

THE USE OF DECISION MAKING MULTI-MEDIA COMPONENTS IN ELUCIDATING THE CONSTRUCTION METHODS OF THE ST. GEORGE CHURCH IN LALIBELA, ETHIOPIA

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Abstract

The proliferation of computing devices in the classroom, such as laptops and desktops, has significantly impacted how students learn; according to the Teaching with Technology survey conducted by Campus Technology, Traditional laptops and desktops most common form of instructional technology used in the classroom, both of which are used in 82 percent of learning environments. For this research, a Microsoft Windows based multi-media graphical system was developed to enlighten interested individuals about the possible construction methods likely employed in the creation of the St. George Church in Lalibela, Ethiopia, an ancient Zagwe Dynasty monument created between AD 1137 and AD 1270. St. George's Church is a UNESCO World Heritage Site that is often touted as the 8th Wonder of the World. Through the media program created by this research, students can explore the possible construction methods used in the construction of Saint George's Church from an engineering perspective. This program has potential for demonstrating construction techniques and other engineering concepts in the educational field, bringing the full detail of historical methods into a modern setting.

Reliable information regarding the construction of St. George's Church is relatively sparse, but based on known literature, two distinct possible methods have been developed to describe the erection of the church: MEOI (Measure, Excavate, Outside, Inside) and MSOI (Measure, Simultaneous excavation, Outside, Inside). Using the multi-media system, students can select the relative hardness of volcanic tufa from which the hypogea could be fashioned. The students can then select whether they want to "virtually build" St. George's using ancient, or modern tools; select a construction method of their choice, and choose the size of the construction labor force while receiving information about the selections made. Such a multi-media system may potentially inspire students and researchers to not only look into ancient construction more closely, but also develop sustainable modern construction methods based on the ideas used back in ancient times.

Background

The proliferation of computing devices in the classroom, including laptops and personal computers, has led to considerable changes in how students learn. According to the Teaching with Technology survey, conducted by *Campus Technology*, Traditional laptops and desktops most common form of instructional technology used in the classroom. They are both used in 82 percent of learning environments [2]. It is because of this prevalence that a Microsoft Windows based multi-media graphical system has been developed by the authors of this research to enlighten interested individuals about the possible construction methods likely employed in the creation of the St. George Church in Lalibela, Ethiopia.

As of April 2016, Microsoft held 89.23% of the Operating System market share [3], which means roughly nine out of ten computers are running a Microsoft Windows based Operating

System. This is one of the many reasons that the authors created the multi-media graphical system as a Windows-based program. Because so many computers are Windows-based, the appearance and interaction between the user and the computer are very familiar and intuitive, which allows learners to focus more on the content presented in the multi-media graphical system, rather than trying to figure out how to operate or navigate the program itself. This would enhance the user experience by minimizing the potential difficulties of using of a new computer program or application. Anyone who has previously used any mainstream internet web browser in the past several years since 2005, or so, would likely have encountered Tabs and a “Back” button of some sort leading them “Back” to the internet location that they were visiting previously [4]. The Multi-media Graphical System works in much the same way as mainstream modern internet browsers: the Tabs along the top edge of the screen allow users to go directly to any location within the program that they so choose. The “Back” button takes the user to the previous Tab, and likewise the “Next” button takes the user to the next Tab to the right in the sequence of Tabs. As learners click on the various buttons throughout this program, there are audible sound effects that act as feedback to inform the user of the program’s acknowledgement of their selection and to reinforce selections made, or indicate that a selection that should have been made, has not yet been made.

The Multi-media Graphical System was developed using a free version of Microsoft Visual Studio. The program was written using the C-Sharp (C#) programming language. The actual program is relatively small and does not require a particularly powerful processor, or large amounts of memory to operate properly. The Multi-media Graphical System can run on even the most modest and inexpensive of computers running a Windows operating system. This is important for school systems that lack adequate funding, or other locations such as developing countries, could utilize the Multi-media Graphical System with some tweaking and translation. It does, however require an internet connection to access the YouTube videos. All of the other features included in the Multi-media Graphical System are self-contained and work completely without an internet connection. The Multi-media Graphical System was developed with the intention of being deployed on a USB Thumb drive, or dongle for ease of distribution, durability, economy, and universality [7].

Literature Search

The multi-media graphical system uses a decision tree to generate output based on choices provided by the student operating it. This kind of media tool has significant potential in the educational industry, but it has not seen much use in the classroom at the time of this writing. On the other hand, decision trees in software have already been shown to be viable in other related industry applications, so the potential jump to education is a short one.

Selby and Porter [14] created a means of automatically generating decision trees for use in a NASA production environment, which would enable such structures to be procedurally created for software resource analysis. The intent was to determine which components of the processes in question took the most labor hours or were the most expensive, allowing researchers to

potentially streamline their development strategies as needed. This approach used existing data, namely 74 attributes for over 4700 objects, to help generate a total of 9600 decision trees representing all the potential processes to show various degrees of productivity. The Lalibela multi-media graphical system starts with just two possible paths based on the possible construction methods, but the idea of using attributes to generate different outcomes is the same.

Moreta, Gamboa, and Palacios [15] proposed a strategy for risk management education, wherein an application with game elements can be used as a positive incentive for the education of students on the identification and remedy of project risks. Findings from this study showed that the framework for this process, known as “gamification”, were an effective means of educating risk management, the strategy being described as having greater potential for educating students than conventional methods. The multi-media graphical system has elements similar to gamification, using interactive choices for each of the required steps in a manner akin to a survey to determine the final outcome of the Lalibela construction project.

