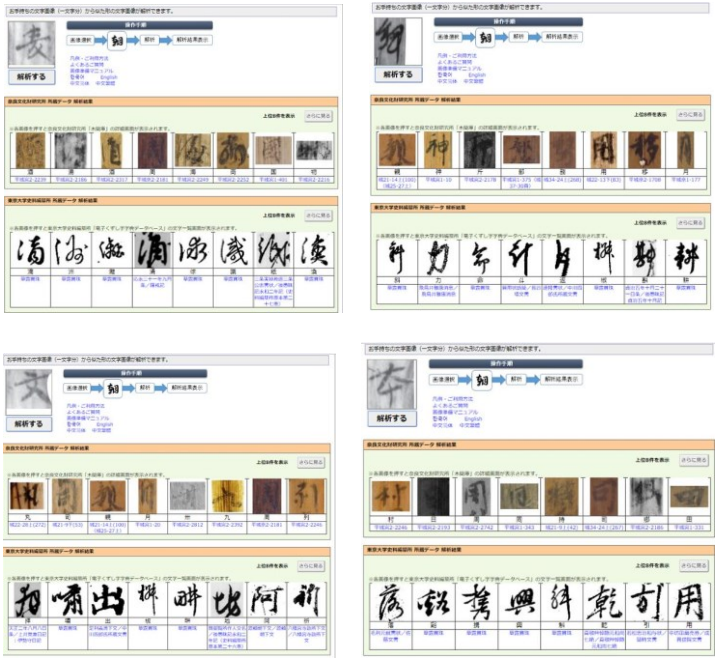

Fig. 3. MOJIZO search results (“maek (麥, 麦)”, “pae (稗)”, “mun (文)”, “bon(本)”)

tion of the ink marks on the wooden tablets. In addition, all the black lines that are not ink marks should be erased. However, damaged sections of the wood may be misinterpreted as character strokes (see <Figure 4>).[5]

After correcting and re-searching the character image according to the manual, the characters “mun (文)” and “bon (本)” were found in the Nara National Research Institute for Cultural Properties database. However, “maek (麥, 麦)” and “pae (稗)” were not found, even after correction (see <Figure 5>).

5 Image preparation manual PDF document (http://mojizo.nabunken.go.jp/)

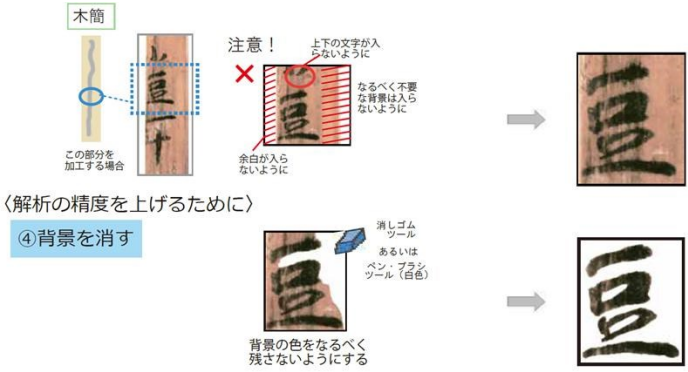

Fig. 4. Image preparation manual of MOJIZO

Fig. 5. MOJIZO search results (“maek (麥, 麦)”, “pae (稗)”, “mun (文)”, “bon (本)”)

As a result of inputting the character images of wooden tablets from the Haman Sŏngsan Sansŏng excavation into MOJIZO; although relatively simple characters such as “gam (甘)” and “ha (下)” were immediately found, others such as “mun (文)” and “bon (本)” were found only after correction. However, no search results for “maek (麥, 麦)” and “pae (稗)” were obtained, even after correction.

It was difficult to determine whether this inconsistency was due to the differences between the Japanese and Korean mokkan characters, or problems resulting from abbreviations and cursive handwriting. Moreover, given that MOJIZO is currently operated using Japanese data for training, it is difficult to guarantee the accuracy of the results when inputting Korean mokkan characters. In addition, to accurately recognize and decipher the cursive characters of ancient wooden tablets, the amount of training data must be continuously increased to reduce the error rate of the AI calculations.

Significant research attention has been directed towards Korean ancient wooden tablets since the 2000s. In particular, the Kaya National Research Institute of Cultural Heritage published a variety of wooden tablet-related materials. Among them, “Ancient Mokkan of Korea Ⅱ” includes digital pictures, infrared pictures, actual drawings, and readings of the mokkan, with focus on the mokkan excavated at Haman Sŏngsan Sansŏng.[6] These studies are the primary data for the development of AI-based mokkan deciphering systems. However, they are limited to publications in the form of books.

