CONFIGURATION METHOD OF HEALTH & SAFETY RULE FOR IMPROVING PRODUCTIVITY IN CONSTRUCTION SPACE BY MULTI-DIMENSION CAD SYSTEM

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ABSTRACT: Safety of workers and productivity in construction site are affected according to the conflict status of work spaces which are performed at a time. The interference among the work spaces in construction site should be minimized because it becomes a blocking factor that causes construction delay and low productivity. Those factors can be managed by reasonable H&S (Health & Safety) practice. This research suggests the requirements of H&S practice and rules to establish the strategy of H&S management based on the literature reviews related to H&S rule. The suggested H&S rule can be visualized for searching space conflict point if the rule is linked with visual simulation tool. Accordingly the research results can be used for improving and visualizing construction productivity by work space control in 4D/nD CAD system.

Keywords: 4D/nD Planning, Work Space, H&S (Health and Safety) Rule, Space Collision, H&S Management Process

1. INTRODUCTION

Conflict between resources and work spaces often occurs because a construction work requires multiple activities being progressed at the same time in a limited work space. This space conflict inevitably delays progress, increases cost, and reduces productivity of the project and safety of the work. Especially in case of earthwork projects which consist of non-repeated horizontal works, due to their non-standard work patterns, space plans are depending on the work conflict of the site. Also, there is a restriction in establishing an efficient preliminary work space plan due to transfer place for materials and equipment.

Riley et al. (1995) [5], Thabet et al. (1994) [8] and Mallasi (2006) [9] have defined the types of space mainly on work space of building work, and classified the space depending on the characteristics of the work. They have defined the performance pattern of work space in building activities. Akinci et al. (2002) [1], Dawood et al. (2006) [6], Guo (2002) [7] and Mallasi (2006) [9] have partially adopted virtual reality (VR) technology in order to verify the space conflict in construction works. Most current researches use numerical verification method for checking space conflict and it is difficult for project manager to find a conflict point by numerical approach.

In this paper, work space of earthwork is classified, and the health & safety (H&S) rule is deduced to check and verify interference between work spaces. This paper also proposes the H&S rule interworking methodology to draw interference of work space through 4D CAD, and the visualization-based space conflict model. Accordingly, the purpose of this study is to propose a reasonable work space planning model based on H&S rule to minimize the space conflict and to maximize productivity in earthwork.

2. DEFINITION OF WORK SPACE AND CONFLICT MODEL

This chapter defines work spaces and lists the causes of conflict which are the basic factors of space conflict inference for configuration of the H&S rules.

2.1 Definition of Work Space and Type of Conflict

Solution for a conflict between work spaces is depending on the type of space and collision status. Therefore, it is required to classify the type of the conflicted space and the characteristics of the conflict in advance. In earthwork, work space is defined as an available space required for a specific activity. Therefore, the type of work space and conflict are classified as shown in Figure 1 according to the type of earthwork and the characteristics of the site.

Work space is classified into dynamic space which is continuously available for the work period of a specific process, and fixed space of which location is not changed for a given period once it is allocated. Dynamic space is subdivided into installation space and transfer space, and fixed space into safety space, fabrication space and loading space. Work space is also classified into base

space and conflicted space depending on the type of conflict. The conflict decision rule is applied differently when a base space is conflicted by interference spaces. And the level of conflict between spaces directly affect the performance of work and the productivity. [2]
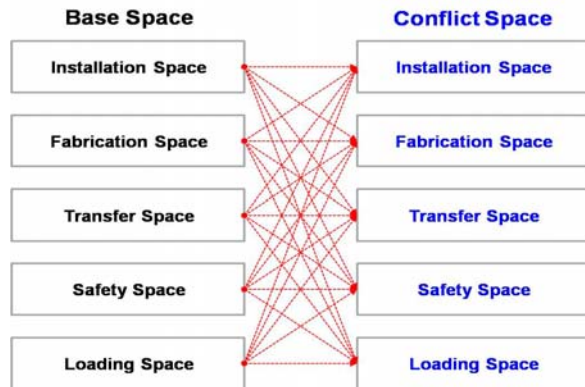

