AN AUTOMATED FORMWORK MODELING SYSTEM DEVELOPMENT FOR QUANTITY TAKE-OFF BASED ON BIM

Seong-Ah Kim[1], Sangyoon Chin[2], Su-Won Yoon[3], Tae-Hong Shin[4], Yea-Sang Kim[5], and Cheolho Choi[6]

[1] PhD Candidate, Sungkyunkwan University, Suwon, Korea
[2] Professor, Sungkyunkwan University, Suwon, Korea
[3] Team Manager, Doalltech, Seoul, Korea
[4] PhD Candidate, Sungkyunkwan University, Suwon, Korea
[5] Professor, Sungkyunkwan University, Suwon, Korea
[6] President & CEO, Doalltech, Seoul, Korea
Correspond to kody25@skku.edu

ABSTRACT: The attempt to use a 3D model each field such as design, structure, construction, facilities, and estimation in the construction project has recently increased more and more while BIM (Building Information Modeling) that manages the process of generating and managing building data has risen during life cycle of a construction project. While the 2D Drawing based work of each field is achieved in the already existing construction project, the BIM based construction project aims at accomplishing 3D model based work of each field efficiently. Accordingly, the solution that fits 3D model based work of each field and supports plans in order to efficiently accomplish the relevant work is demanded. The estimation, one of the fields of the construction project, has applied BIM to calculate quantity and cost of the building materials used to construction works after taking off building quantity information from the 3D model by a item for a Quantity Take-off grouping the materials relevant to a 3D object. A 3D based estimation program has been commonly used in abroad advanced countries using BIM. The program can only calculate quantity related to one 3D object. In other words, it doesn't support the take-off process considering quantity of a contiguous object. In case of temporary materials used in the frame construction, there are instances where quantity is different by the contiguous object. For example, the formwork of the temporary materials quantity is changed by dimensions of the contiguous object because formwork of temporary materials goes through the quantity take-off process that deduces quantity of the connected object when different objects are connected. A worker can compulsorily adjust quantity so as to recognize the different object connected to the contiguous object and deduces quantity, but it mainly causes the confusion of work because it must complexly consider quantity of other materials related to the object besides. Therefore, this study is to propose the solution that automates the formwork 3D modeling to efficiently accomplish the quantity take-off of formwork by preventing the confusion of the work which is caused by the quantity deduction process between the contiguous object and the connected object.

Keywords: Building Information Modeling (BIM), Formwork, Three-dimensional model, Quantity Take-off.

1. INTRODUCTION

With overall increase in the interest on BIM by the construction industry, works of each field that had been performed based on 2D drawing are being developed as 3D models for efficient performance. Many methods for efficient performance of works in each field of construction projects including design, structure, construction, estimation and facilities are being studied, and application programs based on 3D models reflecting such methods have already been commercialized and applied on actual domestic and international construction projects.

Among various fields of construction projects, the field of estimation originally computed quantities of materials necessary for constructions using 2D drawings by inputting the corresponding measurements and calculation processes. Breaking away from such existing method, BIM quantity computation is recently being attempted. This method refers to extraction of quantity information from 3D models according to the details on materials that correspond to 3D objects and computation of material quantity and expenses.

When 3D modeling a building during its design, representative materials permanently used to decide the shape of the building are modeled. For example in case of reinforced concrete column, materials used to complete the column include reinforcement, formwork, concrete and finishing material that surrounds the column. Instead of modeling each material separately, the column with the size that only includes reinforced concrete and finishing material is modeled. Since only the shape of space or

building is modeled during the design step, detailed modeling for actual construction is not performed. Accordingly in the estimation step in which quantity of materials are computed from the completed design drawing, materials (reinforcement, formwork, concrete and finishing materials) to be computed from simple 3D column model become complicated.

As explained earlier, computation based on BIM is a method of connecting the details of 3D model and extracting quantity information on such details from the given 3D model. However, in computation of quantities of various materials from a single 3D object, problems of complicated details occur. If modeling is done separately on each material to resolve such problems, details become simple but the time required for modeling of each material becomes longer.