To utilize this primary data in the form of books with respect to the mokkan deciphering system, a database of each character image is required as secondary data. In this regard, focus was directed toward the Dongguk University “Construction of Collective and Integrated Database of Korean Ancient Historical Data Excavated from Korea and Overseas." The aim of the project was to build a unified database by combining pho-

6 Kaya National Research Institute of Cultural Heritage, *Ancient Mokkan of Korea Ⅱ* (Kimhae Kaya National Research Institute of Cultural Heritage, 2017).

tos, readings, and deciphering for each letter of ancient character data, including mokkan. Unlike the Japanese MOJIZO, the project shifted the deciphering of characters to the researchers, expanded the searchable data to various text beyond mokkan, and diversified the search methods. This completely integrated database can therefore serve as essential training data for future AI-based mokkan deciphering systems.

However, the accuracy of a search system in which the AI is trained is dependent on the bias of the training data. A large amount of unbiased training data is essential for the improvement of the system accuracy. This achieves "generalization," which ensures that the accuracy of the training data and input data are the same, although the data may differ. Furthermore, the success of the AI is dependent on "generalization."[7]

Therefore, the accuracy of the results can be enhanced by utilizing the database for Korean mokkan as the training data, in addition to the Chinese and Japanese data. This is because the bias of the training data is reduced by employing all of the text data encompassed within the ancient Chinese character culture sphere in East Asia. The development of such a system requires the convergence of various research institutions and disciplines, and academic exchange with China and Japan is vital.

The text images that represent the training data must be extended from the ancient mokkan excavated in Korea to text data from the Koryŏ and Chosŏn eras. With the "spatial expansion" of Korean, Chinese, and Japanese character data, in addition to the "temporal expansion" of Koryŏ and Chosŏn era data; the quantity of the training data can be significantly increased. The richness of the data can therefore be considered as a shortcut to improving the system's accuracy.

Chinese characters are part of an ideographic writing system in which one character has one meaning. Therefore, when deciphering specific characters, the amount of data to be processed is significantly large. Extending the spatial range from Korea to China and Japan, or the temporal range from the ancient to modern times leads to an increase in the number

7 Kim Sŏngp'il, *Deep Learning For Beginners* (Seoul: Hanbit Media, 2016), 17-23.

of character images required to be processed, which exceeds the human processing capacity. Mokkan deciphering using AI will substantially improve the speed and accuracy of complex calculations, which were previously difficult for humans to process.

However, this deciphering method is limited. Due to the nature of ancient text data, including the mokkan, the contexts surrounding several sentences may require inference through comparison with the contents of other mokkan. The understanding of the context and comparison of the content are tasks that should be carried out by humans, the researchers of ancient history. Furthermore, the researcher is required to facilitate the preparation of the image, which involves erasing unnecessary traces of ink for the system to read, in addition to the final examination and selection of similar characters based on probability. Moreover, the researcher, not the AI, is responsible for the interpretation and evaluation of the fully-deciphered mokkan data.

In essence, the judgement of the researcher is required, starting from the stage at which the training data for the AI is created. Since 2017, the construction of an integrated database of Korean ancient history data by the Dongguk University research team has ultimately assigned the problem of deciphering the data to numerous researchers. To build an AI deciphering system in the future, consultation with researchers is required with respect to the deciphering of the images to be inputted as training data.

Moreover, it is necessary to establish a system that reflects the characteristics of ancient Korean mokkan data as much as possible i.e., the content, handwriting, form, etc. of mokkan excavated at Haman Sŏngsan Sansŏng by region) Accordingly, the reflection of the regional characteristics in the deciphering system can improve the accuracy when the AI deciphers mokkan text from certain regions.

Virtual Reality (VR)·Augmented Reality (AR) Restoration of Ancient Historical Remains and Applications

Given that most of the Korean ancient historical remains have been reduced to empty sites, their architecture cannot be determined. This has an influence on the tourists or history students who visit the remains, making it difficult for them to envision their original appearance. This is due to the lack of progression of reasoning, reenactment, and empathy, for the strengthening of the historical imagination of the user. However, VR and AR can provide experiential content that enables reenactment and empathy with historical remains without materially restoring them. Accordingly, these technologies can be used to amplify the historical imagination of the user.[8]

