

Integration of Geotagged Photos with BIM

Pavan Meadati, Ph.D., LEED AP, and Parminder Juneja, Ph.D.
Kennesaw State University
Marietta, Georgia

This paper discusses about the integration of Building Information Model (BIM) and Geotagged photos for project documentation. Construction photos are taken at various stages of project to document the project progress. These photos become worthless if they are not retrieved quickly when it is needed. The effectiveness of these photos in decision making can be enhanced by retrieving them through BIM. This can be accomplished through BIM + Geotagged photo environment. This environment facilitates geotagging of photos and automates their integration with BIM. This environment provides seamless flow of photos from smart devices to BIM. This facilitates easy access to the photos, reduces search and corroboration time and enhances retrieval efficiency. In this environment, the user captures the picture through smart device and the captured picture is displayed at appropriate location in BIM automatically and provides easy access to retrieve the picture. As the number of smart devices usage on construction project is on rise, BIM+Geotagged photo environment has the potential to make a paradigm shift in project documentation. The paper discusses about BIM + Geotagged photo environment architecture and illustrates the framework through residential construction project.

Key Words: BIM, Geotagged, 3D, documentation, construction photos

Introduction

Documentation of photos is an important step in the project documentation process. Photographs are taken at various stages of the project such as preconstruction, construction and post construction. Photos are useful to capture the project progress (Abbott, 2012). Photos are also useful to document the site conditions which includes defective work and problem areas. Documentation of photos is a two-step process. Frist step includes capturing the required information through pictures. The second step includes filing pictures appropriately for quick and easy retrieval. Some of these filing approaches include sorting and grouping them by day, week and month. The advent of digital cameras and smart devices has reduced the complexity of taking pictures process. Easy usage of digital cameras and smart device have increased the number of pictures used for documentation. This increase in number has introduced new challenges during sorting and grouping step such as increased time in searching and validating the information. Photos are also useful during the maintenance of the facility. For example, the location of the pipe behind the wall is shown in as-built drawings but the post construction photo is useful to document the existing conditions. Building Information Model (BIM) is addressing challenges faced by architecture, engineering and construction (AEC) industry. Some challenges include rework, coordination, visualization and conflict resolution. BIM is widely used during preconstruction for various applications such as 4D modeling (Trebbe et al. 2015; Park & Cai 2015;), 5D modeling (Aound et al. 2005), energy analysis (Kim & Anderson 2012; Stumpf et al. 2009), and safety analysis (Melzner et al. 2013; Zhang 2013). . Though BIM is capable of producing 3D as-built model, implementation of BIM further into facility's maintenance phase is not feasible without integration of construction and post construction project photos with it. For example, the 3D as-built can be used to indicates the pipe behind the wall. Due to time consuming process it would be not be cost effective to model all the details such as insulation, blockage and electrical fixtures in the 3D as-built model. Lack of more details in 3D as-built model can be supplemented by post construction photo. By using traditional approach, if photos are stored independently and not linked with 3D as-built model, with the passage of time, it becomes more challenging to relate the picture to the corresponding activity or building component. The post construction photo become worthless if it is not retrieved quickly when it is needed. This increases retrieval time and can cause negative effects on the project such schedule delay and cost increase. Further lack of linkage impedes the BIM implementation during facility's maintenance phase (Meadati & Irizarry, 2015). Therefore there is a need for framework which facilitates integration of BIM with construction and post construction photos. The goal of the study is to develop BIM + Geotagged photo environment that provides seamless means to integrate geotagged photos with BIM. This facilitates easy access to the photos, reduces search and corroboration time and enhances retrieval efficiency. In this environment, the user captures the picture through smart device and the captured picture is displayed at appropriate location in BIM automatically and provides easy access to retrieve the picture. It also helps to make effective decisions quickly. The goal of the study can be accomplished through two objectives: (1) Develop an architecture for BIM + Geotagged photo environment; (2) Deploy BIM + Geotagged environment on a construction project. This is a part of a research project, which is in progress. This paper focuses on objective 1. The paper presents an overview of BIM + Geotagged photo environment architecture and illustrates the framework by using residential construction project. The following sections discuss about BIM + Geotagged photo framework components and automated information flow among them.

BIM + Geotagged Photo Framework

Three components of BIM+ Geotagged Photo framework are shown in Figure 1. These includes three components: Geotag module, Server module and BIM module. An overview of these modules is given below.