Figure. 1 Definition of Work Space and Type of Conflict

2.2 Conflict Factors in a Work Space and the Requirements

Conflict between work spaces in a earthwork site varies depending on the work performance pattern in a work space of a block or station section. The cause of a conflict is depending on the type and usage of the work space. Conflict in an installation space may be caused by input of multiple resources in a narrow space or lack of installation space. [3][4] Installation space causes a conflict with the safety space having the safety facilities, affecting the safety of workers. Conflict in a transfer space is caused due to transfer of equipment and materials in a restricted work space. Conflict in a fabrication space occurs when another work space moves to the fabrication space. Conflict occurs in a safety space as an accidental injury or death caused by collision with or fall of

equipment or materials. Conflict in a loading space occurs as damaged materials caused due to fall or collision when moving equipment or materials. The factors of conflict in work spaces are the work spaces themselves and the materials, equipment or men in the work spaces, and the type and level of conflict are depending on the method applied to the process. The factors of conflict are depending on the resources and methods defined in the schedule table. Therefore it is required to consider the space conflict between the processes with conflicted schedule, or plan the work spaces for the processes to be performed in adjacent locations. The H&S rule is drawn to classify space and to verify conflict according to usage of space.

3. H&S RULE-BASED SPACE CONFLICT INFERENCE MODEL

This section defines the rule base for conflict in a work space in order to infer the conflict status of the work space and to deduce the objective solution depending on the physical conflict, and proposes an inference model for decision of the conflict status.

3.1 Overview of Health & Safety Rule

The rule-based system is a part of the expert system that generates the business rule with experience and expertise in the form of "IF (condition) and "THEN (result)". It processes the rule relations automatically through the inference engine with the rule sets and deduces the results required by users. [10] The H&S rule implemented in this study is a inference method of work space by knowledge-based model. This system defines a series of rules based on the rule-based system theory and infers the optimum solution for the conflict between work spaces that deteriorates productivity and safety, and then verifies the rules through interworking with a 4D CAD system.
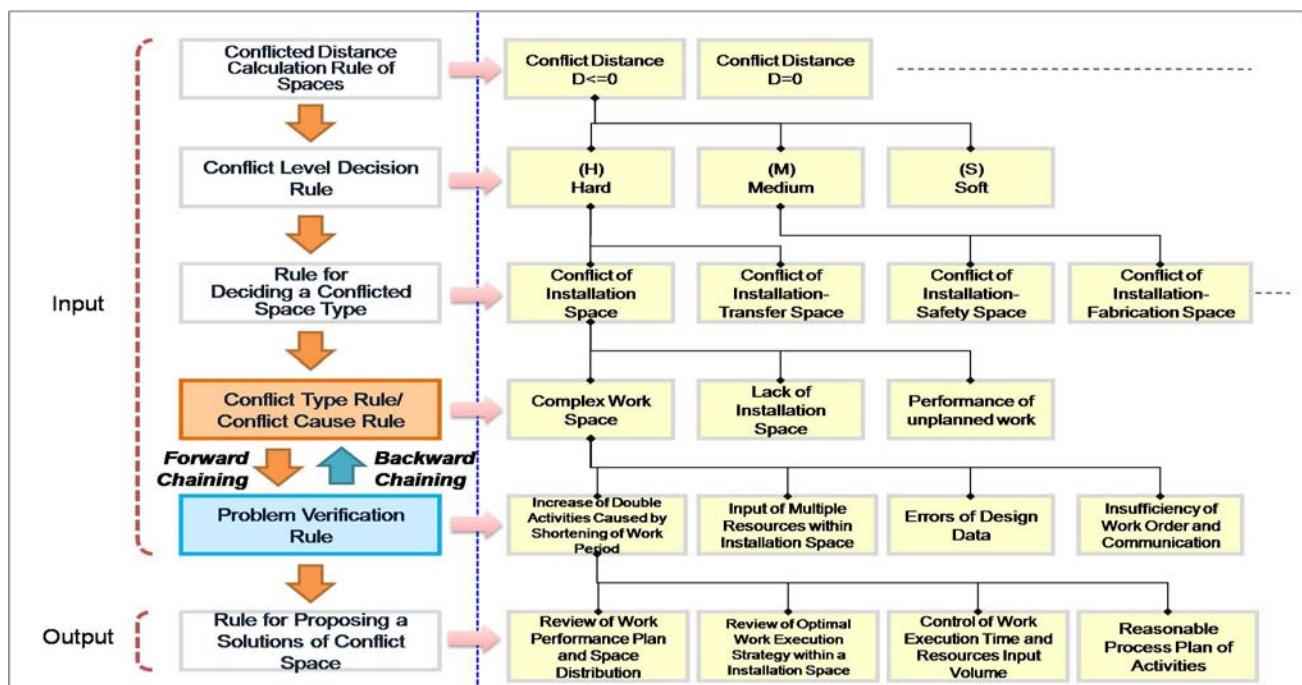