The restoration of ancient historical remains using VR has been carried out for a long period of time. Starting from the computer graphic (CG) restoration of the Mirŭksaji Stone Pagoda in the 1990s, the restoration of Hwangnyongsa was also carried out. These projects provided the public with an opportunity to "re-visualize" the ancient historical remains. From 2010 onward, as the issue of authenticity in VR restoration emerged, the authenticity of restoration through professional participation was emphasized.[9]

From 2000 onward, the VR restoration of Korean ruins was focused on ancient historical remains. A representative example is the Complex of Koguryŏ Tombs VR (see <Photo 6>), which allows for visitors to walk around the virtual reality space while wearing a display device. This example was set up as a walking VR experience. This method allows the user to explore the entire complex of tombs with a multi-directional and 360º in all directions. However, only one user can use the system at a time,

8 Choi Heesoo(Hŭisu), "Experiential Historical Content and Korean Ancient History," *Korean Ancient History Research* 84 (February 2016): 208.

9 Yang Jungseok(Chŏngsŏk), "Development of VR Restoration of Cultural Relics of Korea," *Prehistoric and Ancient History* 53 (September 2017).

and it is limited to the simple transfer of information.[10]

Fig. 6. Hansŏng Paekche Museum Complex of Koguryŏ Tombs VR Experience (YouTube screenshot)

Unlike the abovementioned tomb content, the objective of the VR restoration of Hwangnyongsa was to enable the appearance of the restored structure on top of the ancient historical remains. The Hwangnyongsa VR restoration process can be described as follows. First, a three-dimensional (3D) scan of the remains is carried out, followed by an analysis of the historical data, 3D modeling, etc.; after which it is programmed for a head-mounted display (HMD) environment and provided to the user. The HMD refers to a method that maximizes immersion by attaching a display device to the head of the user. Using the HMD, the user can then experience the environment as though they were actually entering Hwangnyongsa.[11]

National research on the restoration of Hwangnyongsa includes the "Hwangnyongsa Restoration Maintenance Research", which was promot-

10 Park Jinho and Kim Sangheon, "Development and Implications of VR Contents of Complex of Koguryŏ Tombs Using VR Technology," Korea Contents Association 2017 Spring Conference.

11 Park Jinho and Kim Sangheon, "Hwangnyongsa Digital Restoration Virtual Reality Content Development and Application," *Global Cultural Contents Society Winter Conference, 2016.*

ed by the National Research Institute of Cultural Heritage Architectural Cultural Heritage Lab since 2000. From 2007–2012, significant research attention was directed toward the restoration of historical buildings, maintenance of historical remains, and restoration-based studies within humanities fields; which included history, archeology, art, and Buddhism. From 2012 until now, the advancement of restoration research has resulted in the establishment of restoration historical research, design, and maintenance planning for individual buildings.[12] The restoration of Hwangnyongsa is currently carried out based on communication with academia and the local community, in addition to dozens of research reports and basic plans with "authenticity" as the first priority.[13]

Similarly, the National Research Institute of Cultural Heritage is carrying out an AR restoration project for Hwangnyongsa based on basic research. In 2018, the AR-based Hwangnyongsa Chungmun(main gate, 中門) content was created; and in 2019, the Chungmun-Namhoerang (south corridor, 南回廊) AR content development projects are scheduled for promotion.

Given that only the cornerstones of several buildings currently remain in Hwangnyongsa, it is very difficult for visiting tourists and students to envision the original appearance of the site. The VR and AR restoration of Hwangnyongsa provides the advantages of recreating the original appearance of the building, thus overcoming the limits of funding and data. The restoration project should be carried out over a long period of time under the consideration of "authenticity," based on the historical research of related experts.

The restoration of Korean ancient historical remains using VR can

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12 Kim Sookkyung(Sukkyŏng), "Hwangnyongsa Ancient Architecture Historical Research Results," *Hwangnyongsa Ancient Architecture Historical Research Status and Project* (National Research Institute of Cultural Heritage, 2017).

13 Han Wook, "Direction of Hwangnyongsa Restoration and Maintenance," *Hwangnyongsa Ancient Architecture Historical Research Status and Project*, (National Research Institute of Cultural Heritage, 2017).

maximize efficiency when used by students who do not have direct access to the site. The user can enter the VR space and explore the site with full 360º motion, thus immersing themselves in the experience without needing to visit the site.