Geotag Module

Geotag module facilitates to capture and geotag the photo. Geotagging is the process of adding geographical identification data such as latitude and longitude coordinates, altitude, bearing and time stamp to various media such as photograph, video and websites (Wikipedia, 2016 a). There are two options for geotagging photos. It includes: (1) capturing geographical identification information at the time the photo is taken or (2) attaching the photograph to a map after the picture is taken (Wikipedia, 2016 a). The components of this module includes a smart device which has camera and global position system (GPS) tracking system; and an open wireless network such as 4G network for communication between the smart device and the server.

Server Module

A server is a computer program or a device that provides functionality to the clients (Wikipedia, 2016 b). Based on the services provided, servers are classified as database servers, file servers, mail servers, print servers, web servers, game servers, and application servers. In this module, client-server model based database server is used. This database server provides database services to Geotag module and BIM module.

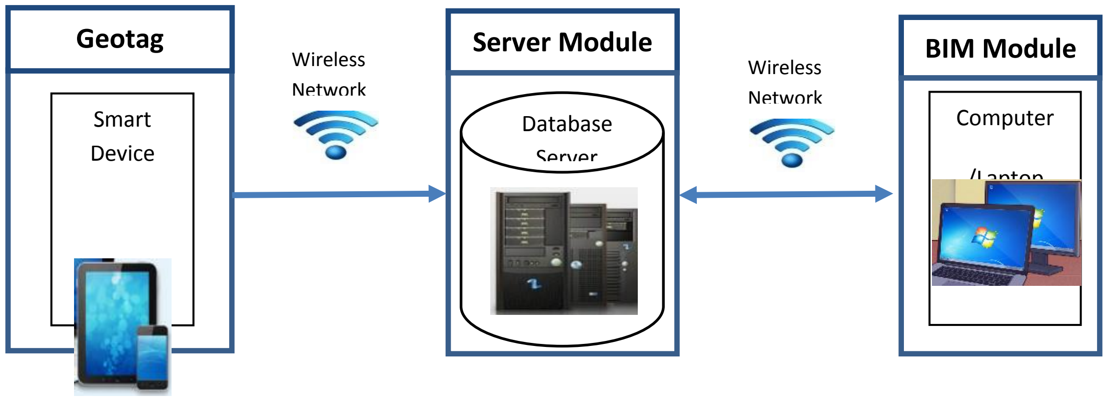

Figure 1: Components of BIM + Geotagged photo frame module

BIM Module

BIM module facilitates development of BIM for a facility and viewing of the photos. In BIM, real world elements of a facility such as walls, doors, windows and beams are represented as objects in a three dimensional (3D) digital model. In addition to modeling, it provides a framework that fosters the integration of information from conception to decommissioning of the facility. BIM serves as an excellent tool for data management. It facilities easy and fast access to the information stored in a database or in different databases through the 3D model. BIM's visualization feature makes it as an effective interactive tool to visualize the data. In this module, location of the geotagged photos is represented by using 3D objects. The user can be able to view picture by clicking the 3D object. The components of the module includes computer/laptop *Computer/Laptop:* Computer/Laptop which has capability to run BIM software; *Wireless network:* An open wireless network for communication between the Computer/Laptop and a server.

Information Exchange in BIM+Geotagged Photo Environment

The different components of an integrated BIM+Geotagged Environment include real world object, Geotag module, Server module and BIM module. An automated flow of information among different components of the BIM+Geotagged environment is shown in Figure 2. Smart device captures the picture of real world object and geotags the geographical identification data of the position of the camera. When capturing and geotagging is completed the user is prompted to save the picture. Once the save option is clicked, the picture and geographical information is stored in the database. BIM module has two components PopulateImage and ViewImage. PopulateImage retrieves geographical information of the picture from database and creates 3D object s at appropriate geographical locations in BIM. Once the 3D objects are created the identification number of the elements is sent to the database. In ViewImage component, when the user selects 3D object to view an image, identification number of the selected 3D object is sent as input to query the image. Based on the query result, image is displayed in BIM.

