AUTOMATED REPRESENTATION OF CONSTRUCTION INTERFACES

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Abstract: The interface problems are usually not resolved or even detected until the construction activities proceed to their execution stage. Some interface problems may be resolved by just rearranging the locations of work elements, some may degrade the designed function of elements, and others may not be resolvable. To overcome the difficulty of discovering and communicating the interface problems, this paper proposes a Construction Interface Automated Representation (CIAR) system. The CIAR system defines the interface elements, links, interactions, and notions of interface problems, and graphically integrates them into the construction schedule network. Also, the computation strategies of implementing the CIAR system are provided.

Keywords：interface elements, interface links, interactions, construction schedules

1. INTERFACE PROBLEMS

Due to the lack of clear understanding of owner's needs as well as the vague drawings and specifications provided by project designers, the physical interface problems are usually not resolved or even detected until the construction activities proceed to their execution stage. A physical interface problem can be viewed as the constructibility problem that is caused by the interactions (such as embedment, attachment, penetration and space interference) between two or more construction work elements. For examples, without conducting an in-depth review of the locations and space requirements for some work elements (such as the pipes, girders, lightning, equipment fixtures and finishes) in a composite way, the contractor may need to stop a concreting activity due to an insufficient height between the ceiling and floor.

Some interface problems may be easily solved by re-arranging the locations of construction work elements. Some of them may degrade the originally designed functions of affected construction elements (e.g., lower-than-planned net ceiling height). More often, many problems may not be curable (e.g., the space of a runway tunnel is insufficient for accommodating an elevator's size), and an extra rework may be required.

2. INDUSTRY PRACTICE

In the Taipei Mass Rapid Transit system, the so-called Combined-Service Drawing (CSD), Structural, Electrical, and Mechanical (SEM), and Coordinating Installation Program (CIP) methods are introduced to help resolve the interface problems. A two-dimension graphic tool is now used to deal with the problems potentially occurring in the Taiwan High-Speed Rail project. By conducting a series of industry interviews, it is firstly found that the interface problems are usually detected until some of the related work elements are almost ready to be constructed or even finished. Secondly, those people who are capable of discussing the problems are normally the experienced seniors. Thirdly, during the problem-solving meetings, different disciplinarians cannot communicate the problems well. These findings may indicate a strong need to have a systematic tool that can help represent the interface problems in a proactive way, to convey the problem to junior engineers, and to set an easy form for negotiating the solutions.

3. LITERATURE REVIEW

Current research tasks related to the interface problems can be categorized into two areas: spatial-related and constructibility-related. The spatial-related tasks intended to either classify the types and constraints of space required for executing construction activities, or optimally sequence the activities according to their resource movements under the constraint of limited space. Riley [5] defined two types of space, area and path, to support space management for building projects. The MovePlan, a dynamic layout planning tool, considered the spatial interactions between resources according to proximity, overlap, or access constraints [6].

On the other hand, the constructibility-related tasks aimed to provide an informative checklist-like manual that was developed based on heuristic rules or experience for easing the execution of construction work. Hanlon [3] defined five categories of constructibility information for reinforced-concrete structures: design rules, lessons learned, external constraints, resource constraints and performance information. Kuo and Wu [4] developed a construction interface checklist manual for step-by-step solving the encountered interface problems. Echevery [2] formalized the knowledge utilized by skilled schedulers for sequencing construction activities. Four basic factors dominating the schedule sequence were identified in his work, including the physical relationships between different building components, the interaction of construction trades, the requirement of an interfered-free path for the objects displaced around the job site, and the code regulation.

In summary, recent research successfully identified the characteristics of space requirement for site planning, and developed thorough checklist data for providing solutions to interface problems. A tool that can systematically represent interface problems is still missing. Without such a tool, the basic characteristics (e.g., types, causes, interactions, or even effects, etc) of complex interface problems are not well understood, communicated, and negotiated between involved multi-disciplinarians for finding the solutions. The objective of this paper, thus, is to propose a Construction Interface Automated Representation (CIAR) system.

4. THE CIAR SYSTEM

In the CIAR system, a construction interface problem is precisely defined as the constructibility problem that may occur when more than two construction work elements (also called interface elements) run across with each other at an interface point. An interface point may be a point, a one-dimension line, a two-dimension plan or a three-dimension space. An interface problem may exist within a construction activity itself or between multiple activities. The problem may force the construction work elements to be re-sequenced, changed in their specifications (such as size, shape, height, or longitude, etc.), or even fell into an irrecoverable situation.