Furthermore, although AR technology is primarily used in museums, a space-oriented approach is required to effectively utilize the technology's characteristics. Here, "storyscape" and "spacetelling" are concepts highlighted in the literature. Storyscape refers to the spatiotemporal-linked content for the tour of the remains; and the content is arranged in several stories linked through space and time. Spacetelling is a compound word made up of the words "space" and "storytelling", and it allows for the user to experience the passage of time in space using AR.[14]

The incorporation of spatiality into AR technology requires methods in which it is applied to outdoor cultural heritage sites. Accordingly, researchers proposed AR tourist information services for sites such as Tŏkksugung Palace.[15] This study was significant in that it provided outdoor AR content that can be simultaneously enjoyed by multiple users on separate smartphones. In 2019, an outdoor AR application was created for several buildings in Ch'angdŏkgung Palace[16]; which is considered as an example of the incorporation of AR technology with the spatiality of cultural heritage sites.

The use of AR technology for outdoor cultural heritage sites, which include ancient r;historical monuments, allows for visitors to experience changes in sites with respect to time, various historical events, and a wide range of parameters. The restoration of ancient historical remains using

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14 Kim Eunseok(ŭnsŏk) and Woo Woontaek(unt'aek), "Augmented Reality-based Framework for Supporting Historic Site Tours," *Journal of the HCI Society of Korea* 10, no. 2 (December 2016).

15 Oh Sunghwan and Kim Kideok(kidŏk), "Development of Tŏksugung Palace Tourist Information Service Using Augmented Reality Technology," *Cultural Assets* 46, no. 2 (May 2013).

16 The application titled "Treasures of Ch'angdŏkgung Palace-AR Experience" can be downloaded from the Google Play Store.

AR provides visitors with the opportunity to vividly experience the historical site in its original form.

In particular, the emergence of the fifth generation (5G) era substantially improved the data processing speeds, which is critical for the utilization of outdoor AR. With the support of the smartphone performance, many visitors can simultaneously experience the historicity of the historical site. The AR restoration of ancient historical remains is expected to effectively enhance the viewing satisfaction of visitors exposed to the site.

However, there are limitations to the VR and AR restoration of ancient historical remains. The first limitation is that of restoration authenticity. Given that VR and AR restoration is a concept that was proposed as an alternative to actual restoration projects, it is required to accurately reflect the results of research with respect to planning and production, as is the case in actual restoration projects.[17] If the participation of the researcher is insufficient, the contents of the restoration may become distorted due to attempts to satisfy the desires of the public, i.e., by the emphasis of beauty or size, which may significantly differ from the actual case.

The VR and AR contents for ancient historical remains are typically produced using HMDs, which do not allow for viewing by multiple users simultaneously. AR contents using smartphones are mainly displayed in indoor exhibitions such as museums. It is therefore necessary for researchers to develop methods to utilize AR in outdoor cultural heritage sites and allowing for the majority of users to simultaneously experience in the site by using smartphones.

Finally, the restoration content may not exceed the simple transfer of information. Existing VR and AR contents are generally focused on the transfer of information related to a single monument, thus failing to promote complex interpretations or historical context. For use in remains or historical education, this content should promote critical thinking, as it relates to history and re-enactment learning in historical sites.

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17 Yang Jungseok, “Development of VR Restoration of Cultural Relics of Korea,” 211-212.

Hence, to achieve historical re-enactment, the user should be able to proactively and critically interpret the data through storytelling and narrative. For this purpose, beyond the exchange of information, the user should be able to enter the virtual world and achieve an understanding of the people of a specific time and space. For example, the Hwangnyongsa virtual reality should allow for users to experience the perspectives and national views, with respect to status, at the time.[18] Numerous virtual reality content about ancient Korean history has been produced, but there is a limit to developing historical imagination and thinking ability.[19]

This problem is underlined by research that highlights the limitations of existing cultural heritage AR contents. In particular, existing AR contents are generally focused on the fragmentary description of single cultural heritage sites, and therefore cannot showcase modern cultural heritage. Storytelling is required to address this problem; which allows for users to experience the local culture that formed the cultural heritage, with a link to modern cultural heritage.[20]

To summarize, the following should be addressed for the VR and AR restoration of ancient historical remains. First, expert researchers should participate to solve the problem of authenticity. Second, AR content that recreates the spatiality of the site should be created, which allows for many users to experience the VR and AR at once. Third, the VR and AR system should be extended beyond the simple transfer of information to provide historical re-enactment learning, storytelling, and narrative.

An example of successful VR restoration through the active participation of researchers is the ancient Assyrian Palace VR content of the Yale

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18 Choi Heesoo and Kim Sangheon, "A Research on Metaverse Contents for History Education", *The Journal of Global Culture Contents,* 26, (February 2017).