The multi-media graphical system also implements a digital model to aid in demonstrating the various construction techniques presented. This too has a precedent – Ha and Fang [16] showed that spatial recognition, an asset for Science, Technology, Engineering, and Mathematics (STEM) education, can be improved significantly with 3D models. Digitally rendered models are manipulated in virtual space via user input, and students can view these models from any angle and interact with them dynamically, allowing for greater comprehension and problem solving. Rather than interactive manipulation, the multi-media graphical system uses videos and digital stills to showcase its models of the Lalibela monument, which saves on data usage and increases portability while providing the same effect.

History

The multi-media graphical system presented in this research is specifically catered to students learning about the St. George’s Church in Lalibela, Ethiopia, as shown in Figure 1; as such, a historical overview of this monument may be necessary and is incorporated into the program. The St. George’s Church is an ancient Zagwe Dynasty monument created between AD 1137 and AD 1270 [5]. St. George’s Church is one of 11 rock-hewn churches in Lalibela. King Gebre Mesqel Lalibela (AD 1181-1221) is credited with the construction of the churches in the city that now bears his name. The city of Lalibela was formerly known as Roha, or “Red,” after the color of the soft volcanic tufa from which St. George’s Church was created [10]. Significantly and suitably, Roha also means “Clean,” or “Pure” in Ge’ez, which is the liturgical language of the Ethiopian Orthodox Church. Of the 11 Churches, there are seven that are semi-monolithic and four that are truly monolithic. St. George’s Church is one of these four monolithic churches and the youngest of the 11 rock-hewn churches located in Lalibela. St. George’s Church is a UNESCO World Heritage Site that is often touted as the eighth Wonder of the World. St. George’s Church is visited by thousands of tourists and religious pilgrims every year. [6] Among the many unique features of St. George’s that set it apart from most other constructions are the fact that it is an hypogea, excavated into the ground instead of built up, and it is monolithic,

hewn from one solid piece of rock, or “living rock.” St. George’s Church was carved from soft red volcanic rock (scoriaceous basalt). It is believed by some historians that it took 23 years for St. George’s to be constructed [9].

Thanks to the multimedia program presented in this research, learners can interactively explore the possible construction methods used in the construction of Saint George’s Church from an engineering perspective, resulting in an explanation of the probable construction methods used in the construction of Saint George’s Church.

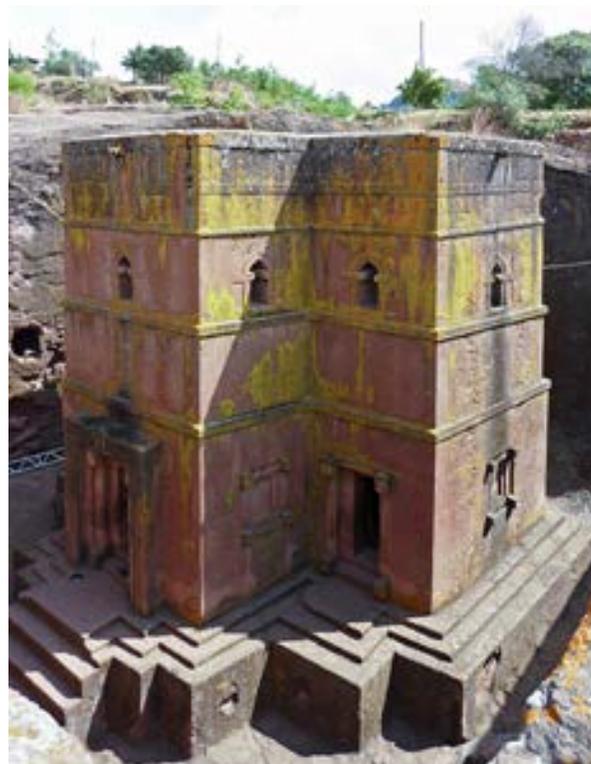


Figure 1: The St. George’s Church in Lalibela, Ethiopia (Bernard Gagnon, November, 2012) [11]

Construction Methods

Reliable information regarding the construction of St. George’s Church from an engineering perspective is sparse. Based on the information that is available, two distinct possible construction methods have been developed to describe the creation of St. George’s Church: MEOI (Measure, Excavate, Outside, Inside) and MSOI (Measure, Simultaneous excavation, Outside, Inside) [1]. The MEOI construction method begins with measuring out, on the surface of the rock, the plan dimensions which the 12 meter x 12 meter church and the 25-meter square trench that surrounds the church. Once the measurements were taken, the soft volcanic tufa could be carefully marked or scored such that the outline of the trench and the church were clearly delineated. After the plan view was “drawn” on the surface of the soft volcanic rock, the

excavation could begin. As the workers began to excavate down within the established trench and church lines, the spoil was gathered and transported away from the worksite. One advantage to this method, at least at this stage, is that it starts off inherently safe for the workers. As the work progresses downward and the trench and cruciform shape of the church begin to take shape, the work platform for the workers is the soft volcanic rock beneath their feet. As the workers excavated downward, their work platform moved downward with them as the “rough” shape of the church and trench also began to emerge. This operation continued until the desired depth of 13 meters is reached. The rough outside form of the church could then be smoothed and detailed, after which all stairs, doors, and windows were added to the structure. This is when this construction method began to lose some of its safety, as a scaffold of some kind was needed to serve as a work platform for the workers as they created the doors, windows, and architectural features that decorate the outside of the church. Among the architectural features were the first floor “blind” windows and “Monkey Heads” which enhanced the outer appearance of the church. On the other hand, the upper or second story windows are functional. Once all windows and doors are created, the focus of the work shifts to the inside of the church. The interior walls and intricate ceiling arches have to be roughed in and finished. Scaffolds also have to be used on the interior to carve the ceiling details.

