A SOFTWARE FOR AUTOMATICALLY VERIFYING COMPATIBILITY IN COMPLICATED BUILDING ASSEMBLIES
Components Moving According to the Installation Sequence

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Abstract

The research we are carrying on is intended to develop a tool aiding to design building mechanical assembly systems, which are often characterised by high complexity levels. In fact, when designing complicated building assemblies by making use of common graphical representations, it might be impossible for the operator to choose the proper shape and installation sequence of components so that they do not interfere during the assembly, and to check, in the meantime, the most favorable setting up modalities according to execution problems.

Our software, running within CAD, by starting from the definition of the node features, will allow the operator to automatically get three types of representation that can simulate the assembly according to the assigned installation sequence:

- instant images of the phases for setting up each component into the node;
- 3D views showing the position of each component disassembled from the node and indicating the movements required for connection;
- the components moving while the node is being constructed.

All the representations can be updated step by step each time modifications to the node are made. Through this digital iterative design process - that takes advantage of various simultaneous and realistic prefigurations - the shape and function compatibility between the elements during the assembling can be verified. Furthermore, the software can quickly check whether any change and integration to the node is efficacious, rising the approximation levels in the design phase.

At the moment we have developed the part of the tool that simulates the assembly by moving the components into the nodes according to the installation sequence.

1 Introduction

The building elements made by the current construction systems which utilise ready-made components and are based on industrial production techniques, consist of a set of nodes where the connections among pieces belonging to the same technical element or to other elements are concentrated.

At each node end a large number of components, different in size, weight, shape, material and having special technical requirements for their assembly.

Planning of the entire system consists of devising the individual component nodes, whose conception is often difficult owing to their multiple pieces and functions. These systems are often so complex as to require the construction of solid models on a scale.

In our opinion, an alternative or additional realistic preview during the planning stage, could derive from an automatic computer tool able to simulate the assembly.

By taking care of each feature necessary to produce the construction nodes and by making use of various types of computer graphic representation, the tool could be a valuable aid for the preliminary simulation of the assembly, thus enabling the operator to define the appropriate geometric characteristics and the best assembly sequence. This should be done by:

- verification that the node is shape-compatible, in other words ensure that, from the viewpoint of geometrical and positional features and ways of connection, components do not create any interference [1] during assembly.
- verification that installation is easily done. Moreover, the software must enable the operator to check that solutions verified for a single node are compatible and coherent with production of the other nodes in the entire system.

2 Planning with the Aid of a Computer Tool

The computer tool we are realising as an aid to the planning of building nodes will consist of several CAD programs, that will enable the operator, starting from initially defining the system, to verify the project at a later stage. [2]

The level of automatisation at the various stages will vary, at crucial times the operator having to intervene personally.

The programs realised to verify the planning of the node during the assembly will consist of images made in accordance with the node geometrical and functional characteristics and the sequence previously arranged.

Images will be created automatically by the computer through different representation modes:

- instant viewing of the assembling phases of individual components into the node;
- exploded axonometric view of the whole system indicating the movements required for connection into the node;
- sequential movements of the node components.

The software will enable the user to see the images as these rapidly change on updating the definition parameters.

The simulated installation of each component, will allow the operator to work out more easily the “optimum assembly”, that is the set of components liable to be connected in a given sequence their shapes being compatible and their particular realisation needs satisfied.

Presently, we have developed the means to verify the project by moving the components along a given sequence.

2.1 Empirical Definition of the Node

2.1.1 Definition of the Technical Characteristics

When planning a construction node, the initial phase is usually the empirical definition of its technological (geometrical and functional) characteristics as based on models whose main performances are already known.

Through the basic CAD programme a first graphic representation of the node characteristics is given.

The following characteristics are entered in a CAD-related database:

- types of components
- types of connections
- geometry of components
- geometry of the whole system
- identified subgroups of components 3

The above data can also derive from an updatable virtual library supplying details of individual pieces or nodes similar to that being examined.

2.1.2 Working out a Sequence for the Components Assembly

In this phase each component is attributed a number indicating its place in the assembly sequence. Having made further verifications, the sequence can be modified should the assembly prove to be unfeasible.

2.2 Visual Verification of the Project by Simulating Assembly

Data from the stages of definition of the node characteristics and position in the assembly sequence are processed by programs that enable the user to generate three types of graphic representations in order to verify the project.