19 Choi Heesoo, "Current Status and Tasks of Virtual Reality Contents in Korean Ancient History", *The Journal of Global Cultural Contents*, 38, (February 2019)

20 Lee Jongwook, Park Hyunah, Park Kangah, "Development of Augmented Reality-based Tourism Contents Using Local Cultural Heritage," *Journal of the Korea Contents Association* 18, no. 6 (June 2018).

University Center for Teaching and Learning (CTL).[21] Researchers from Yale University explored the site of the ruins of northern Iraq in 2015, after which they recreated the remains of Nimrud of the Assyrian Palace through VR. The project involved the participation Mesopotamia majors and university museums. The resulting VR content restored the original appearance of the palace, and allowed for the students to view relevant descriptions when they touched objects in the virtual environment. Although this data is limited to the transfer of information, it offers an advantage in that majors can participate and provide authentic information necessary for university education.

Fig. 7. Yale University Ancient Assyrian Palace VR Restoration Content (Youtube screenshot)

However, this example, has a clear drawback in that multiple users cannot experience the content simultaneously. This problem can be addressed by the existing smartphones and VR-related technologies. In this regard, significant research attention was directed toward Paekche culture tourism content that incorporates portable VR glasses. This study proposed the use of Google Cardboard in outdoor cultural heritage sites. Based on this method, the user can easily experience the VR content

21 See https://ctl.yale.edu/UsingImmersiveEnvironments for details.

while using their smartphones at the site of the remains.[22]

This case was significant in that it created an environment in which many users could simultaneously experience the VR. However, at the site of the remains, AR restoration is more efficient than VR, and it controls the field of view of the user. Thus, the user can simultaneously perceive the real space in front of him, in addition to the original historical space. Moreover, VR restoration will be implemented in university classrooms where it is difficult to directly visit the sites, such as Yale University.

In the future, visitors and students should not only receive information through VR and AR restoration data. In particular, the stage of historical re-enactment is expected, wherein the user can enter the original time and space of the historical site. Hence, storytelling that exceeds restoration and detailed depictions of the historical environment, in addition to the lives of people at the time, is required; while linking different layers of time in the same space and different layers of space in the same time. Furthermore, many history majors should participate in the restoration project.

Chapter 3 presents a method of restoring ancient historical remains using VR and AR, with the specific example of the Anyang ruins. These ruins include Anyangsaji (Anyangsa temple site, 安養寺址), which is located in Anyang-si, Kyŏnggi-do, and the surrounding cultural assets.

Anyangsaji, which is located in Sŏksu-dong, Anyang-si, began with Chungch'osa(中初寺) in the Unified Shilla period, flourished with the name of Anyangsa during the Koryŏ period, and declined during the Chosŏn period. Subsequently in 1959, the Yuyu industrial factory designed by architect Kim Chung-up was built in its lot. In 2007, Anyang City purchased the site of the Yuyu factory and conducted an excavation survey. The survey uncovered the original layout of the temple and led to its renovation as a heritage park. Part of the Yuyu industrial building was

22 Kang Byeonggil, Lee Wanbok, Yoo Seokho, "Development of Baekje Culture and Tourism Content Using Portable Virtual Reality Glasses," *Journal of Convergence Studies* 9, no. 1 (January 2018).

remodeled into the Kim Chung-up Architecture Museum and Anyang Museum. Nearby are Chungch'osaji Tangganjiju(中初寺址幢竿支柱), Sŏksu-dong Maae-jong(磨崖鐘), and the Anyang Temple turtle(龜趺), which indicates that the Anyangsaji and its surroundings have been transformed into a historical site in which the layers of its appearance in the times from Shilla, Koryŏ and Chosŏn to the modern times are stacked in one space.

Fig. 8. Distribution of Cultural Assets around Anyangsaji

Fig. 9. Anyangsaji and Temple Layout

However, the site was significantly damaged due to the construction of

the Yuyu industrial building. As the site was developed into Anyang Amusement Park, the organic connection between the cultural assets and Anyangsaji deteriorated. As a result, it is very difficult to imagine the historicity of Anyangsaji in its present state. In this regard, VR and AR technology can significantly facilitate the reproduction of the past without physically changing the present surroundings of Anyangsaji. The introduction of these technologies requires the following steps, which enhance the effectiveness of education and the authenticity of restoration.