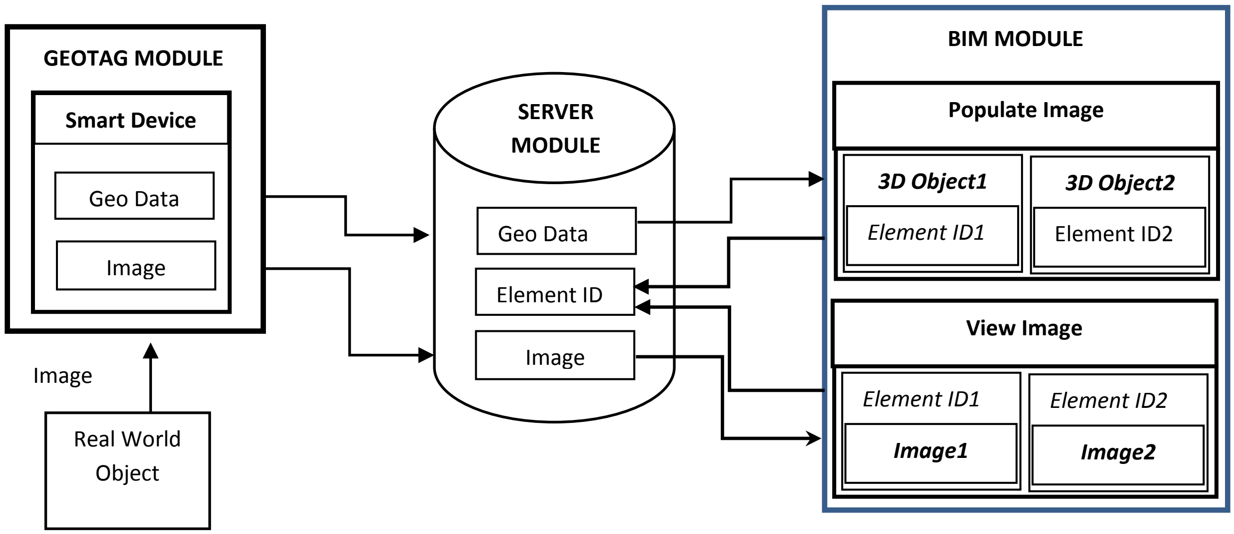

Figure 2: Automated information flow in BIM+Geotagged Photo environment

Framework Illustration

The above proposed integrated BIM and geotagged photo framework is illustrated by using a residential house project. Autodesk's BIM software Revit 2016 is used for developing 3D model of the residential house. In Revit software, real world objects are referred as Elements. Revit classifies the elements by categories, families, types and instances. A category is a group of elements that is used to model or document a building design. For example categories of the model elements include walls, columns, and beams. Families are classes of elements in a category. A family groups elements with a common set of parameters having similar graphical representation and identical use. For example families include round, square and circular columns. Revit has two kinds of families. They are system and loadable. System families are predefined and useful to create basic building elements. Walls, floors, and roofs are some examples of system families. Loadable families are used to create both building components and annotation elements. Some examples include doors, windows and casework. Loadable families are created in external files and are loaded into a project. A specific size of a family is referred as Type. A family can have several types. For example, a door may be available in several sizes. Instances are the actual items that are placed in project and have specific locations in the building (Irizarry et al. 2012).

Typical BIM components like walls, slabs, windows, and doors are useful to represent the finished component but cannot serve to depict actual construction progress (Goedert & Meadati, 2008). For example, the different layers in the exterior wall include 3-5/8" thick brick veneer, 1" thick air membrane, 3/4" thick OSB, 3 ½" thick stud frame, and 1/2" thick gypsum board. The exterior finished wall can be represented by duplicating and modifying the Exterior – Brick on Metal Stud type wall from the system library. When this wall type is used, all the different components of the wall are combined and behave as a single entity. This will not allow depiction of the actual construction sequence since it is done in stages. In addition, it would not facilitate independent selection of the different components. To depict the actual construction sequence and to facilitate the selection of individual components, each of these were represented as independent components.

A 3D model of the 2800 square feet, two story residential structure as shown in Figure 3 is used for illustration. Some of the different components of the 3D model include foundations, wood stud frame, wall sheathing, exterior brick veneer, drywall, open web wooden floor beams, floor sheathing, roof trusses, roof sheathing, asphalt shingles, plumbing pipes, HVAC ducts, doors and windows. The development process includes four steps: (1) Develop Geotagged module; (2) Set Up Server (3) Develop BIM module; and (4) Exchange of Information between Modules. Overview of the steps are presented below.