Figure. 2 Procedure and Example for H&S Rule Based Inference of Space Conflict

3.2 Method of Configuring H&S Rule to Infer the Space Conflict

Verification of a work space requires not only a visual inspection of the conflict status caused by a physical collision but also the H&S rule-based inference to check the characteristics and status of the conflict. In order to infer the conflict status of the work space, it is required to configure the H&S rule base by defining individual rules according to the conflict verification procedures and by establishing relationship between the defined rules. The rule base is stored in the knowledge base in order to deduce the optimum result through the inference procedures. The H&S rule supports the procedural forward inference through pattern matching of rules. Creation of the H&S rule requires 5 rule types and 4 condition-result variables. The H&S rule type is defined with the conflict detection rule, the conflict determination rule, the conflict cause determination rule, the conflict problem indication rule, and the conflict solution inference rule. The H&S rule base is comprised of the calculation rule that checks the conflict of work space and the condition rule that infers solution against conflict.

3.3 Method of Configuring H&S Rule to Infer the Space Conflict

The Figure 2 illustrates an overview of procedures for H&S rule based inference of space conflict.

First, determine the size of a work space, and then, create the 3D space model. Second, create the 3D model of the space, and then, check the conflict seizure

according to the schedule and the work space transfer pattern. Third, check the type of conflict depending on the physical conflict status. Fourth, infer the space conflict through the H&S rule based pattern matching process of H&S rule base. Fifth, determine the type of conflicted space and infer the cause of the conflict type. Sixth, the problem and solution on the space conflict is provided according to the procedure depending on the relationship between the rules. If the cause of a space conflict is known but the problem is not known, a forward inference is applied. On the other hand, if the problem of a space conflict is known in advance, but if it is difficult to determine the cause, a backward inference may be adopted to deduce the cause. The hybrid chaining method uses forward and backward inference according to the conflict status in the work space.

4.   IMPLEMENTATION   OF   4D   CAD INTERWORKING MODEL BY H&S RULE BASE

This chapter proposes a 4D CAD interworking model by H&S rule base that infers conflict visually in a work space.