As shown in Figure 1, the development of the CIAR system discussed in this paper is only the first research task for eventually generating an interface-based scheduling model. Other on-going research tasks include the evaluation of the effect of interface problems, rearrangement or re-sequence of work elements, and generation of possible approaches to solve the problems. The development process of the CIAR system is described in the followings.

As presented in Figure 2, the system is presented by an input-control-output mechanism that is facilitated by an $IDEF_0$ (International Definition Model 0 Language) information flow model [1]. The inputs are required to identify the interface points. For example, the CSD/SEM drawings provide source for retrieving information of the attributes (such as location, dimension, etc) of interface elements. The material information provides data of the quantities of interface elements. And the construction schedule activities carrying with interface elements allow to identify which and when the elements will encounter with each other. The outputs of the CIAR system are the identified interface points and their possible interactions.

As shown on the top of Figure 2, several components control the information required for executing the CIAR system. These components include the definitions of: (1) types of interface elements; (2) types of interaction that may occur when different interface elements run across with each other; (3) types of interface links for logically deriving the corresponding interaction.

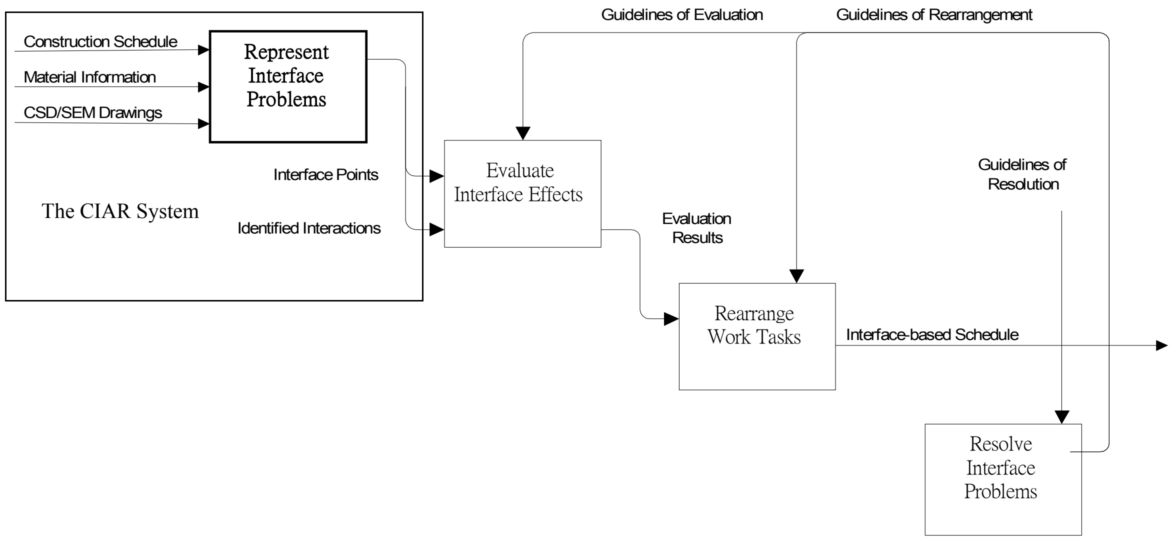

Figure 1. Role of the CIAR System for Solving Interface Problems

4.1 Types of Interface Elements

The execution of a construction project can be viewed as to putting the physical construction work elements together in varying sequential, parallel, penetrating, attaching, or enclosing ways. Each element has a potential to proactively interfere with or to be reactively interfered by other elements. In the CIAR system, a proactive work element is called as an aggressor; and a reactive work element is viewed as a container.

The aggressor is the interface element that has a physical shape of Article (or Point) or Tube (or Line). Typical examples include the electrical flush-mounted panelboards, pullboxes and lightning fixtures for Articles and the tollery ducts and busways for Tubes.

On the other hands, the container has a physical appearance of Plan, Cubic, and Enclosure Space. Typical examples include the wall and slab for a Plan, the column and girder for a Cubic, and the equipment vertical ducts, runway tunnels of the elevator and ceiling void for a Enclosure Space. The types, graphical representation symbols, and typical examples of interface elements are summarized in Table 1.

Thus, for example, if a set of some electrical tubes is designed to be concreted in a column, then this set of electrical tubes (Line) is an aggressor, and the column (Cubic) is a container. No matter what resolution approach (e.g., installing the tubes before concreting the column) may be adopted, a potential interface problem exists at this interface point (a three-dimension space for this example).

