An Intuitive Heritage Education System for Learning Architectural Structures and Styles

Focusing on the historical Korean architectures

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Although national and international attention toward the cultural heritage is on a rise, there is a lack of public attention toward cultural heritage sites. One of the main problems is the lack of interaction and the visualization of cultural heritage on the sites. Especially Korean historical architectures are structurally complex and are not easily understood by common people. To improve the public awareness of architectural heritages, we propose a model-based diagnosis system to educate the visitors and tourists. The system is designed to guide the users to model an appropriate architecture in accordance with the era, location, and the usage. For the system, we built a robust set of cases based on the ontological structure we designed especially for architectural heritage education. It basically enables users to reconstruct buildings intuitively in six steps from bottom to top. A system evaluation was conducted on the affective, cognitive, operative aspect of the system at a heritage site. The results show well in terms of cognitive aspect but was evaluated poorly in terms of the operative aspect.

Keywords: Historical Korean architecture, JESS rule engine, heritage education system

INTRODUCTION

As Korea shifts from a developing country to a developed country, national attention toward the cultural heritage is on a rise. For example, Baekje (AD 892-936) Historic Sites have recently been listed as one of UNESCO World Heritage and there are efforts to gain public attention toward cultural heritage sites through cultural festivals. While diplomatic and public relations efforts advance, the cultural heritage sites as tourist sites are still under poor conditions. One of the main problems is the lack of interaction and the visualization of traditional Korean architectures. Today, the base stones are the only component that remain along with vague description panels. Just a field of architectural remains does not engage the visitors and does not give much information and context of how the place used to look like. Korean historical architectures are structurally complex and are not easily understood by common, meaning untrained, people. Even after when people visit the cultural heritage sites with Korean historical architectures, the understanding toward building structures
is unclear because often, these cultural heritage sites
do not give attention to the architectural structure
themselves.

To overcome the problems of widening knowl-
edge gap between the experts and the common
people, and decreasing public awareness, we pro-
pose a model-based diagnosis system to educate
the visitors and tourists. To develop this system,
we reviewed the benefits of CBR for education,
summarized related systems previously suggested,
and explained the components of Korean architec-
ture. Next, we interviewed the expert to reflect
experts' heuristic knowledge for system implement-
tion, gathered the historical Korean architecture
cases, and implemented the system. Finally, we ex-
ecuted the system evaluation through user tests for
system enhancement.

BACKGROUND
There have been many researches on the gamifica-
tion of architectural heritage and on ways to edu-
cate the public in virtual environments. For instance,
Champion (2008) made a list of categories of cultural
heritage games which include tourist game, puzzle
games, resource management games, historical bat-
tle games and others. As can be seen, educating the
architectural heritage to the public is being actively
researched to the point where a list of categories are
appearing. Of the categories, the ‘puzzle games’ is a
game where people solve quests by interpreting re-
mains and epitaphs to reconstruct architectural her-
itage indicating the public’s interest toward architec-
tural heritage (Champion 2008). Meanwhile, Juvan-
cic (2008) researched for the optimal interface design
for educating the general public on architecture and
conducted the experiment for the interface design
of eco-spatial education system at a primary school
(Juvancic 2008). The result showed the effective-
ness of interactivity on learning outcomes. However,
there have not been education systems based on the
reasoning of architectural styles nor researches re-
grading the reasoning of architectural styles based
on the usage of the building (such as its purpose),
geographical location, and built period. While the
architecture education systems are researched, re-
searches on digital reconstruction of architecture are
recently on a rise through the advancement of tech-
nology. For instance, Liu (2015) researched about de-
signing a historical architecture based on architec-
tural style rules of a certain period, and Apollonio
(2011) researched about estimating destructed archi-
tectures based on an architect's pattern book and ar-
chitecture cases (Apollonio 2011). However, there
have not been education system and gamification re-
searches for learning architectural heritage (style and
structure) through digital reconstruction. Ontology
is a useful tool to explain an object’s concept and
relationship between the sub-elements of the ob-
ject. Ontology of an architecture can be represented
through components, spatial arrangements, materi-
als, usage or function, and others. Stefano Cursi
(2015) defines the architectural heritage information,
and in order to explain the multiple context of these
information, the Cursi (2015) suggested an ontologi-
cal structure that are at large classified into the arte-
fact knowledge domain and the historical context
domain. Cursi (2015)’s research aims help the experts
in the field of architecture and preservation to share
and obtain information related to architectural her-
itage.