Accordingly, the purpose of this study is to propose a method of separately modeling the formwork instead of computing the quantity of formwork from the building structure as a means to efficiently perform BIM quantity calculation and to propose an automated formwork modeling system that can shorten the modeling time..

2. METHOD OF COMPUTING THE QUANTITY OF FORMWORK BASED ON BIM

BIM based quantity calculation refers to extraction of quantity information such as area and volume in addition to measurements like length, width and height from a 3D object and computation of quantity from details of 3D model. In existing 2D based quantity calculation, the worker decided on the measurements of parts in which materials are to be installed by looking at a 2D drawing to input all necessary information (details and calculation processes) into an estimation program. 2D estimation program calculates the resultant values from information inputted by the worker and is composed of functions that add up the quantities computed on each part. Estimation programs based on BIM support connections with 3D object and addition of quantity information from 3D object. Therefore in BIM based quantity calculation, existence of a 3D model is presumed instead of 2D drawing. If there is no 3D model, quantity information cannot be extracted, resulting in a failure to compute the quantity.

The way in which 3D model is constructed influences the details of corresponding model. As an example for the reinforced concrete column with a cube shape, representative materials used for reinforced concrete columns are reinforcement, formwork and concrete. There are two methods of 3D modeling: modeling of an entire column and separate modeling of formwork as a temporary material. The reason for modeling the temporary material formwork separately is because quantity of formwork is computed differently according to the measurements of nearby materials, while quantity of reinforcement or concrete is computed based on measurements of corresponding element such as length, width and height. For example in case of formwork on the side of beam, quantity is computed by multiplying the measurement of beam height minus slab thickness by beam length. Accordingly in computation of formwork quantity, quantity information of adjacent materials instead of quantity information given by a single 3D object must be reflected.

On one hand, if a single reinforced concrete column is being modeled, materials that correspond to construction of reinforcement, concrete and formwork must be systemized and computed using one 3D object. When only modeling the formwork, computation can be done by linking the details of each 3D object. Therefore in BIM based quantity calculation, 3D models and linked details become different according to the customized methods of modeling for each material.

3. LIMITATION OF BIM BASED QUANTITY TAKE-OFF FOR CONSTRUCTION FORMWORK

Methods of computing formwork based on BIM include computation of quantity of a reinforced concrete column together with reinforcement and concrete and computation of quantity of a separate formwork model. To compute quantities of reinforcement, formwork and concrete from a single 3D object, system of modeling or details that can satisfy all materials must be completed. To compute quantity of a structure in general, object is classified by the type of each material. Layer is used in CAD as a method of classifying the objects, but it becomes difficult to control such layers if layers are divided according to each element and type.

Looking from the perspective of details, details of reinforcement are classified by type (SD24 and SD40 according to strength) and diameter (D10, D13, D16 and etc.) for computation of each layer. Computation for formwork is done according to the part of use and type as the number of use and material for the formwork. Since there are too many cases to be considered if both classification methods are applied, it becomes extremely inefficient in terms of management.

Also when modeling the formwork separately, work time required for modeling is over twice as much as modeling of a reinforced concrete column. In addition, formwork is a temporary material that is installed during construction and does not remain after completion. This material therefore is not a mandatory object in terms of modeling for the building. However in computation of formwork quantity instead of unique quantity taken by the 3D object, different quantities are reflected according to the measurements of adjacent materials. That is, subtraction of side corners of the surface of adjacent materials becomes necessary. Fig. 1 shows the changes in the formwork area of wall according to changes in adjacent materials on a plane. Since there is no adjacent material in Fig. 1a, area of formwork is L*H (height is assumed as H). Since Fig. 1b has an adjacent material on the left, area of formwork is (L-t1)*H. Lastly in Fig. 1c, area of formwork becomes (L-t1-t2)*H. It is also possible for the worker to look at the 3D model and examine adjacent materials, but such method can easily cause errors

because it relies heavily on the subjective decision by the worker.