Figure 3: 3D model of two story residential structure

Develop Geotagged Module

In this step, a mobile application was developed by using Adobe Cardova software. "Apache Cordova is a library used to create native mobile applications using Web technologies. The application is created using HTML, CSS and JavaScript and compiled for each specific platform using the platform native tools. Cordova provides a standard set of JavaScript APIs to access device features on all supported platforms."(Cardova, 2016).The application was developed using Camera, Compass, and Geolocation objects. The camera object provides access to the device's default camera application. Compass Object obtains and provides the direction that the device is pointing. Geolocation provides location information for the device, such as latitude, longitude, and altitude. The interface developed by using these objects is shown in Figure-3.

Set Up Server

In this step, a database was created using Microsoft SQL database server. The different fields in the database include ElementID, X, Y, Z, Direction, and Picture. ElementID field stores the element unique identification number. Latitude, Longitude and Altitude fields store latitude, longitude and altitude obtained from Geotagged module. Direction field stores the compass direction that the device is pointing. Picture field stores the image of the real world object.

Develop BIM Module

This module is used to create 3D objects and view pictures in BIM. The development of this module includes two steps: Populate images and View image. In Populate images step, based on the latitude, longitude and altitude 3D objects corresponding to the location of the images in the database are created in BIM. In the View image step, the corresponding image linked to the 3D element is displayed. These two steps were accomplished by using the C# programming language thorough Revit APIs. The two steps were added as two features to Revit under "AddIns" tab.

Exchange of Information between modules

In this step, the communication between Geotag module, Server module and BIM module was established. The information flow between the Geotag module and Server module is shown in Figure 4. As shown in figure, the mobile application interface screen displays the current longitude, latitude, altitude and Direction and the user is prompted to activate the camera. Once the user captures the picture and clicks the Save button, data such as longitude, latitude, altitude, and picture are sent to the server and stored in the x, y, z, and Picture fields in the database respectively.

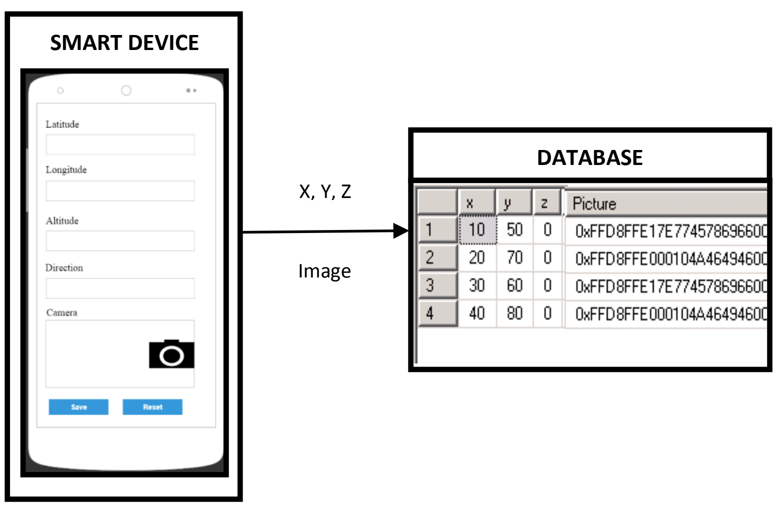

Figure 4: Automated information flow between Geotagged module and Server module

The information flow between the Geotag module and Server module is shown in Figure 5. When the Populate Images button is selected, the connection between the database server and Revit is established. Once the connection is established, the latitude, longitude, and altitude of the photos are obtained and using these parameters, 3D element at respective coordinates are created in Revit. After creating 3D elements, the Element ID associated with newly created elements are exported to the ElementID field of the database. When the View Images button is selected, the user is prompted to select the 3D object. Once object is selected, the ElementID of it is sent to Database and corresponding image is queried and sent back to BI M to display it. The screen shots of the different modules and their information flow is shown in Figure 6.

Figure 5: Automated information flow between BIM module and Server module

Conclusion

BIM has the potential to serve as a project documentation tool. However BIM cannot be effective until it is integrated with construction and post construction photos. BIM+Geotagged photo environment provides a seamless flow of information and automates the linkage of construction photos with BIM. This integration of BIM and photo documentation eases the data collection and documentation during construction and post construction stage of the project. This automation reduces the sorting and corroboration time, reduces manual errors and helps decision makers to make effective decisions. This integration also helps the facility manger to increase their efficiency and enhance their contributions towards value added tasks. Factors such as BIM software and their interoperability with the databases are to be considered during the development process. On large projects, addition of photos to the BIM will increase the file size. This addition, demands more computing capacity. To minimize the computing load, effective data filtering techniques needs to be implemented. As the number of smart devices usage on construction project is on rise, BIM+Geotagged photo environment has the potential to make a paradigm shift in project documentation. The methodology discussed in this paper serves as an initial step to develop an integrated BIM+ Geotagged environment for effective project documentation.