MSOI works very similarly to MEOI, except that instead of waiting until the rough outside of the church is complete from top to bottom, the workers completed the inside of the church at the same time as the outside. The MSOI method would have been safer for the workers, in that the workers were never subject to falling hazards because there was no need for scaffolding. As the church began to take shape, this time from the top down, and openings to the interior begin to emerge, the ground beneath their feet is the work platform for the duration of the construction. There are disadvantages to MSOI method though. One disadvantage is that great care has to be taken in order to protect the work that has already been completed from being damaged by the new work taking place. Use of the MSOI construction method could greatly increase the likelihood of damage to completed work. Protecting recently completed work could be very challenging and time consuming, even to the point where it negatively affected the new work by slowing down the process. Another disadvantage would be the precision, accuracy and overall quality of the finished product could be negatively affected. From a visualization standpoint, it could be difficult to do the detail work without seeing the entire structure.

Both of these methods are described both in visual and textual form by the media simulation, as the current archaeological evidence could lend credence to either theory and both of them have advantages and disadvantages with respect to safety, efficiency, and material and labor conservation. As such, the simulation allows learners to choose which strategy with which to gauge the soundness of the construction process, along with the materials and tools used, labor force size, and general organization of the construction process.

Multi-media Graphical System

When learners use the multi-media system, they are greeted by a Welcome Screen Tab. There are six other such tabs that comprise the multimedia system. The other tabs include a History tab that features a brief written history of St. George's Church along with the option to view two YouTube based videos. There is a dimension tab that provides the physical dimensions of St. George's Church. The Material tab allows learners to select the relative hardness of volcanic tufa from which the hypogea could be fashioned. There is a Construction tab which allows the learner to select whether they want to "virtually build" St. George's using ancient, or modern tools: select the MEOI, or MSOI construction method: and choose the size of the construction labor force while receiving information about the selections made. There is also a Decision Tree Tab for later discussion.

Using the multi-media system, learners have the option to "virtually build" St. George's Church using materials of varying hardness, modern tools, and varied labor force sizes to gain a more thorough exploration of the thought processes that brought St. George's Church to fruition. Use of the multi-media system may potentially inspire learners to develop sustainable modern construction methods based on ideas used back in ancient times.

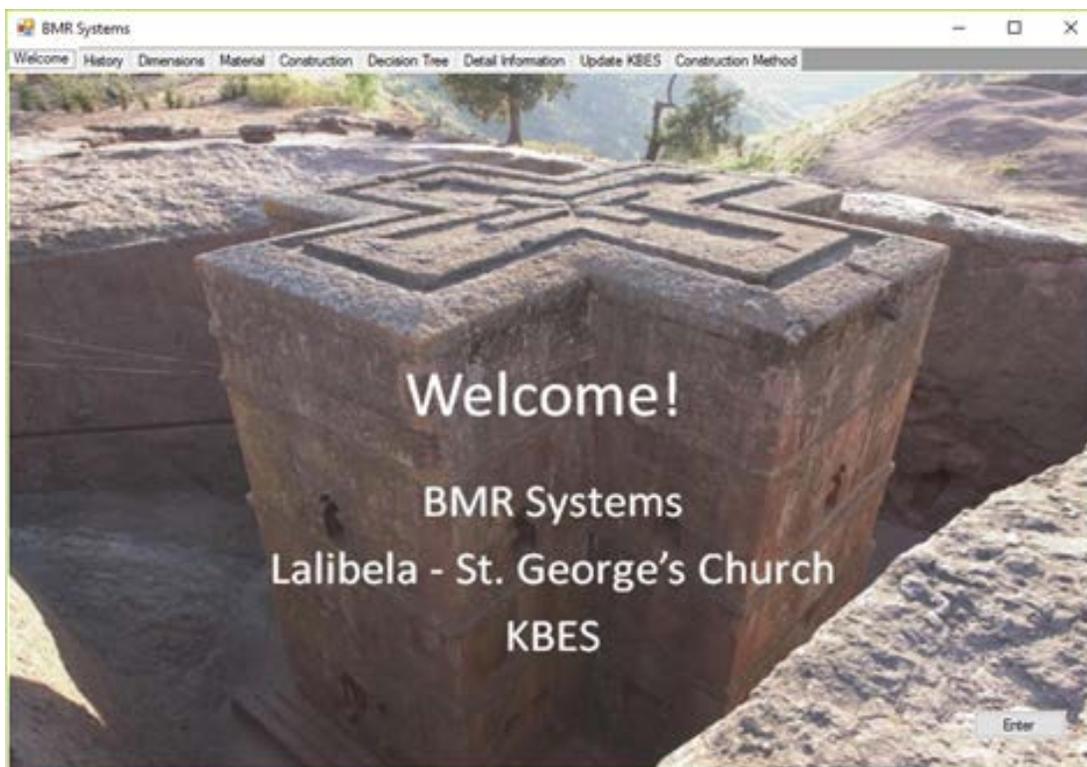


Figure 2: Multi-Media Graphical System Welcome Tab Screenshot. [13]

Beginning with the Welcome Screen, the learner is visually drawn into the multi-media system. At the upper right hand corner of the screen, there are the familiar, easy to use windows icons for minimizing, maximizing, or resizing, and closing the multimedia system. Across the top of the cover image of St. George's Church are the tabs that take the learner to the eight separate areas

of the multi-media system. The available Tabs are Welcome, History, Dimensions, Material, Construction, Decision Tree, Detail Information, and Update. At the bottom right hand corner of the Welcome Screen there is an Enter Button, where the learner can interact with the multimedia system. When the Enter Button is selected, the learner is then forwarded to the next Tab, which is the History Tab.