Table 1. Anyangsaji VR, AR restoration process example

① Academic Research	② Restoration Plan	③ Development	④ Utilization
Confirm temple layout and Chronological study of cultural assets, Establish comprehensive maintenance plan	Devise multiple restoration plans by time, Continue academic verification	Through storytelling, Achieve historical re-enactment, address authenticity problems	Historical education site (VR) Ruins site (AR)
Expert researchers	Expert researchers	Developers and researchers	Students and tourists

First, at the academic research stage, researchers in each field confirm the temple layout and conduct a chronological study of the surrounding cultural assets. A time-based restoration plan can be therefore be prepared, although multiple restoration plans can be devised for each researcher. Moreover, basic research on Buddhist rituals, structures, and everyday life of temples can be utilized in storytelling through VR and AR materials. Such academic research should be promoted in accordance with a comprehensive maintenance plan. Furthermore, the “Hwangnyongsa Restoration Research Project” of the National Research Institute of Cultural Heritage has been promoted over a long period of time according to the basic plan and comprehensive maintenance plan.

Next, the development phase requires the implementation of historical re-enactment of the remains through storytelling. This includes the restoration of daily life with respect to the time period and space, visible experiences of non-visible elements, and empathy for specific organizations and human figures.[23] After completing academic verification and storytelling, the VR and AR restorations can be developed based on this. Finally, in the utilization stage, history education students can learn using the VR content, and tourists of the site can perceive the AR content.

An example development process that addresses the issue of authenticity and achieves historical re-enactment is exhibited in the single cultural asset of Chungch'osaji Tangganjiju within Anyangsaji. Storytelling work to restore Chungch'osaji Tangganjiju through VR and AR should begin with the participation of researchers from various fields. First, for example, in art history, researchers can analyze similar cases and infer the original appearance of Tangganjiju. In archaeology, the environment can reproduced based on the results of excavations. In the field of history, through the records engraved in Tangganjiju, researchers can review the participation of monks in moving stones and carving. Based on this basic data, the original environment at the time of formation, the formation process, and the appearance after completion of Tangganjiju were restored. In addition, the stories of various characters who participated in the process can be incorporated. Finally, through layers of time, space-related changes in Tangganjiju from ancient to modern times can be depicted. Moreover, Sŏksu-dong Maae-jong in the surroundings of Tangganjiju should also be incorporated to showcase the changes in the spaces over the same time period.

Until now, the restoration of ancient historical remains through VR and AR was focused on single remains for a given period of time. However, it is necessary to capture the time span that encompasses both the ancient and modern times, in addition to the spatiality that includes the surrounding cultural assets. Anyangsaji began with ancient Chungch'osa, and then

23 Choi Heesoo, "Experiential Historical Content and Korean Ancient History," 215.

flourished with Anyangsa after the Koryŏ period into an industrial heritage in the modern age, which was referred to as Anyangsaji. Its temporality and spatiality, which encompassed cultural assets such as Sŏksu-dong Maae-jong were noted as data to address the limitations of its VR and AR restoration.

This work follows the same major framework as the "Hwangnyongsa Restoration Maintenance Project". This Project involved basic research from experts in various fields prior to VR and AR restoration, who then prompted the restoration project over a long-term plan based on this. This restoration method can lead to storytelling that enhances the authenticity of the VR and AR content, and allows for historical re-enactment.

The VR and AR content produced using this method should be utilized based on the characteristics of the implementation method. First, the VR content should provide the user with a strong sense of immersion, although the user may not be able to visit the site in person. This will make it more accessible to students in school or university who cannot easily visit the sites. Thereafter, AR content is provided to direct visitors of the site, thus allowing for them to simultaneously experience both the "reality" in front of them and the "augmented reality" projected by their display monitors.

The pilot project of the Kyŏnggi-do Office of Education exemplifies the use of VR content for ancient historical remains in history education. The Kyŏnggi-do Office of Education is planning a pilot project to produce local cultural heritage VR content for use in school classes.[24] Although this project will not promote the restoration of historical remains through VR, it allows for students to experience cultural heritage sites using VR in the classroom.

The Aurelian Walls in Rome, Italy, is an example of AR restoration at an ancient historical site. The Rome Tre University research team and Sovrintendenza Capitolina ai Beni Culturali produced AR content that can

24 Kyŏnggi-do Office of Education press release, May 1, 2019, "Let's teach Kyŏnggi-do cultural heritage with a 360° VR experience!"

be utilized in the remains of the Aurelian Walls built in 3rd century Rome. Although this content is an AR restoration of only part of the walls, it should be noted that it incorporates AR technology; thus helping the user experience the original site of ancient historical remains, which is difficult to recall.[25]

The use of VR and AR restoration in addressing the limitations of "invisible" ancient historical remains was discussed above. In addition, the feasibility of using these methods in history education and the sites of ruins was examined. Until now, VR and AR content for Korean ancient historical remains were limited with respect to the authenticity of restoration, difficulty of simultaneous experience, absence of spatiality, and simplicity of information transmission. The solution of these problems requires the participation of expert researchers, the utilization of smartphones, and the application of VR content to history education and AR content at the sites of ruins. Furthermore, with the participation of researchers from various fields, content developers should devise storytelling techniques that enable users to develop their historical thinking abilities.