4.1 H&S Rule Based 4D CAD Interworking Model

For inference of conflict in a work space, it is desirable to propose a 4D CAD based inference model that supports automatic physical calculation of the conflict status and supports procedural inference according to the
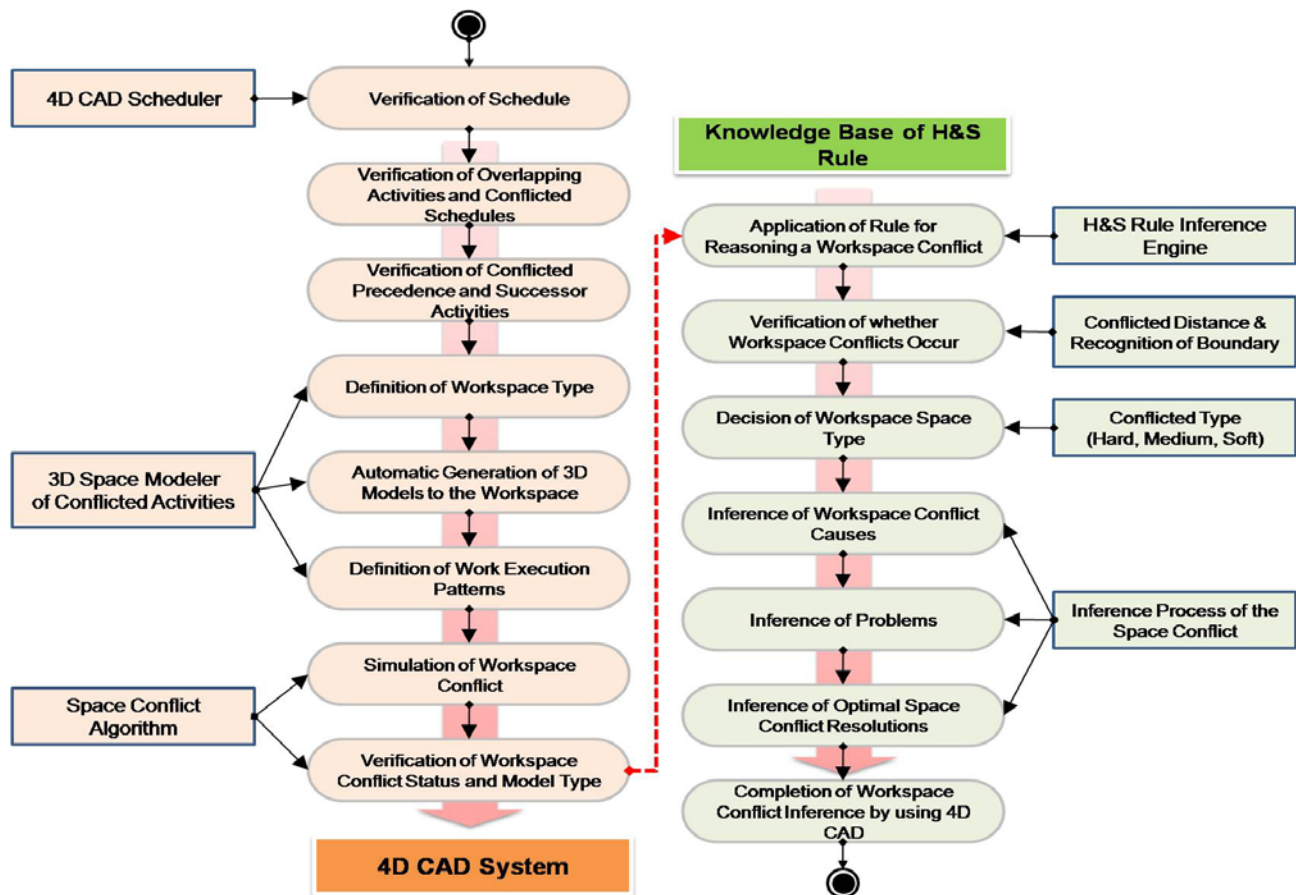

Figure. 3 Inference of Work Space via Interworking between 4D CAD and H&S Rule

result of the calculation, rather than to use a numeral inference method with input of conditions.

When creating a 3D model of the work space, it is required to determine the type of space to be used, and then, to allocate the work space planned on the design drawing and the work plan. Figure 3 shows the procedures of H&S rule based inference of space conflict in interworking with 4D CAD system.

In order to find out how the work space conflict occurs, it is required to check the 4D modeled schedule. The activities mutually conflicted on the schedule can be checked via review of overlapped activities for specific period. For the conflicted activities, the work spaces are defined through 3D modeling, and are allocated by the coordinates in the pre-planned work area. Change of work space is visibly displayed by the patterns in the 4D CAD system during the work period. Therefore, the part of the work space conflicted according to the predefined space type can be simulated in the system. And the procedural condition search of H&S rule by the conflict inference engine configured in advance in the knowledge base provides the optimized verification result of space conflict status.

4.2 Integrated Architecture Model of H&S Rule Base with 4D CAD System

Figure 4 shows the architecture of the space conflict inference procedure by using 4D CAD system.

The architecture of this system is divided into the 4D CAD system that creates objects of work space data by extracting conflict and performs the conflict simulation, and the H&S rule based system that solves conflict of the collided space objects through the inference rules. The space objects configured through 4D CAD determine the type of work space. The space type and conflict status are interworked with the rule base, triggering H&S rule inference. The H&S rule needs to support the user interface for easy modification and management under the 4D CAD environment. The inference result data deduced by the H&S rule engine is a fact of the work space conflict rule, and shall be defined as the rule base. It is stored in the knowledge base, supporting an efficient inference without application of a new rule when the space conflict environment is changed.