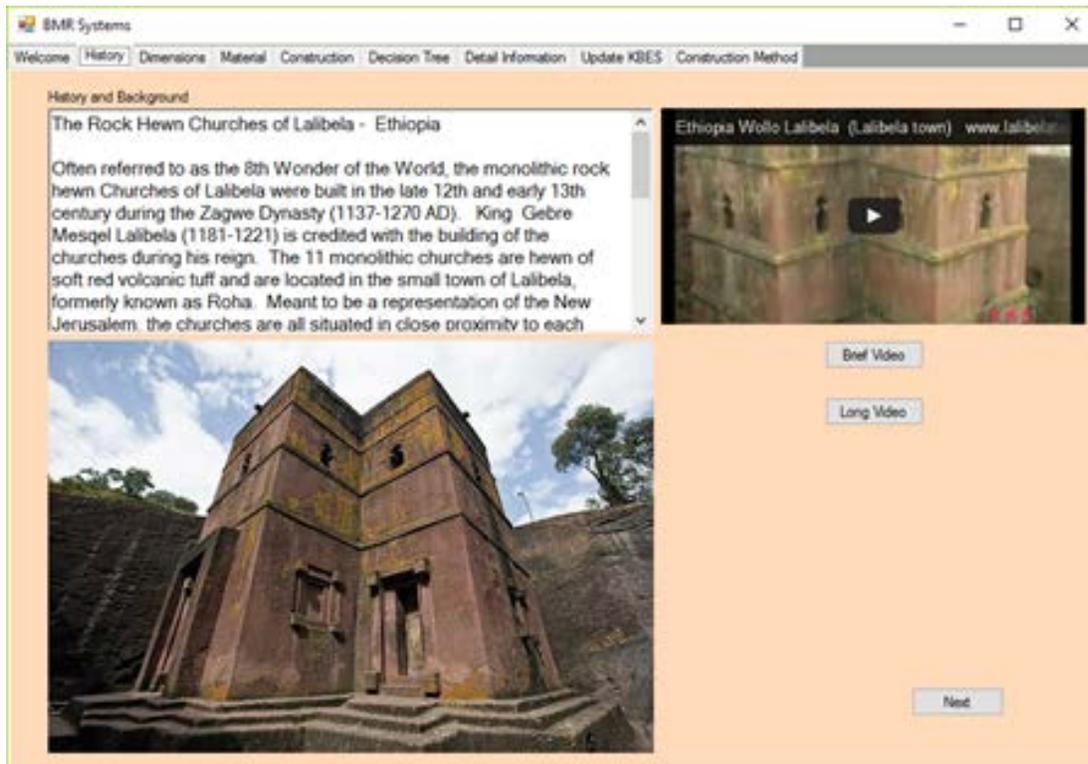


Figure 3: Multi-Media Graphical System History Tab Screenshot.

The History Tab engages the learner with a Text Box with historically significant information regarding St. George's Church located on the upper left side of the Tab. On the upper right side of the Tab, there is a YouTube video window that features two videos that discuss historical aspects of St. George's Church. The two Buttons immediately below the YouTube video window offer the learner a choice between a Brief, or Long historical video. In the photograph below the Text Box there is another view of St. George's Church from a different perspective. On the bottom right of the History Screen there is a Next Button that takes the learner to the Dimensions Tab.