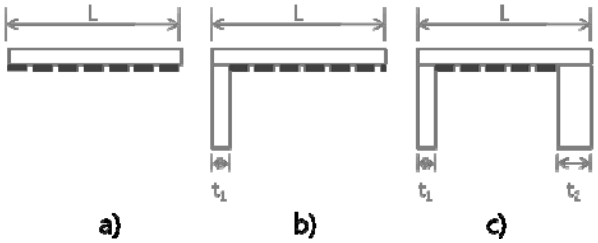

Fig. 1 Changes in formwork area according to adjacent materials

4. AUTOMATED BUILDING INFORMATION MODELING SYSTEM FOR FORMWORK

If quantity is to be computed through direct modeling of formwork instead of computation of formwork quantity together with reinforcement and concrete from the 3D model, additional modeling of formwork is necessary. Therefore, the modeling time required to compute the quantity is increased. If formwork quantity is to be computed with other materials such as reinforcement and concrete form 3D model instead of modeling the formwork separately, details on such materials become diverse and complicated. Accordingly in this study, computation of formwork quantity from modeling of the formwork was determined to be more efficient than the method of computing the quantity from the structure of building. An automated building information modeling system for formwork is proposed as a means to efficiently perform quantity computation by simplifying the modeling work on formwork.

Automated formwork modeling system refers to automatic creation of the object that corresponds to the formwork on 3D CAD by the worker through internal calculation by the system. That is, the process of structure model drawing by the worker is automated to select a model that corresponds to the structure as shown in Fig. 2. Once automated system is executed, modeling is complete.

The type of formwork used for buildings is applied differently according to position. If external shape of each floor of the building is identical, gang form is used for vertical formwork that corresponds to the exterior of the building in order to reduce the process of installing and dismantling the formwork. Here, interior of the building mostly makes use of plate or euro form. Interior of the building may apply different types according to elements such as euro form for slab and plate for beam or girder. The decision is made with consideration on air and cost according to the characteristics of construction projects upon preparation of construction plan. Therefore, this system has a concept of modeling the interior and exterior formworks separately. In case of interior formwork, type of formwork can be differentiated according to the position of each element and linked with other details.

Methods of BIM based formwork quantity computation include computation from structure model and computation from separate modeling of formwork. The result of comparatively analyzing the case of formwork modeling and case of computation from structure model are shown in Table 1.

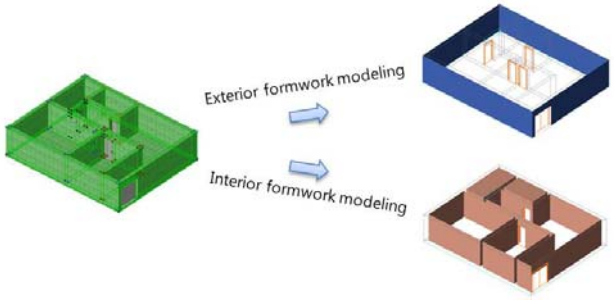

Fig. 2 The concept of automated building information modeling system for formwork

5. PROCESS OF THE AUTOMATED BUILDING INFORMATION MODELING SYSTEM FOR FORMWORK

The automated formwork modeling system for effective computation of quantity with simplified formwork 3D modeling applies different processes for the user and system as shown in 'Fig. 3'. The user first inputs basic information (ex: project name) for the corresponding project in general configurations and selects the type of formwork. When configuring the formwork type, it is possible to input different types for each position. Information inputted in this step is stored as initial configuration values required before modeling of formwork.

Table 1. Comparison on BIM Based Formwork Quantity Computation Methods

Classification	Computation from structure model without separate modeling of formwork	Computation after modeling the formwork using automated formwork modeling system
Advantages	- The process of formwork modeling is skipped. - Management of CAD file becomes easy.	- There is no need to check on the adjacent materials. - Since only the formwork quantity is computed, faster quantity review is possible.
Disadvantages	- Details of 3D model are complicated. - A process of checking on adjacent materials is necessary. - There is an increase in quantity error by the mistake of users.	- Formwork modeling work is added. - If modeling with finishing materials, confusion may be created in model management.

