

4D System for Visualizing Schedule Progress of Horizontal Construction Project Including Earthwork

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Abstract

One of the main functions of the 4D system includes visualizing numerical schedule data of construction project. The existing 4D tools have an excellent function for simulating building projects that all activities are progressed according to vertical work zone. However, it is not easy to implement all of it in the civil engineering project because the construction activities of highway and railway projects are progressed on the horizontal work zone and the 4D simulation for those projects should include earthwork objects that depend on the natural ground condition. This study suggests a new methodology for improving those limitations of 4D system for the civil engineering project and develops a new system by the suggested methodology. The morphing technique developed in the study can be a new approach to simulate 4D object for the earthwork such as cutting and banking whose activities are progressed on the natural ground condition. The research results can be expected as draft functions for improving the application of 4D system in civil engineering projects.

Keywords

4D CAD, Earthwork, Horizontal Work Area, Work Breakdown Structure (WBS), Morphing

1. INTRODUCTION

Various researches relating to 4D CAD systems are being conducted recently. Even though there are some differences in the aspects of functions, most 4D systems now under development are for building and plant projects that 3D objects consist of vertical and artificial elements. However, as visualized expression of schedule data for civil engineering projects that are composed by horizontal and natural topographical conditions such as earthwork and pavement of highway are also necessary parts definitely, a methodology that can increase the utilization of 4D in the field of civil engineering is being required. This study suggests a 4D system that the completion status of projects per period can be simulated on real-time in 3 dimensions through the connection of construction schedule with 3D drawings information. In particular, this study attempts to build 4D system with multimedia functions for civil engineering projects that fall short of development cases through the survey researches of similar system. For this end, the 4D system includes special functions such as 4D information management system centering on WBS (Work Breakdown Structure) and 4D realization tool of natural topography including earthworks.

The current 4D systems are focusing on the simple expression of 3D completion status of progress schedules. Because of this, provision of information of traditional results like schedule progress control provided by the existing schedule management softwares become weak and applicability on construction sites is worried to be decreased. That is, for the improvement of applicability for practices of 4D system, it is required additional functions that can express diverse schedule data to practitioners of sites that the existing 2D management system of construction schedule cannot provide.

And the examples of development of the existing systems are contents centering on schedule connection function of the projects composed of artificial parts such as buildings construction. This research has differentiation in an aspect of the purpose to build 4D system for civil engineering projects with natural topographical conditions.

2. CHARACTERISTICS OF 4D OBJECT OF CIVIL ENGINEERING PROJECT

Building projects can have convenience of CAD works as they are relatively easy for the 3D object composition as the works are progressing vertically and repetitively and shape of each object is composed of artificial shape

standardized like column and slab. Also, at the time of realization of 4D object linked with schedule, consecutive visual realization of the completion status is easy since activity and 3D object are linked in the shape of vertical schedule progress. On the contrary, as civil engineering projects are progressing with horizontal works composed of non-repetitive parts, the differentiation of 4D realization technique is required. In addition, at the time of 4D realization of earthworks, technique of 4D object realization of natural topography by the composition of triangulate network and technique for objectification of shape of topographical changes according to works shape of filling and cutting are needed. These techniques cannot be realized by the functions of existing system and need unique 4D realization technique that civil engineering projects have. For these reasons, there is no example of 4D system realized for the existing civil engineering projects and in this research, this study develops a realizing system of practical stages based on the suggested techniques.

In civil engineering projects, main activities such as earthwork, pavement, and tunneling are progressing horizontally in wide work area and at the same time, pier structures of bridge are progressing vertically. When compared to construction projects with mainly vertical works, these points need 4D realization techniques that are possible in both horizontal and vertical realization for increasing the degree of visualization of the completion at the time of consecutive realization of 4D objects.

That is, for horizontal projects such as highway and railway, after the whole project is being spread in linear type, if it is possible for the relevant section to have 4D realization by selecting temporary section horizontally, then it can have applicability as an appropriate 4D tool in the actual works situation of civil engineering projects.