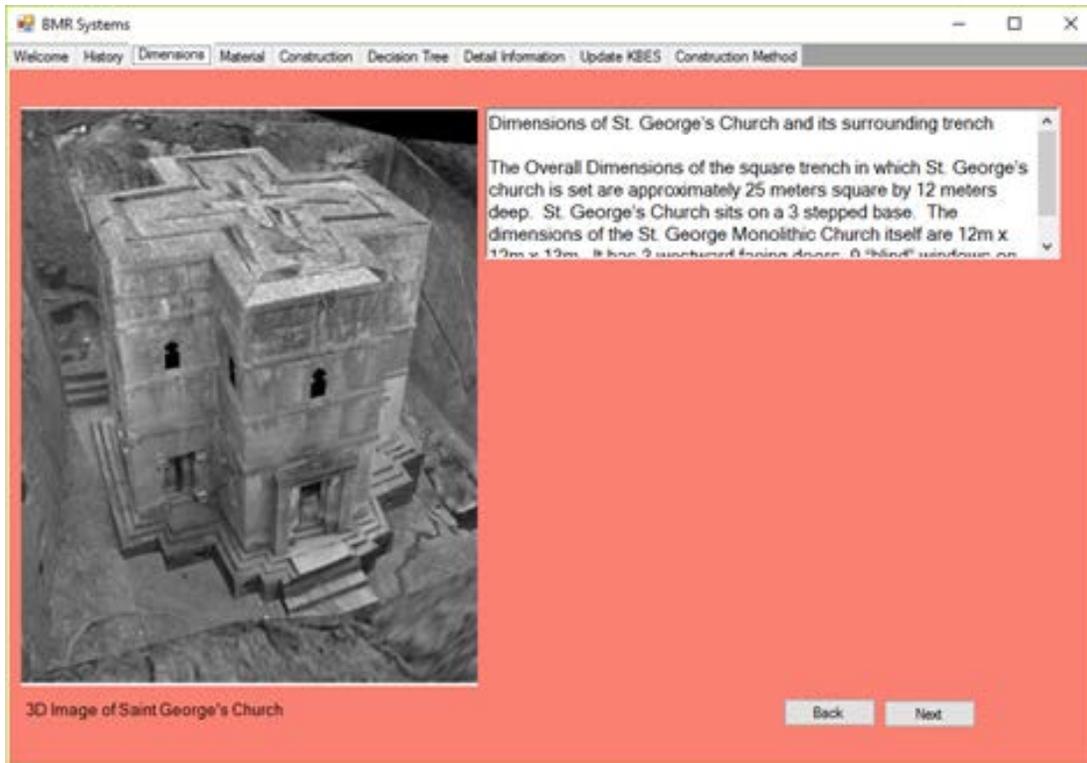


Figure 4: Multi-Media Graphical System Physical Dimensions Tab Screenshot. (B&W 3D Photo [12])

The Physical Dimensions Tab shows a black and white image of St. George's Church and a text box listing the physical attributes and dimensions of St. George's Church and trench that surrounds it. Like the other Tabs, the Dimensions Tab has a "Back" and a "Next" button located at the bottom right hand of screen. The "Back" Button returns the learner to the previous Tab in the sequence, which is the History Tab. The "Next" Button takes the learner to the Next Tab, which is the Material Tab.

The Material Tab is unique to the previous other Tabs. Where the previous other Tabs provided information about St. George's Church, the Material Tab begins the Decision Making portion of the program. This is where the learner gets to think about what they have just learned and apply it to the situation at hand. In the upper left hand corner there is a "drop down" selection menu that allows the user to select the type of volcanic tufa for use in "virtually" constructing St. George's Church (Soft, Medium, or Hard). The learner may also use a large Text Box immediately to the right of the "drop down" selection menu, which offers hints at what impacts are to be expected that correspond to each of the three options if selected. At the bottom right of the screen are the two familiar "Back" and "Next" buttons. If the "Next" button is selected without an option selected, the learner is made aware that they have not made a selection. After closing the notification, the learner can then make their selection and make their way to the next Tab, which is the Construction Tab.

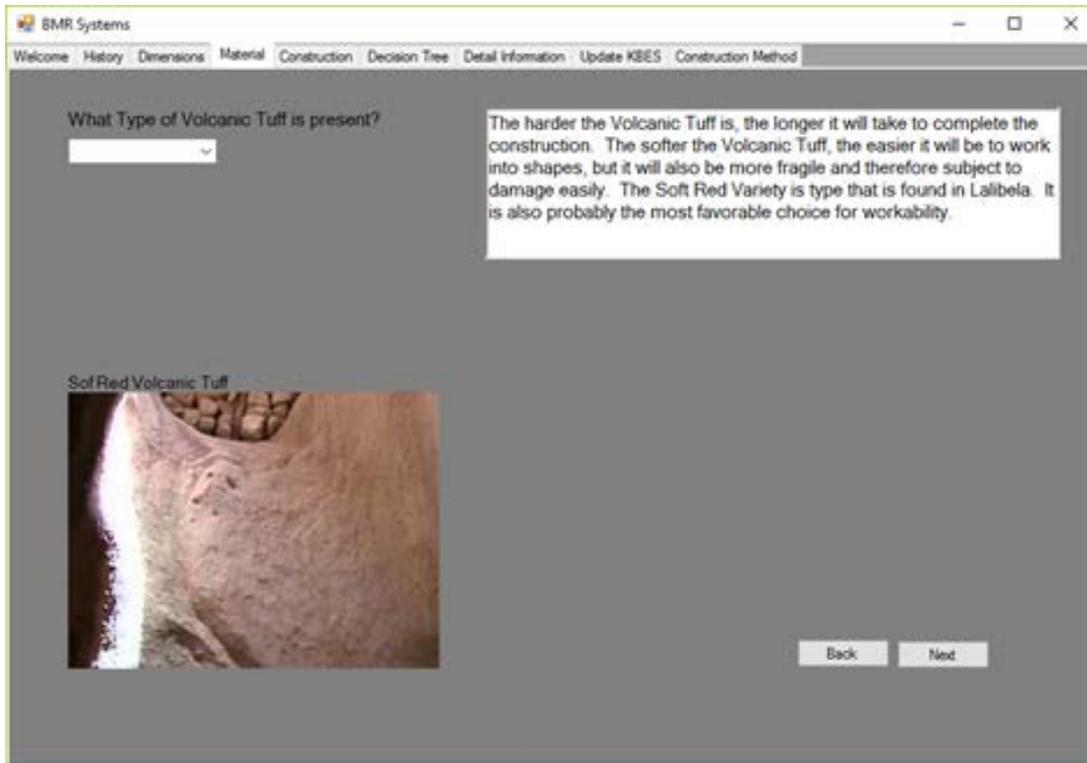


Figure 5: Intelligent Multi-Media Graphical System Material Tab Screenshot.