Once the user selects the structure model that corresponds to the modeling region and executes the automated modeling system, the system performs an efficacy check on whether correct space is formed by the selected materials. Then, spatial coordinates are calculated on adjacent materials to decide on the interior and exterior of the room. After calculation of coordinates, formwork is modeled with walls as vertical materials and slabs as horizontal materials according to the attributes given by the user on formwork model. In order to compute the quantity, details on the formwork type inputted by the user are linked to the estimation program.

Separate modeling of the interior and exterior of room can be processed by executing the automated modeling system and appointing the region for modeling before inputting the attributes of formwork model. However, such options were excluded in Fig. 3 to show overall process.

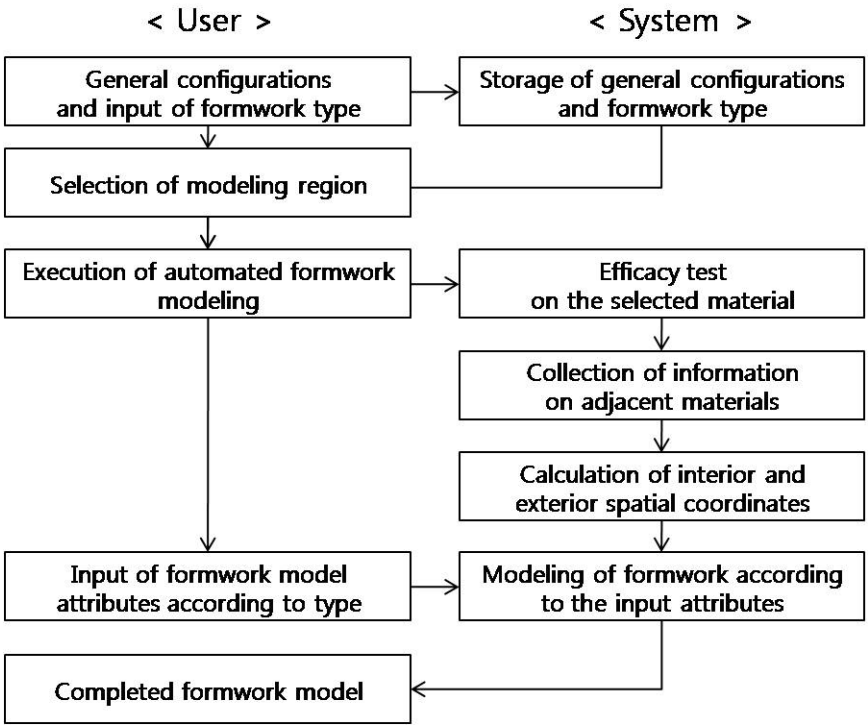

Fig. 3 A Process of the Automated Building Information Modeling System for formwork

6. CONCLUSION

In BIM based formwork quantity computation, effective method is to separately model the formwork instead of computing the quantity from the building structure. However, if the formwork is being separately modeled, work time increases and productivity of work is reduced. Therefore, this study proposed an automated modeling system to effectively perform quantity computation of the formwork by reducing the work time for modeling. As proposed by this study, development and verification of automated modeling system and demonstration of the effects of such system remain as future tasks. However in terms of BIM based quantity computation, results of this study can be used to propose different methods of access, thereby contributing to future development of BIM.

REFERENCES

[1] Rafael Sacks and Ronen Barak, “A Methodology for Assessment of the Impact of 3D Modeling of Buildings on Structural Engineering Productivity”, *Computing in Civil Engineering*, Vol. 41, pp.179~188, 2005.

[2] K. Nassar, W. Thabet, Y. Beliveau, “Building assembly detailing using constraint-based modelling”, *Automation in Construction*, Vol. 12(4), pp. 365~379, 2003.

[3] Chia-Hui Shih, Bill Anderson, “A design/constraint model to capture design intent”, *ACM Symposium on Solid and modeling and applications*, pp. 255-264,1997.

[4] Javier Monedero, “Parametric design: a review and some experiences”, *Automation in Construction*, Vol. 9(I 4), 369-377, 2000.