244	90	29	27	1160	5	22	93	75	5	1705	27	90	935	
0	0	0	0		1	1	1	1	1		3	3	3	4
+	+	+	+		+	+	+	+	+		+	+	+	+
0	2	3	3	3	5	5	5	6	7	7	4	4	5	5
0	4	3	6	9	5	5	7	7	4	5	5	8	8	1
0	4	4	3	0	0	5	7	0	5	0	5	2	0	5
■ Construction Method by Block														
Filling	Ret	Cut	Open Cut	NATM (Crossing 1 Tunnel)	Open Cut	Filling	Cutting	Open Cut	NATM (Crossing 2 Tunnel)	Cutting	Filling			
■ Block No														
1	2	0-1	1-14	0-2	3	4	5	0-2	1-20	0-3	6	7		

Fig. 1 Concept of Block Classification for Composing Horizontal Work Space

In actual construction site of highway or railway project, the works are progressing in division of construction sections horizontally if construction manager (CMr) analyzes the progress procedures of construction in linear direction. That is, earthwork, pavement section as well as tunnel section are all divided into construction section in the unit of 100M or 200M. And construction sequence of each section is composed of several repetitions of filling/cutting in several layers in earthwork, and excavation of tunnel and lining are also progressing in a concept of construction section. In this research, the concept of con-

struction block is introduced as in Fig. 1 to express these types of horizontal divisions of construction sections.

Fig. 1 is example of division of construction section in blocks using data of construction site of highway project now undergoing including bridge and tunnel, and each block is distinguished per station number of route survey. That is, this research is trying techniques of managing the relevant 4D objects collectively by dividing into blocks selectively per station number of route survey for 4D realization of these horizontal facilities. In these methods, as 4D object of each activity and 4D object of the whole block are used as grouping of information to compose one block, it becomes to realize 4D object by selecting temporary range horizontally per station number at the time of linking schedule and 3D object.

Different from 4D realization of the existing building projects, automatic realization technology of triangulate network is definitely required for expressing the natural topography at the time of 4D realization of linear civil engineering projects. That is, as 3D objects required for the 4D realization of building projects are all composed of artificial elements that have no relationship with natural topographical conditions, compositions of 3D objects can be expressed with only information of general attributes such as length, thickness, area, and shape. On the contrary, most of construction items of civil engineering projects are comprised of lots of earthworks and the completed status of these earthworks also must be visualized according to determined schedule per each work. And at this time, it becomes problems that 3D objectification for the allocation of work quantity of filling and cutting per each schedule is not easy.

3. NEW METHODOLOGY FOR REALIZING 4D OBJECT OF EARTHWORK

If earthwork section of civil engineering project is expressed by the method of sequential generation of the unit of 3D object which is the existing realization method of 4D system, 4D user has to generate in 3D object of volume that is the difference between triangulate network belonging to natural topography and triangulate network belonging to planned profile. At this time, however, if the difference of volume between natural topography and planned profile can be generated in a single 3D object, user can only confirm visually the two stages of the original ground foundation and the final finished profile. It becomes impossible to identify detail progressing process of earthwork which occupies significant portion of the total construction period of civil engineering project. In order to express these detail progressing process of earthwork, it needs more efficient method to generate 3D object by the difference of topographical profiles. That is, the 3D object caused by the difference of earthwork profiles needs to divide with several 3D objects that have similar volume change with the change of shape according to the work progress.

This study introduced and applied morphing technique for the generation of 3D object of these earthwork sec-

tions. Morphing means the realization of changing shape between initial objects and final objects to be changed using geometrical principle, and morphing method applied in the study is like Fig. 2.