METHODOLOGY
In order to design a model-based diagnosis system to
educate the visitors and tourists. A model-based di-
agnosis tackles the problem of troubleshooting sys-
tems starting from a description of their structure
and function or behavior (Vittorio Brusoni, 1998). It
means tracking the causes (faults) is responsible for
a system failure. we first interviewed an expert to in-
vestigate what kind of historical cases to use. Then,
we built a robust set of cases based on the onto-
logical structure we designed especially for architec-
tural heritage education and we derived tasks, corre-
sponding rules and ways to control the rules.
Knowledge acquisition through expert interviews

An expert interviewed was a researcher from the National Research Institute of Cultural Heritage with experience of 19 years. From interviewing the expert, we had two findings. First is, since we do not have access to Chinese and Japanese architecture data in a given amount of time, we should narrow down the case library scope to the existing national treasure architectures from 'after middle age architecture' including early, middle, and late eras of Goryeo Dynasty and early, middle, and late eras of Joseon Dynasty. Second is, as the experts do, we should incorporate the location of the architecture into our system as one of the constraint along with the era and the usage of the architecture; therefore, the user input information was revised to era, usage, and location. For the era, the experts refer to the architectural styles appeared during the same era and estimate the architectural style of its golden age. As for the location, the experts refer to the architectural styles appeared near the site of excavation. To summarize, we learned that we should narrow down the case library to existing national treasure architectures and that we should include the location information as a constraint as it plays an important role in identifying architectural styles.

Ontological approach to well-indexed set of cases

The ontological structure suggested in this paper is designed for digital architecture education. As shown in Figure 2, a 'wooden architectural heritage' is divided into three classes which are context, component, and style. The context class includes information that affects the style of the building such as its period when built, location of its existence, and usage or the function. The components class includes four of the main parts of a building because Korean architectural heritages are mainly wooden and have a precast structure. The four parts representative at each of their vertical placements are base, bracket, frame, and roof. For example, on the bottom of the building is the base component that includes elements such as basestones, steps, and stylobates. Likewise, on the top of the building is the roof component that includes elements such as dori, rafter, and rooftile. Lastly, the style class includes all possible components' types.
From the abovementioned classes, we only focus on the style class since we are designing a system that can illustrate the building styles. Of the components under the style class, we use basestone type, stylobate type, column type, bracket type, roof structure type, and roof type because these elements are the most deterministic according to the built period, building’s usage, and geographical location which is the context class in our ontological structure. With these styles, architects estimate the construction period of the historical building or reconstruct historical remains. As illustrated in Figure 2, these six components enables users to reconstruct buildings in six steps starting with the stylobate (gidan) at the base of the architecture, base stones (choseok), columns (gidoong), bracket (gongpo), roof structure (gagu), and ending with the roof (jiboong).

**Tasks and rules to control the rules**

At large, there will be seven main tasks where each task narrows down the list of architectural case according to the input or selected information (see Figure 3). For instance, in Task 1, the cases are narrowed down according to the initial data input by the user: era, period, and location. From the remaining cases, the cases are even more narrowed down according to the stylobate type selected by the user in Task 2. This process repeats until Task 7 where a final list of architecture cases is reconstructed. While the components are narrowed down systematically, to the users, all components are visually listed.

Each task will be composed of three rules. First rule will assert specification to the working memory. Second rule will compare the asserted specification with the list of cases to find those that match which are the possible cases. Lastly, if the selected type is not in the list of cases, then the third rule fires where the system prints out a reason why the particular type does not work. The tasks will be controlled using the status slot of the facts. The status will first begin as (status initial). However, once the narrowing down using the user input on era, usage, and location is completed, the cases that remain will have a (status
Figure 3
Six basic components for building case library and case example.

Figure 4
Tasks and Rules.