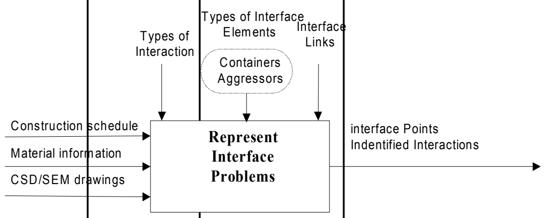

Figure 2. The CIAR System

4.2 Types and Subtypes of Interactions

When an aggressor runs across with a container, an interaction may occur. The types of interaction depend on the types of aggressor and container involved. In the CIAR system, three broad categories of interaction are defined: embedded, attached, and space-interfering interactions. An embedded interaction occurs when an aggressor is totally embedded in, partially embedded in, or penetrating through a container. For example, the interaction for a set of electrical tubes (aggressor) concreted in a column (container) can be treated as totally-embedded. And the sleeve of water pipes (aggressors) buried in walls has a penetrating interaction.

Terminologically speaking, an attached interaction is the interaction that an aggressor is attached to the surface of a container. For example, a set of pullboxes (aggressor) attached to the finish of interior wall has an attached interaction. Similarly, a space-interfering interaction occurs when aggressors interfere with an enclosure-space element. For example, the equipment pipes laying inside certain ducts cause a space-interfering interaction. This space-interfering interaction can be further divided into three subtypes: crossing, layered, and parallel interactions. Table 2 summaries the types, subtypes, graphical symbols, and the typical examples of interactions between interface elements.

Table 1. Types of Interface Elements

Types of Elements	Elements	Representation Symbols	Typical Examples
Aggressor	Article	●	electrical flush-mounted panelboards, pullboxes, lightning fixtures
	Tube	▬	tollery ducts, sewer pipe and busways

Container	Plan		wall, slab
	Cubic		column, girder

	Enclosure Space		equipment vertical ducts, runway tunnels of the elevator, ceiling void

Table 2. Types and Subtypes of Interaction

Types of Interaction	Symbol	Definitions	Subtypes of Interaction	Symbol	Typical Examples
Embedded		Aggressors are totally or partially buried in, or penetrating through a container	Totally-embedded		Electrical tubes are totally concreted inside a column
			Partially-embedded		Electrical flush-mounted panelboards are partially buried inside a wall
			Penetrating		Sleeves of water pipes are penetrating through a wall
Attached		Aggressors are attached to the surface of containers	Attached		Pullboxes are attached to the finishes of an interior wall
Space interfering		Aggressors interfere with space-enclosure elements	Crossing		Equipment pipes are crossing in certain duct space
			Layered		Equipment pipes are layered in a floor
			Parallel		Equipment pipes are placed parallel in certain space

4.3 Using Interface Links to Identify Interaction

After individually defining the interface elements and interactions, this sub-section proposes the concept of using interface links to integrate them. An interface link is the logical relationship that can derive the type or subtype of interaction according to the involved interface elements. And an interface link connects a preceding activity with an aggressor (or aggressors) and a successive activity with a container. In other words, the interface link is the schedule network link that has a mapping function to identify the interaction between a preceding aggressor and a successive container.

Take Figure 3 as an illustration example. Figure 3-(1) shows an embedded link at the broad or primary level (i.e., higher integrated or summary level of construction activities). The preceding activity is the construction of conduits (with a Tube aggressor) and the successive activity is the concreting of slabs (with a Plan container). In addition to the traditional scheduling data (Early Start, Early Finish, Late Start, Late Finish, and Duration), the symbols (i.e., the upper right corner of the block) of interface elements are also included for each activity. This embedded link graphically represents a potential interface problem that may occur between the two consecutive activities carrying with interface elements.

As shown in Figures 3.(1)-1.1 to 3.(1)-1.3, the management may desire to investigate the interface problem to a greater detailed or secondary level. Thus, by further breaking down the preceding activity, three sub-activities are found: the construction of E.M.T. & PVC conduits, pipe sleeves, and box cases. And each sub-activity has a Tube, Article, and Article aggressor, respectively. Thus, in this secondary level of schedule, three more detailed interface links are generated according to the three derived subtypes of interaction (Tube → Plan for totally-embeded, Article → Plan for partially-embeded, and Article → Plan for penetrating). This graphical representation of interface interactions provides management the foundation for discovering, communicating, and further resolving the potential interface problems.