5. CONCLUSION

Conflicts occur frequently in construction work space depending on the work pattern at the construction site and the characteristics of the resources. In order to provide an efficient solution against the conflicts, this study proposes the space conflict inference model and the interworking system between H&S rule base and 4D CAD tool. This study defined the work spaces and the type of conflict in order to create the work space conflict inference model. The study also proposes the inference procedure of solution against conflict and the H&S rule model. The H&S rules are stored in the knowledge base, and provide the efficient space inference model visually through interworking with 4D CAD system. This method is expected to have further automated algorithm in the H&S rule base system to establish an efficient work space allocation and assignment plan. It is also expected that the system will become a tool to visualize the conflict status frequently occur in the construction sites and to infer the object conflict status.
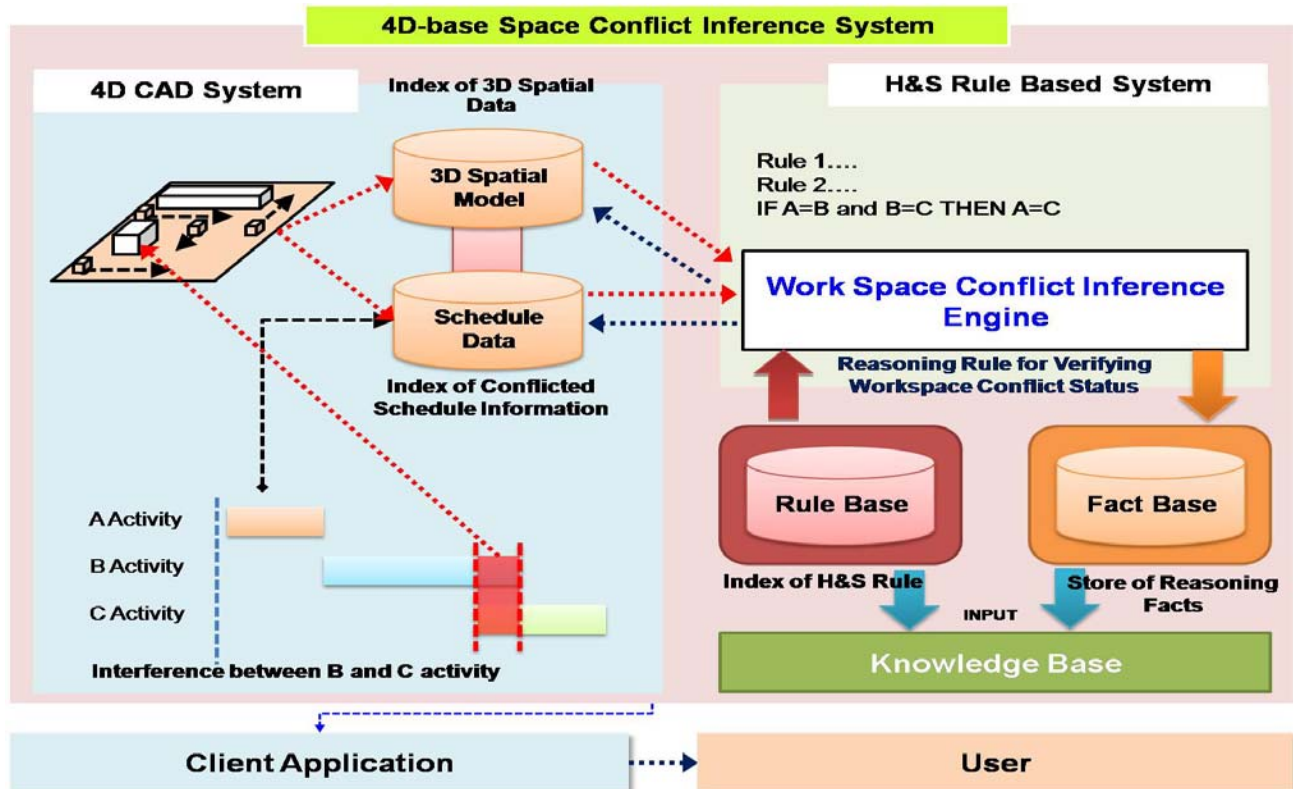

Figure. 4 Architecture of Space Conflict Inference System with 4D Object

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