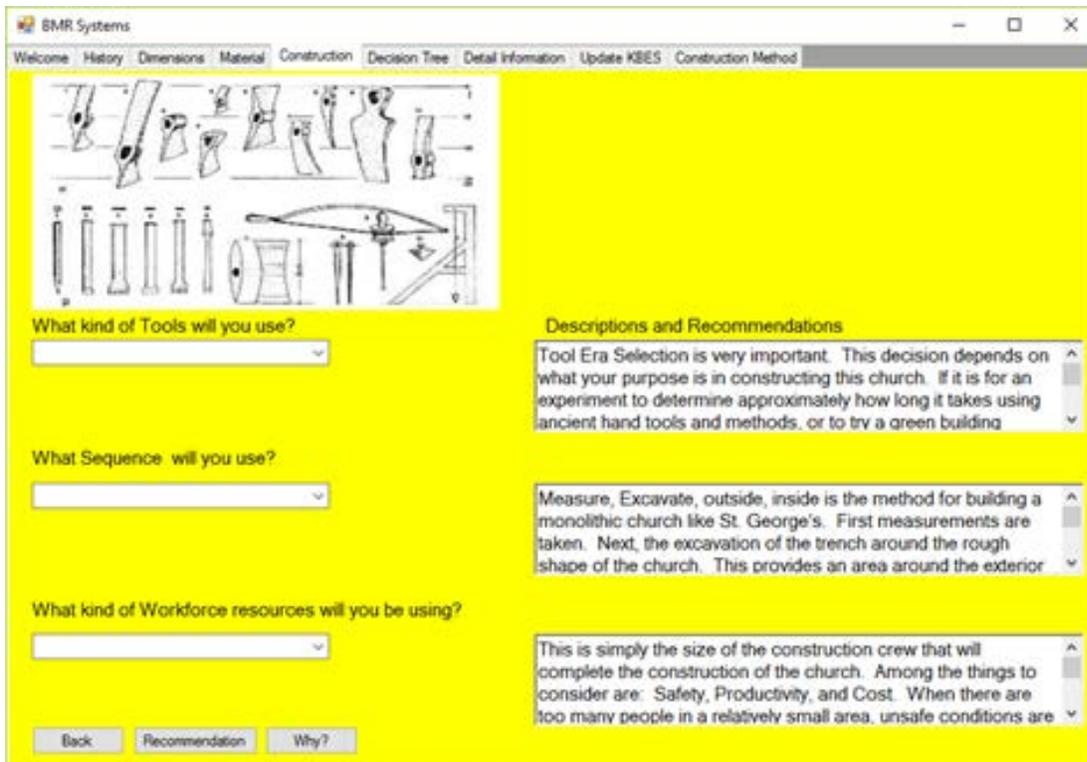


Figure 6: Multi-Media Graphical System Construction Selection Tab Screenshot.

The Construction Tab has an illustration of ancient hand tools in the upper left corner. Just below the illustration are three questions and “drop down” selection menus. To the right of those three questions and “drop down” menus are three corresponding Text Boxes that provide feedback to user in the form of descriptions and recommendations. The first question asks for the kind of tools used; the learner has the option of selecting “Ancient”, or “Modern” Tools, which may impact the efficiency and speed of construction during the decision-based analysis. The second question asks for the construction sequence, either MEOI and MSOI. Finally, the last question asks what kind of workforce resources will be employed, and the selection options for this question are for crew sizes of ≤ 100 , ≤ 1000 , and $\leq 40,000$. All of these questions and answers are variables that greatly affect the construction of the “Virtual” St. George’s Church. At the bottom of the screen there is the familiar “Back” button, a “Recommendation” button and a “Why?” button. The “Back” button functions just the same as the “Back” buttons on the previous screens. The “Recommendation” and “Why” buttons are departures from the schema of the previous screens. The “Recommendation” button, when clicked, provides descriptions and recommendations based on the selections made in the “drop down” selection menus. If selections have not been made prior to the clicking on the “Recommendations” button, a reminder appears informing the learner not only that they have yet to make a selection, but tells the learner which question needs a selection. The “Why” button does behave similarly to the “Next” button in previous screen, but further alerts the learner if selections have yet to be made. The “Why” button takes the learner to the next Tab, which is the Decision Tree Tab.