Conclusions

Korean ancient history and education may initially appear unrelated to the 4IR. However, new applications can be discovered in this field by introducing advanced technologies such as AI, VR, and AR.

Mokkan, or wooden tablets, are ancient documents from Korea that are especially difficult to decipher. Accordingly, researchers are currently

25 M. Canciani, E. Conigliaro b, M. Del Grasso c, P. Papalini d, M. Saccone, "3D Survey and Augmented Reality for Cultural Heritage. The Case Study of Aurelian Wall at Castra Praetoria in Rome," *The International Archives of the Photogrammetry XXIII ISPRS Congress, XLI-B5* (The International Archives of the Photogrammetry) (June 2016).

comparing the significant amounts of data from Korea, China, and Japan. However, due to the characteristics of *hanja*, which refers to ideographic Chinese characters, the amount of data required to be deciphered will gradually exceed human processing capabilities. The AI that employs character recognition technology is a 4IR technology that can be used to solve this problem. Hence, Japan developed the system "MOJIZO" in 2016, and the used it to decipher the text of ancient mokkan.

Furthermore, in Korea, for each character, researchers are constructing primary data in the form of book publications, and secondary data in the form of databases. Thus, the development of an AI-based mokkan deciphering system based on this data is required. Here, "generalization" by expanding the scope of the time and space of the training data can be achieved by including data from Korea, China, and Japan; in addition to that from ancient history, the Koryŏ period, and the Chosŏn period. Such a system would be able to decipher Korean ancient mokkan and text data across the ancient Chinese character culture sphere in East Asia with an improved speed and accuracy. However, understanding the context and comparing content are tasks that can only be completed by humans, the researchers of ancient history. In essence, the judgement of the researcher is required from the stage at which deciphering of training data for the AI.

Korean ancient historical ruins are limited with respect to "the invisibility of ruins." As a result, tourists or history education students visiting the remains find it difficult to imagine the original appearance of the ruins. Therefore, as an alternative to actual restoration projects, VR and AR were employed for the restoration of ancient historical remains.

However, until now, VR and AR content for Korean ancient historical remains were limited with respect to the authenticity of restoration, difficulty of simultaneous experience, absence of spatiality, and simplicity of information transmission. The solution of these issues requires the participation of expert researchers, the utilization of smartphones, and the application of VR content to history education and AR content in the sites of ruins.

In particular, the ancient historical remains of the Anyang region were

noted as an example in which VR and AR can be used to restore the various layers of time and space surrounding Anyangsaji (Chungch'osaji). Anyangsaji began with ancient Chungch'osa, and then flourished with Anyangsa in the Koryŏ period; it is now an industrial heritage site. Moreover, there are related cultural assets such as Sŏksu-dong Maae-jong. However, due to the surrounding development, it is difficult for visitors to recall the "spatiality" and "temporality" of Anyangsaji in the actual ruins. Thus, VR and AR technologies are required for the restoration of the historicity of Anyangsaji, which also requires stages of academic research, restoration plan establishment, development, and utilization. Particularly, from the academic research stage to the development stage, the participation of related experts is vital for storytelling and content authenticity.

The aim of this study was the determination of solutions using the new technologies of the 4IR from the perspective of a Korean ancient history researcher. However, the development of actual mokkan research based on an AI-based mokkan deciphering system was not examined. In addition, in this study, the results of actual restoration were not obtained, and only the feasibility of VR and AR restoration for ancient historical remains was discussed. Moreover, the abovementioned limitations of this study will be overcome by future research.

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〈**Abstract**〉

Advanced Technology of the Fourth Industrial Revolution and Korean Ancient History - Study on the use of artificial intelligence to decipher Wooden Tablets and the restoration of ancient historical remains using virtual reality and augmented reality -

Dongmin Lim

Mokkan are ancient documents from Korea that are especially difficult to decipher. Accordingly, researchers are currently comparing the significant amounts of data from Korea, China, and Japan. However, the amount of data required to be deciphered will gradually exceed human processing capabilities. The AI that employs character recognition technology is a 4IR technology that can be used to solve this problem. Hence, Japan developed the system "MOJIZO" in 2016, and the used it to decipher the text of ancient mokkan.