2.2.1 Instant Viewing of the Assembling Phases in Sequence

The phase sequence consists of two-dimensional images plotted onto the three Cartesian planes, and three-dimensional views of the components in accordance with the assembly sequence previously worked out. By viewing the different assembly phases the position of each piece in the node is evident.

2.2.2 Exploded Axonometric Views

The exploded axonometric views show individual components separately from the assembled unit, indicating their relative positions in the node. Simultaneous viewing of all the node components from various viewpoints enables the operator to evaluate relative positions and connecting relations.

2.2.3 Sequential Movements of the Node Components

Following the assembly order worked out, components appear on the screen and move to their position in the node.

At present we have verified the valve of the representation that is based on the sequential movements of the components, by simulating as realistically as possible the ways by which the latter can reach their definitive site, by shifting or rotation.
We aim to automatize such as visualisation on the basis of the initial data entered by a rough estimate: geometrical characteristics, course and direction of the connecting movements, assembly sequence etc. Obviously the result of such automatic process may require adjustments from the operator (wider or narrower field of view, shifting of viewpoint) so as to render the simulation more effective.
In the present case, besides the representation of a node we have created a program that allows us to visualize a complex system by which the installing and assembly of the whole system itself and of individual nodes is simulated.

3 Applying the Tool: a Case of Verification through the Simulation of Components Moving in Sequence

3.1 The Software

The programme utilized to verify the construction nodes being planned is Microstation '95 rel. 05.05.02.23 from Bentley System Incorporated. It can give a realistic view by representing the three-dimensional model in Rendering Phong Antialias.

By means of Basic and MDL languages the programme offers applications for a variety of uses in the field of aided architectural design.
The optimum interface to effect the verification is the application of a user-friendly Microstation which utilizes buttons located inside special bars.
Three tool bars have been devised in order to:
- continuously visualize the assembly of the whole system;
- analyze in detail the assembly of the individual nodes;
- analyze sections of the whole system being installed.
Purpose-built information windows help the operator to follow the most logical sequence.

Two types of films are generated; they can supply:
- Visualization of the assembly of components into the whole system, in this case by eight films that highlight, also through variations of the field of view, the connecting relations among the nodes being linked ;
- Detailed visualization of the assembly of components for each construction node. The number of films for each node depends on the assembly sequence of the elements into the whole system.

The whole system assembly visualization through partial films supplies indications on the relations among the nodes involved in the various stages of the construction. Circles particularly underline the nodes involved by the installation of the beam. They can be also recalled from the appropriate buttons in order to visualize the node assembly in sequence.

The two tool bars for the two types of films allow the simultaneous verification of the nodes and the whole system. In this way it can be better evaluated if, in the optimum installation sequence, all elements constituting the system and its assembly points in the various nodes, are shape- and function-compatible.

A single film could represent the sequence required to verify the assembly shape and function compatibility for a single node. Nevertheless, between the starting and the ending instant of the assembly, some phases need also the components ending into the other nodes of the system to be taken into account. Therefore, it is necessary to divide the visualization of the single node into partial films that must be seen alternating with the whole system assembly visualization films.

The assembly sequence of the components into node C is linked to the assembly sequence of the same components in the whole system. By visualizing both the film types, the node can be verified, taking into account not only the shape compatibility of the components belonging to itself, but also the components installation sequence commanded by other nodes assembly.

Films C2 and C3 show, in detail, components installing into node C and appearing in films No. 4 and 5 of the whole system assembly. Film No. 5, at the same time, shows components which are to be also installed into node D and E. Therefore, in the viewing sequence of the whole system assembly, before going on visualizing node C, it would be better to see node D and E while being setting up. The program allows the operator to choose the real assembly sequence viewing (indicated in the fixed window on the right) and the single node assembly view (by digitizing Ci buttons).

NOTES

1 Interference generally occurs when at assembly or disassembly an element collides with an already installed one.

2 E. Costanzo, A. De Vecchi, Computer-Aided Planning of Connections among Building Components, Proceedings of XIV ECAADE Conference in Lund (Sweden, September 1996)

3 A subgroup is defined as a partial set of components in connection with each other but made up independently of the whole node assembly phases. A subgroup is thus either an individual component, consisting of few easily assembled elements, or a ready-made component, consisting of even numerous pieces.