Figures 3.(2) to 3.(3) also represent the examples of other types and subtypes of interface links similar to Figures 3.(1). An in-progress related research task is that these interface links will carry an attribute of

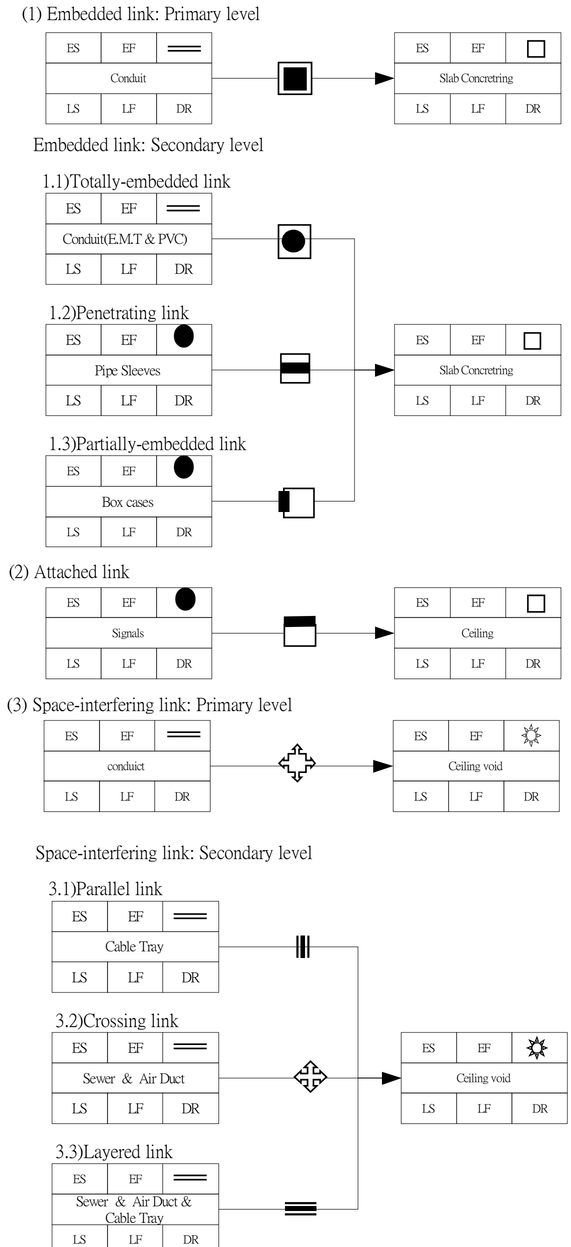

Figure 3. Classification of Interface links

interaction effect. In this same example, each of the totally-embedded, penetrating, and partially-embedded links will carry a duration sub-effect, and these duration sub-effects can be aggregated into a duration effect at the primary level of schedule. Thus, this approach will eventually allow to consider the potential interface effect in the schedule.

5. COMPUTERIZATION STRATEGIES

Figure 4 illustrates a multi-classification structure of the database for computerizing the CIAR system. The database consists of three modules: interface report module, access module, and linkage module. The interface report module provides the source data of interface information, such as the quantity, height and location, for each interface element; and these data are obtained from reviewing the CSD/SEM drawings and material information. According to an users' selection, the access module will provide the outputs of those interface data of interest. For example, as shown in the lower part of Figure 4, an user may demand for the access files of listing all containers, aggressors, interactions, and effects. The linkage module performs the process of selecting and posting the data from the interface report to the access file.

As mentioned previously, the CIAR system will be combined into an interface-based scheduling model. The strategies for developing such an integrated scheduling database is provided in Figure 5. The upper part of the same figure shows that the symbols of potential interface problems are graphically combined into the network schedule. The lower part of the figure shows that how the interface data are integrated into a project data file. Note that the interface data (interface elements, interactions, and effects) are hierarchically stored in the data files of network activities.