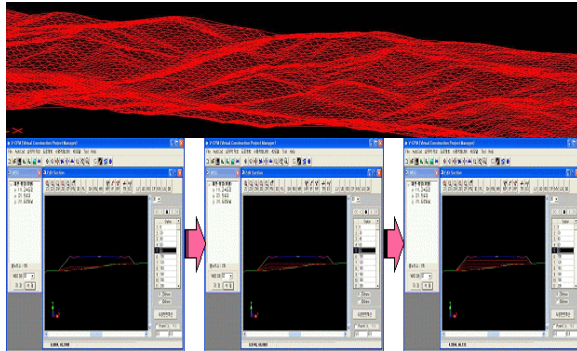


Fig. 2 4D Model Application of Morphing Technique for Earthwork Section

As the left side of Fig. 2, in general morphing concept for the realization of earthwork, as the distance between both end points in vertical direction is divided by n sections to reach the final point, and therefore, there is difference in the shapes of actual work progressing. That is, actual progressing of earthwork is processing in stages in the shape of horizontal layer that forms vertical angle with gravity direction like the right side of Fig. 2. This study has realized works progressing process in such shape. Specifically for filling and cutting profile, the distance between the highest point and the lowest point among topographical triangulate network and planned triangulate network is divided by the number n for distinguishing the stages. If the height difference is divided by this pattern, the work section of earthwork can be represented in parallel to the level of each stage at all starting points. The right side of Fig. 2 shows these concepts in map.

4. REALIZATION FUNCTION OF 4D SYSTEM FOR CIVIL ENGINEERING PROJECT

Based on the previously mentioned schedule information composition and 3D object composition method, this study develops the system that actually realizes 4D object. Name of the developed tool is called V-CPM (Virtual Construction Project Manager). V-CPM is composed based on JAVA and visual basic language. Essential function in 4D tools is the role of 4D Simulator that links 3D object with 4D object, and basic function composition map of 4D system suggested in this research is like Fig. 3.

Fig. 3 is integrated function composition screen of V-CPM and they are consisted of largely 4D object realization in upper part, WBS classification code in right side, and schedule realization information in lower part. In the existing 4D systems, it is the general method to generate 4D object using link tools existing in 4D system after making schedule and 3D information using separate outside schedule and CAD tools for schedule and 3D object

generation. On the contrary, in V-CPM, engine that can generate schedule and 3D object within 4D system itself without outside related tools is composed and therefore, now 4D object can be generated with only V-CPM without schedule and CAD tools.

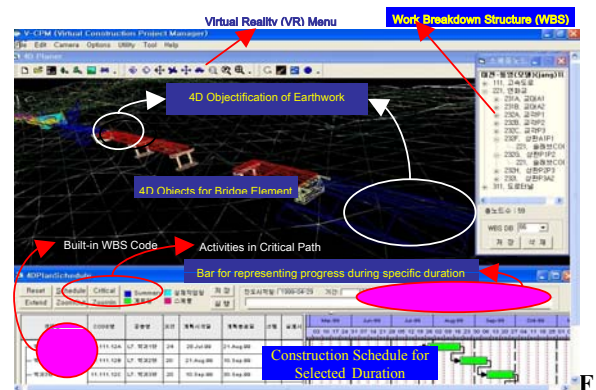


Fig. 3 Composition of Basic Functions of 4D Planner

V-CPM is being applied as common information for the link of schedule and 3D drawings information by installing standard WBS code system within 4D system. Therefore, function that can realize 4D object only for some construction items selected partially in the standard WBS code system is included.

Like this, in this research, technique that can realize 4D object selectively of structures user wants per work level or element item is composed by applying WBS-centered link system in information system for 4D realization, and additional link process of complex schedule object and 3D object is omitted.

That is, it is a method that composition of all functions of 4D system is arranged basing on WBS-centered by composing standard project WBS inside of 4D system in advance as internal files. For the composition of schedule information for schedule management, V-CPM generates schedule information directly based on WBS code and name of the works that are provided in advance. At the time of composing drawings information, the drawings object is also being saved centering on WBS code provided in the system. As schedule and drawings objects are saved centering on the same WBS code in this method, it is the system that is automatically linked without additional link works for realizing 4D object.