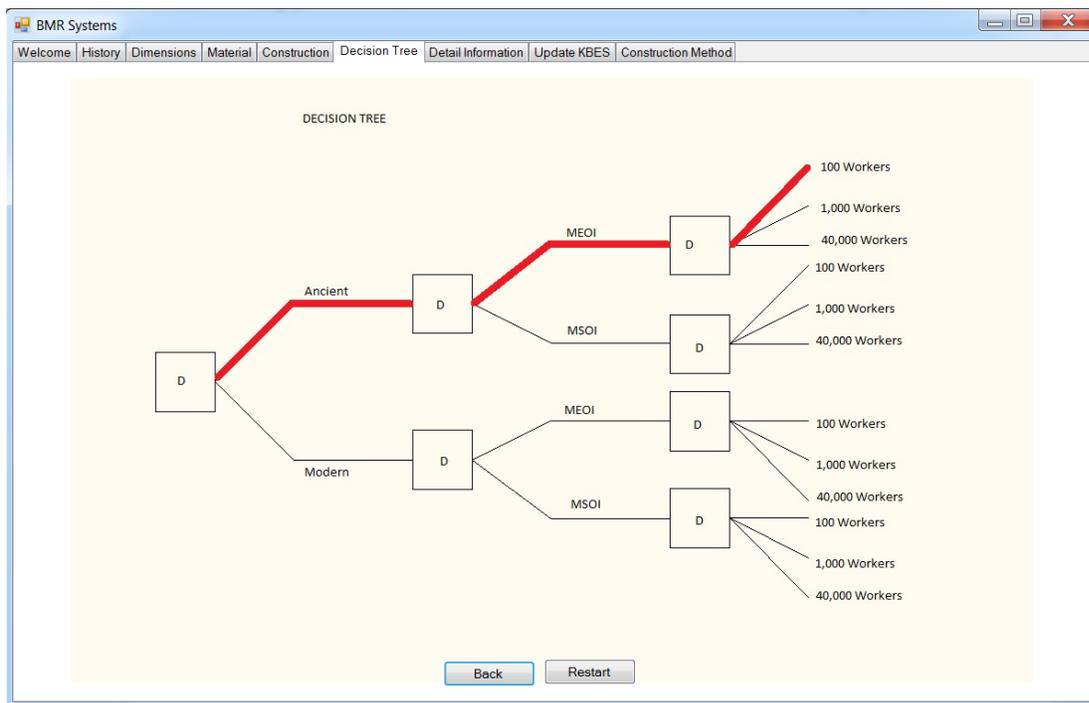


Figure 7: Multi-Media Graphical System Decision Tree Tab Screenshot. [1]

The Decision Tree Tab reinforces the learner’s understanding of the selections that they made and graphically shows the path selected and the other possible paths that could have been chosen through the options selected on the Construction Tab. The path shown graphically on this Tab

helps to show how those selections tie in to the recommendations made in the Text Boxes in the Construction Tab. The path shown in the graphic changes based on the decisions made in the previous Tab. At the bottom of the screen are the “Back” button and the “Restart” button. The “Back” button behaves as in the other Tabs, taking the learner back to the previous Tab. The “Restart” button clears out all of the previous selections and allows the learner to begin again and start the decision making process over again. This allows the learner to experiment with the different options available and explore the different outcomes based on their decisions. In this way the learner “Virtually” builds St. Georges Church using different Materials, Tools, Construction Methods, and Construction Crew Sizes. By experimenting and trying different option combinations learners get a feel for how each of the variables affect their “Virtual” build of St. George’s Church. This reinforces decision making skills and helps develop a sense of how to arrive at a satisfactory construction outcome, or at least an outcome that makes sense to the learner.

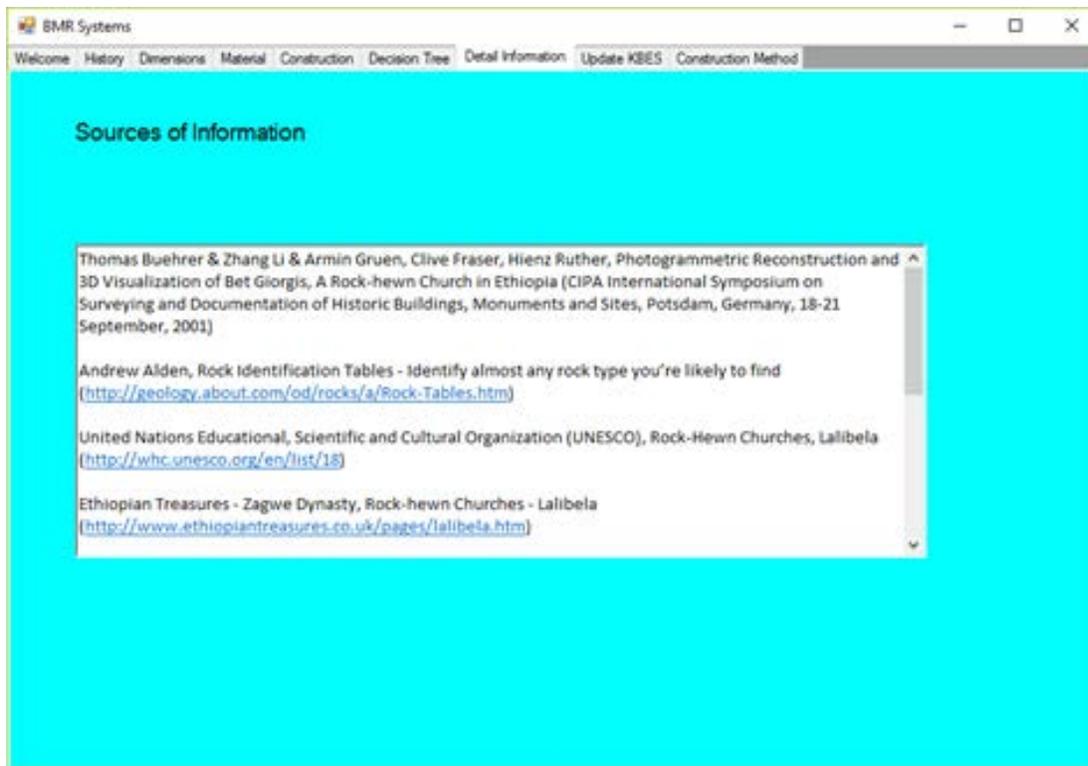


Figure 8: Multi-Media Graphical System Detail Information Tab Screenshot.

The Detail Information Tab contains information on sources for information, illustration, and photographs used in the creation of the Multimedia Graphical System. Since this Tab does not directly elucidate on the construction process of St. George’s Church, it can lead learners to other information that may be of particular interest regarding St. Georges Church and construction of structures in general.