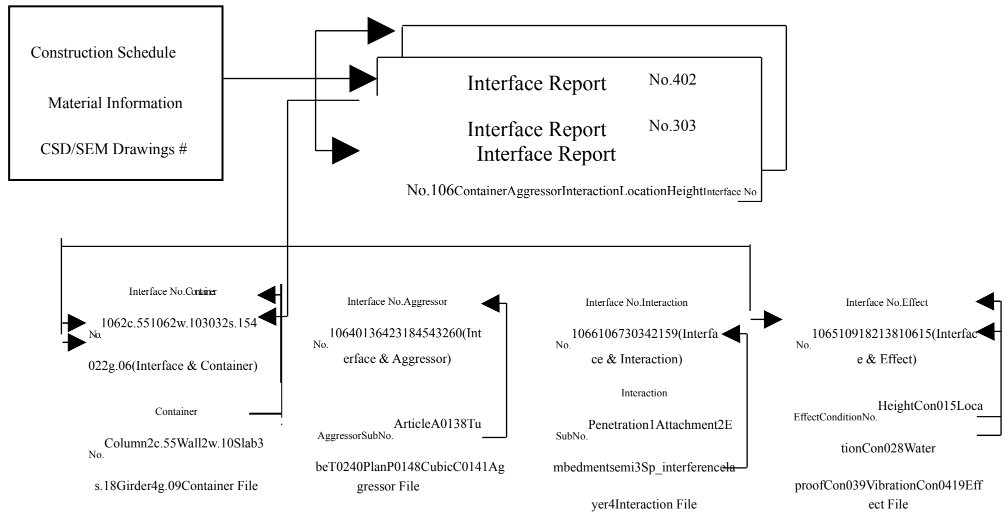

Figure 4. Structure of Interface Database System

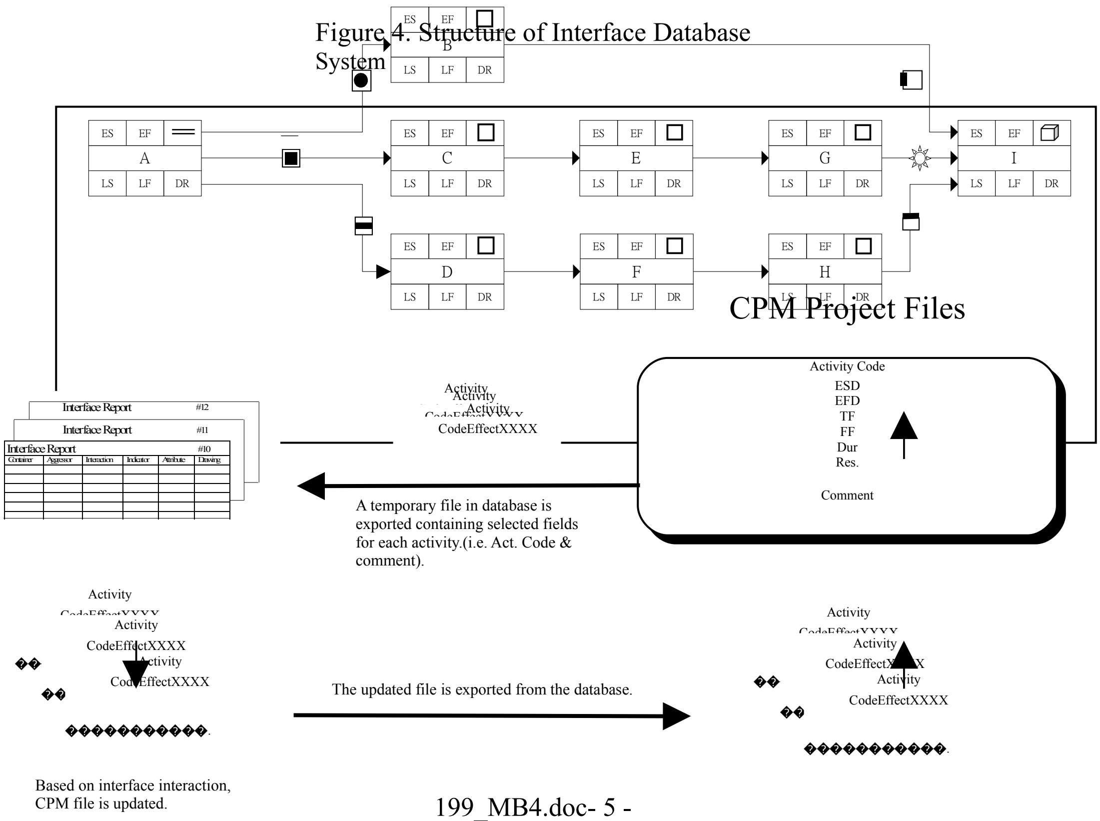

Figure 5. Structure of an Interface-based Schedule Database

6. CONCLUSIONS

While the management of construction interface problems traditionally demands substantial experience and practical knowledge, the CIAR system provides a possible approach to help better represent the construction interface problems. The system identifies two types of interface elements (aggressor and container) that are associated with construction activities. And by using the proposed interface links, the interaction between interface elements are identified and represented on the network schedule. This graphical representation provides the management a proactive and clear warning of potential interface problems that may occur at some point in time during the project construction stage.

Also this CIAR system is possibly computerized for automatically supporting the resolution of interface problems. It is believed that this system shall set a base to consider the interface effect for more objectively controlling schedules.

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