IMPLEMENTATION
Using the built cases, tasks, rules, and control methods, we designed the system GUI and implemented into a system using JESS for inference engine and JAVA swing for interface design. Our system, LogiRec, is divided into seven tasks (see Figure 4). The 'User Inputs' panel on top left is the panel that retrieves the initial information for the system to run such as the building name, the era, the usage, and the location. When the ‘Submit’ button is pressed, the system will search for the cases that meet the requirements. For example, historical cases with the same era, usage, and location are considered. However, on the interface is the complete list of all the types under the architectural component. The panel located under the phrase "RECONSTRUCT YOUR BUILDING HERE" is the 'Instruction' panel where the system and the user can communicate especially to explain why the selected type is wrong. Below that is the 'Workspace' panel which displays all the choices for the building components. The 'Check' button verifies whether if the selection is appropriate. On the bottom is the 'Information' panel which provides explanation for the building component with an image.
Lastly, below the User Inputs panel is the 'Progress' panel which shows the progress of the building being built for user experience and understanding.

The system is designed to guide the users to model an appropriate architecture in accordance to the era, location, and the usage. It basically enables users to reconstruct buildings intuitively in six steps from bottom to top starting with the stylobate (gidan) at the base of the architecture, base stones (choseok), columns (gidoong), bracket (gongpo), roof structure (gagu), and ending with the roof (jiboong). The users' selections and the knowledge in the system (which is the list of all the architectural cases) are compared to diagnose the selection by finding the discrepancy between the actual user selection and the ideal selection and informs the users on why the selection is inappropriate.

**SYSTEM EVALUATION**

Using the implemented system, we executed the system evaluation through user test for system enhancement. The quantitative evaluation method was derived based on the evaluation model of MOSAICA System proposed by Barak (2009) with few adjustments made adding questions about understanding of architectural heritage and awareness of traditional culture. The survey questions consist of 13 statements soliciting level of agreement about affective, cognitive, operative aspect of the system (see Table 1). Four questions are related to the 'Affective' cate-
category measuring whether or not operating the system is interesting, enjoyable, and fun; six questions are related to the 'Cognitive' category measuring whether or not the system is educational and provides new knowledge at its use; finally, three questions are related to the 'Operative' category measuring whether or not operating the system is easy to learn and do not involve technical problems (Barak, 2009). Each statements were measured on a 5 point likert scale. In addition to the quantitative approach, we conducted interviews to gain specific feedbacks for the improvement of our system.

<table>
<thead>
<tr>
<th>Aspects</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affective aspect</td>
<td>1. I found this system usage comfortable.</td>
</tr>
<tr>
<td></td>
<td>2. Using this system gave me motivation to use such kind of programs in the future.</td>
</tr>
<tr>
<td></td>
<td>3. Content of this system was interesting in my opinion.</td>
</tr>
<tr>
<td></td>
<td>4. Exploring this system was challenging and exciting.</td>
</tr>
<tr>
<td>Cognitive aspect</td>
<td>5. Exploring this system encourages thoughts about architectural heritage.</td>
</tr>
<tr>
<td></td>
<td>6. Exploring this system improved my understanding of architectural heritage.</td>
</tr>
<tr>
<td></td>
<td>7. Exploring this system improved my understanding of architectural heritage structure.</td>
</tr>
<tr>
<td></td>
<td>8. Exploring this system improved my understanding of architectural heritage style.</td>
</tr>
<tr>
<td></td>
<td>9. This system provides sufficient information of architectural heritage.</td>
</tr>
<tr>
<td>Operative aspect</td>
<td>11. This system's interfaces are friendly and easy to use.</td>
</tr>
<tr>
<td></td>
<td>12. The move from one screen to another was quick.</td>
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<tr>
<td></td>
<td>13. I didn't encountered technology problems while using this system.</td>
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</table>

We conducted the user test on the 28th of May in 2016 from 5 p.m. to 6 p.m. on site at Deoksugung Palace. The participants were randomly gathered on site as potential system users. A total of 10 tourists who have no professional knowledge about architectural heritage were asked to reconstruct the building on site (Deoksugung Palace) by interacting with our system on a laptop. After completing the task, the participants answered the questionnaire. When the evaluation was finished, interviews were conducted to get feedbacks for system improvement.