The right upper side of Fig. 4 shows the process of composing 4D object for construction items of composition of bridge section after dragging code of bridge section (Yeonhwa bridge) from standard WBS code that is built-in within the system. Also, in the right lower part shows the function for users to simulate manually the completion status by dragging 4D object of the selected WBS code per specified period with a mouse. This partial 4D realization by code selection per the level of WBS is very useful function to be utilized under the situation of the necessity of partial 4D realization for intensive management in case the whole project scale is enormous.

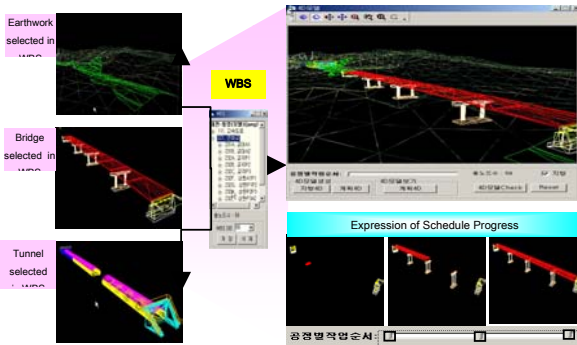


Fig. 4 Realization Function of 4D Objects per Level of WBS Code

5. VERIFICATION OF INTERFERENCE SCHEDULE BY 4D SYSTEM

Visualizing of interference between activities can be used beneficially in building project and plant project where many activities are being carried out in limited work space. In particular, in plant project where various piping activities and apparatus and supplies installation activities are being carried out in narrow space, the establishment of priority among activities becomes the essential management element of construction schedule management.

This research presents the method of deciding activity sequence according to the depth of piping network by 3D coordinates as a methodology for verifying interference status of these piping activities. This method makes it possible to determine the establishment of priority of activities as it is possible to identify the depth of piping by confirming the passing parts of piping with profile at the time of realization of piping network activities in 4D. Fig. 5 shows the possibility of identifying the depth of each piping network by composing spaces in profile that various piping networks installed buried underground pass through.

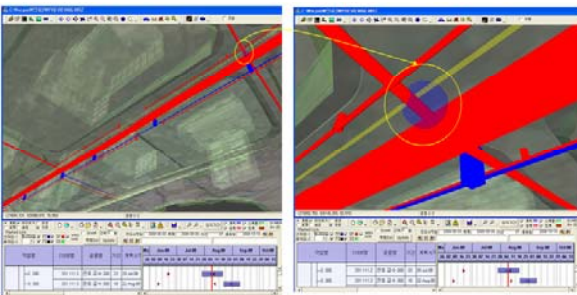


Fig. 5 Verification Function of Interference Status of Piping Activity

This profile verification function makes it possible to confirm profiles of all projects undergoing. In case of installation of various apparatus and supplies and piping networks like in a plant project, it can be the function for the whole construction site management by visualizing the spatial layout of each facility or element with vertical and horizontal profile. And at the stage of drawings design, it can be used as decision-making tool of spatial

depth for each element and protecting tool to reduce space conflict for each activity.

6. CONCLUSIONS

4D system suggested in this study is a technique to have 4D realization of civil engineering projects as an application object. Considering that there is no representation of 4D object realization technique in earthwork where activities are progressing under the existing natural topographical conditions and 4D tool application of civil engineering project is relatively weak, this research can have the utilization as basic technique in the establishment of 4D system for civil engineering projects.

In the aspect of practical business of construction schedule management, since function of 4D system focuses on the realization of the completion status of 3D object in comparison to schedule, inconvenience of link process with schedule and 3D object is presented as problems. This research has introduced technique of using WBS as central concept of information for requirement and occurrence information of 4D system for simplification of these objects link processes. Since this standard classification system is built-in as WBS DB and it can be used as central information in all functions of 4D system, V-CPM could provide construction manager with the convenience of the link process between schedule and 3D object information.

7. ACKNOWLEDGEMENTS

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