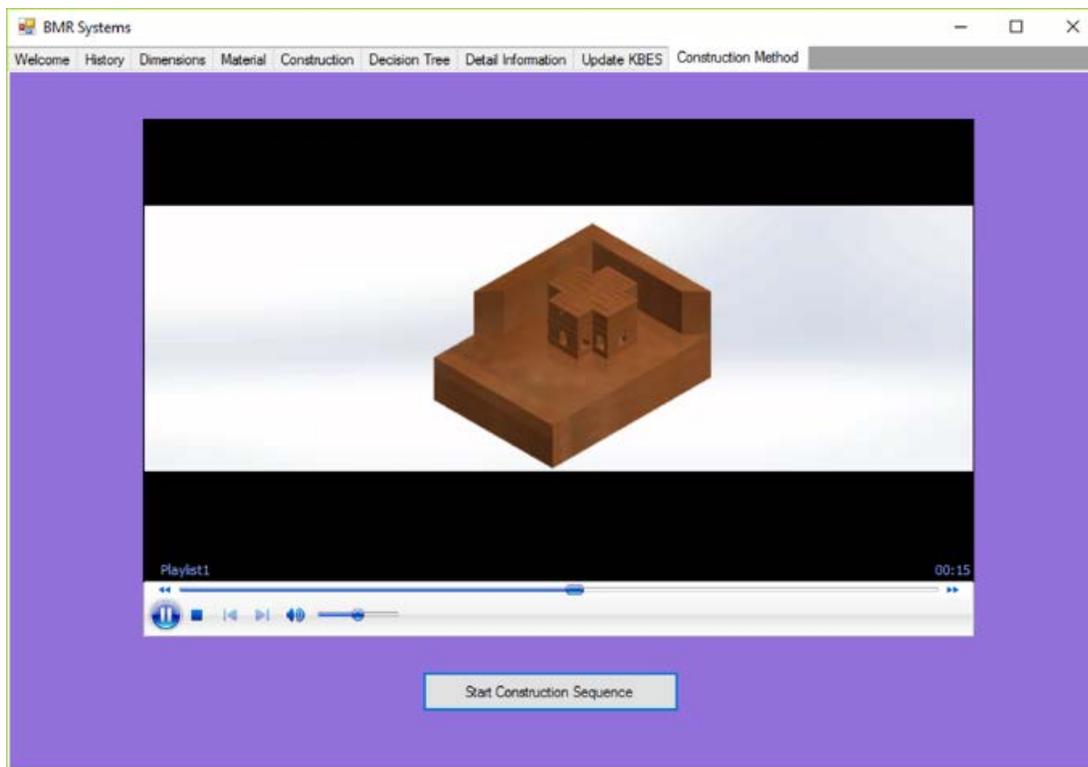


Figure 9: Multi-Media Graphical System Construction Method Tab Screenshot.

The Construction Method Tab is a recent addition; it has a Media Player Window in the center and a “Start Construction Sequence” button on the bottom center of the tab. The Media Player Window has its own controls for playing, stopping, and skipping forward or backward throughout the construction sequence. There is no “Back” button on this tab, as it is a stand-alone Tab like the Detail Information Tab. The Media Player Window contains a Dassault Systemes SOLIDWORKS-generated Simulation of the construction of St. George’s Church. This simulation provides a visual representation of the emergence of monolithic St. George’s Church from the “living rock”, or soft volcanic tufa as the excavation of the site may have taken place. The simulation of the construction method shown in this research is not purely MEOI, or MSOI, but rather a hybrid of the two, or MESSOI. It is highly unlikely that a completely pure form of either Construction Method was exclusively used in the construction of St. George’s Church. There most likely would have been times where using one or the other method would have been beneficial, but there were also likely times when both methods would have been employed simultaneously where convenient. By creating additional tabs, the program could also be capable of demonstrating either MEOI or MSOI singly, so that learners can also understand how each of these two methods works by itself.

Potential Impact

The Multi-Media Graphical System has significant amounts of potential as an educational tool, on the grounds that it presents a lot of information on the construction of St. George’s Church in

a manner that is easy to comprehend. This is a pivotal aspect of engineering education, particularly with digital models being used to demonstrate the techniques described. In addition, the flexibility and applicability of both decision trees and computer modeling can allow this type of program to be applied to a variety of topics, both in civil engineering and in other fields of study. Aside from the St. George's Church, other structures and construction techniques with multiple hypotheses on their progression can also be replicated with varying paths and base conditions, enabling students to gain a new understanding of these methods in a variety of hypothetical circumstances.

While no formal surveys have been implemented with this program as of this writing, the program itself has been shown to a seminar body of 15 civil engineering graduate students. The feedback from these students about the program has overall been positive and the overall consensus is that it is capable of demonstrating the subject matter in a clear fashion, making it useful in the classroom setting. Potential future work on this project may include formal surveys with both undergraduate, graduate students, and experts to gauge the effectiveness of the program, using multiple test cases and audiences to gain feedback on improving the program and its content.

Conclusion

The endeavor of the Multimedia Graphical System is to elucidate, or make clear the process by which the St. George's Church was created. The creation of the Multi-media Graphical System was executed to pique the interest of learners, of various ages and backgrounds, not only regarding the construction of St. George's Church, but also engineering and construction in general. The Multi-media Graphical System is appropriate for all classroom use because of the low supporting computer system requirements. The animation from SOLIDWORKS aids the students' visualization of the construction method used in the creation of the structure. The program, overall, contributes to and preserves the history of construction of the famous structure, Lalibela. The authors hope this research spurs renewed interest and fosters new ideas regarding the significance of the ancient engineering of construction.

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