Furthermore, in Korea, for each character, researchers are constructing primary data and secondary data in the form of databases. Thus, the development of an AI-based mokkan deciphering system based on this data is required. Here, "generalization" by expanding the scope of the time and space of the training data can be achieved. However, understanding the context and comparing content are tasks that can only be completed by humans, the researchers of ancient history. The judgement of the researcher is required from the stage at which deciphering of training data for the AI.

Korean ancient historical ruins are limited with respect to "the invisibility of ruins." Therefore, as an alternative to actual restoration projects, VR and AR were employed for the restoration of ancient historical remains.

However, until now, VR and AR content for Korean ancient historical remains were limited with respect to the authenticity of restoration, difficulty of simulta-

neous experience, absence of spatiality, and simplicity of information transmission. The solution of these issues requires the participation of expert researchers, the utilization of smartphones, and the application of VR content to history education and AR content in the sites of ruins.

In particular, the ancient historical remains of the Anyang region were noted as an example in which VR and AR can be used to restore the various layers of time and space surrounding Anyangsaji (Chungch'osaji). VR and AR technologies are required for the restoration of the historicity of Anyangsaji, which also requires stages of academic research, restoration plan establishment, development, and utilization. Particularly, the participation of related experts is vital for storytelling and content authenticity.

Keywords: The Fourth Industrial Revolution (4IR), mokkan(wooden tablet), deciphering, virtual reality, augmented reality, Restoration of Historical Remains, ancient history, Anyang, Anyangsaji, Chungch'osaji

〈국문초록〉

‘4차 산업혁명’의 첨단 기술과 한국 고대사 - 목간의 인공지능 판독과 고대사 유적의 VR, AR 복원을 중심으로 -

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한국 고대의 문자자료인 목간은 판독하기 까다로운 자료이다. 따라서 한·중·일의 방대한 자료를 비교하는 작업이 이루어지고 있다. 하지만 판독에 필요한 자료의 양은 점차 인간의 처리능력을 벗어날 것이다. 이러한 문제를 해결할 수 있는 ‘4차 산업혁명’의 기술로는 인공지능을 활용한 글자 인식 기술이 있다. 이와 관련하여 일본에서는 이미 2016년에 ‘MOJIZO’ 시스템을 개발하여, 고대 목간 글자의 판독에 활용하고 있다.

한국에서도 목간과 관련하여 간행물 형태의 1차 자료, 각 글자별 DB 형태의 2차 자료는 구축되고 있으므로, 이를 토대로 인공지능 기반의 목간 판독 시스템을 개발할 필요가 있다. 이때 학습 데이터의 ‘시·공간적 확장’을 통해 ‘일반화’를 꾀할 수 있다. 이러한 시스템을 개발하더라도, 맥락에 대한 이해, 내용의 비교, 검색 이미지 편집, 판독된 자료에 대한 해석과 연구 등은 결국 고대사 연구자의 몫으로 남을 수밖에 없다. 근본적으로 학습 데이터의 판독 과정에도 연구자의 판단이 필요하다.

한국 고대사 유적은 ‘유적의 비가시성’이라는 한계를 갖고 있다. 따라서 고대사 유적의 실물 복원을 대신하여, 가상현실(VR)이나 증강현실(AR)로 복원해보는 작업은 일찍부터 이루어져 왔다.

하지만 지금까지 한국 고대사 유적의 VR·AR 복원은 복원의 진정성, 동시 체험의 어려움, 공간성의 부재, 단순 정보전달 등의 한계를 지녔다. 이를 해결하기 위해서는 전문 연구자의 참여, 스마트폰의 활용과 더불어 대학 교육에서는 VR 자료를 활용하고, 유적 현장에서는 AR 자료를 활용하는 방안이 필요할 것으로 생각된다.

구체적으로 안양 지역 고대사 유적은 안양사지(중초사지)를 둘러싼 다양한 시공간의 층위를 VR과 AR로 복원할 수 있는 사례로 주목된다. 안양사지의 역사성을 복원하기 위해서는 VR, AR 기술이 필요하며, 이때 학술연구, 복원안 도출, 개발, 활용의 단계를 거쳐야 한다. 특히 콘텐츠의 스토리텔링과 진정성 부여를 위해서는 관련 전문가의 참

여가 중요하다.

주제어: 4차산업혁명, 목간, 판독, 인공지능, VR, AR, 유적 복원, 고대사, 안양, 안양사지, 중초사지