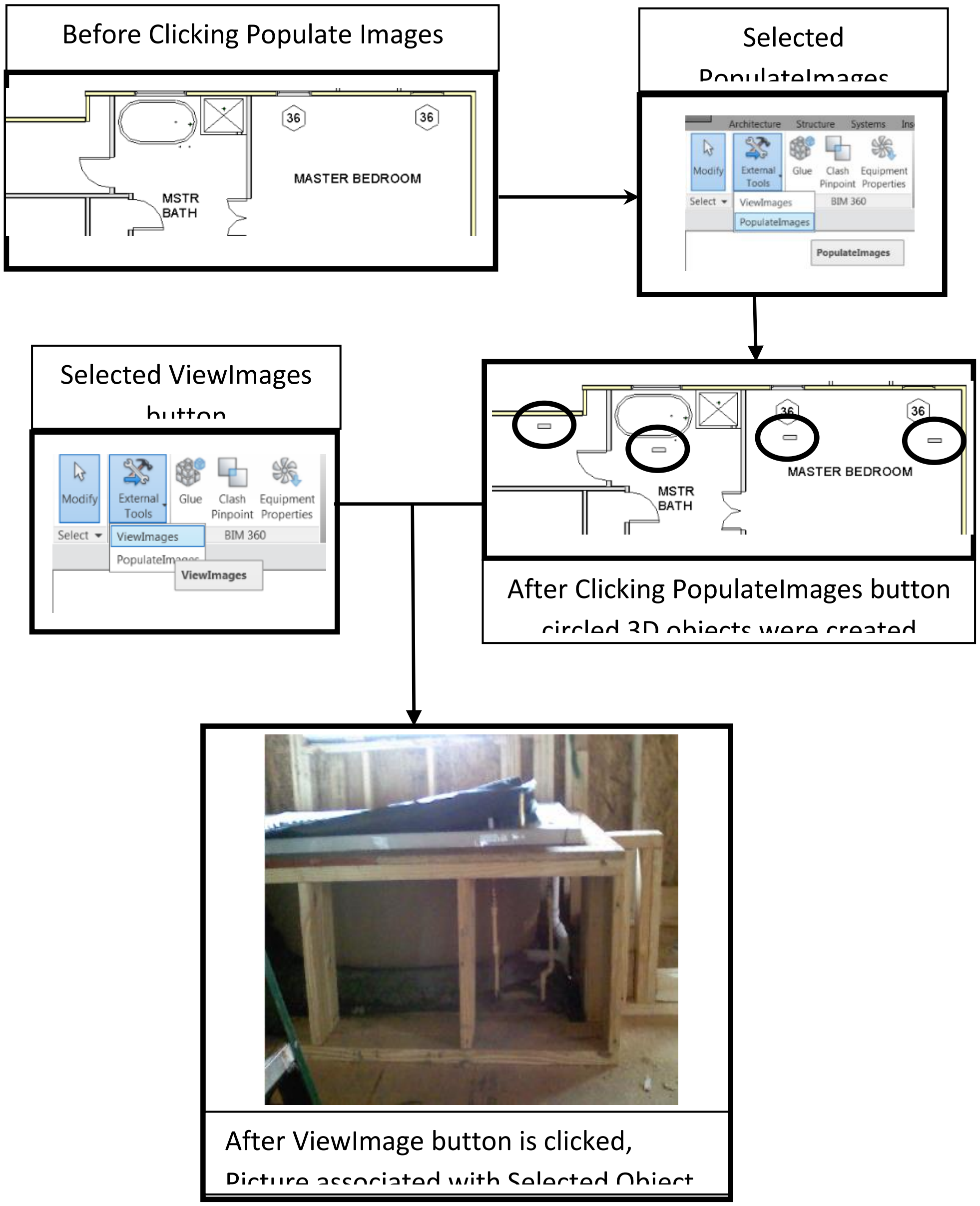

Figure 6: Screen shots of information flow in BIM+Geotagged Photo environment

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