**RESULTS**

From the survey results, we made a bar graph to visualize which question had a positive rating and which had negative rating. As shown in Figure 5, questions with the most positive rating were the question 4 under affective aspect and question 8 under cognitive aspect, which are consecutively, 'exploring this system improved my understanding of architectural heritage' and 'exploring this system enhances open-mindedness towards traditional culture'. These results indicate that tourists had positive response about learning architectural heritage at the heritage site and that the system actually helped to improve their knowledge about traditional culture. On the other hand, questions with the most negative rating was the question 9 under operative aspect which is 'this system provides sufficient information of architectural heritage'. This result indicates that the participants had a difficult time understanding the concept of dividing the architecture into parts and classifying the architectural styles based on the era, period and location. The detailed results of the surveys are presented in Table 2 under positive and negative assertions along with the results of the improvement feedbacks from user interviews.

From Table 2, it is easy to see that our system was evaluated well in terms of cognitive aspect but was evaluated poorly in terms of the operative aspect. As
our aim of this system was to provide an educative experience and new knowledge to the potential users, we believe that the aim was achieved at this point of our research.

CONCLUSION
The present system shows possible component cases with input data and users can combine possible components and construct possible Korean traditional architectures. We hope that this 'model-based diagnosis system' will help to overcome the problem of lack of interaction between the cultural heritage sites and the visitors. Especially, we hope that his system to educate the young adult tourists interested in Korean cultural heritage. By taking them step by step to reconstruct buildings intuitively in six steps, the tourists can understand the structures of architectures more in detail. Our system allows the users to explore Korean traditional architectures and guide them to reconstruct buildings intuitively piling up the building bottom-up like building with building blocks. Whether if our system evokes curiosity and the desire to learn to the users was tested during the system evaluation; the result showed that the system performed well in terms of the cognitive aspect which measures whether or not the system is

<table>
<thead>
<tr>
<th>Positive response</th>
<th>Negative response</th>
<th>Improvements</th>
</tr>
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<tbody>
<tr>
<td>Affective aspect</td>
<td></td>
<td></td>
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<tr>
<td>• motivational to use</td>
<td>• usage not very comfortable</td>
<td>• To make the system comfortable to use and interesting, the concept of gamification should be incorporated like the reward items.</td>
</tr>
<tr>
<td>• challenging and exciting</td>
<td>• content not very interesting due to a lack of basic knowledge</td>
<td></td>
</tr>
<tr>
<td>Cognitive aspect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• encourages thoughts about architectural heritage</td>
<td>• Do not provide sufficient information of architectural heritage</td>
<td>• To enhance understanding, the system should provide more fundamental information of Korean architectures.</td>
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<tr>
<td>• improves the understanding of architectural heritage, structure, and style</td>
<td></td>
<td></td>
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<tr>
<td>• enhances open-mindedness towards traditional culture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operative aspect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• No technology problems while using this system</td>
<td>• The move from one screen to another was no quick.</td>
<td>• To improve the transition of the screen, we intend to incorporate intuitive gestures by using pad with a touch screen.</td>
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Table 2
Evaluation matrix and examples of users' remarks.
educational and provides new knowledge at its use. However, we found out that our system performed poorly in terms of the operative aspect which measures whether or not operating the system is easy to learn and do not involve technical problem. As for the limitation of our work, we defined the architectural style at a high-level division of era, usage and location while each could be subdivided further. In addition, we assumed that buildings we included in our case library had maintained their original form instead of the transformed form created while undergoing repair. Therefore, we had to exclude transformed heritages from heritage cases. In response to the system evaluation, for future works, we intend to make the system comfortable to use and interesting by adding the concept of gamification incorporating the reward system. And to enhance understanding regarding Korean historical architecture, we plan to add a section that provides fundamental information on Korean architectures explaining what each components are and that they can be considered separately like building blocks. Lastly, to improve the transition of the screen, we intend to incorporate intuitive gestures by using pad with a touch screen.

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