Title:
**Piping Design for Production Facilities Using 3D-CAD**

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Introduction:
Many designers design production facilities using three-dimensional computer-aided design (3D-CAD) software. Production facilities typically have many machines and piping structures. Designers design the piping routes while designing the machines of a production facility. Designers may change the shapes of some machines when designing the piping routes because they must arrange the piping within the limited space availability. The design of piping is best done using a 3D model of the machines in the facility because the machines and piping affect each other. However, in piping design, designers typically use simplified shapes as substitutions for the detailed shapes of machine models. The reason for this is that traditional 3D-CAD cannot handle the types of massive 3D models that are often required for production facility design. In other words, designers usually must design piping routes using simplified shapes as substitutes for the detailed shapes of machine models. As a result, some fatal problems, such as interference between piping and machines, can occur in real assembling work.

In previous research, we proposed a data structure that can handle the data of massive 3D models such as production facilities [1, 2]. In this paper, we propose a method to address this issue by applying this data structure to piping design.

Features of Piping Design for Production Facility:
Production facility is comprised of many elements, i.e., machines and piping, electric wiring, frame for machines, and so on. Therefore, piping design for production facility has following features.

- Designers must arrange all elements not only piping within the limited space availability.
- Designers may change frequently the shapes of some machines when arranging piping.

In this way, it is very difficult that designers design piping separately from designing of machines because those affect each other.

Description of Problem:
In piping design, designers usually use a column or cuboid that represents a machine as a substitute for the detailed shape of a machine. In other words, designers design piping separately from designing of machine. The following problems occur as a result.
(1) It is very difficult for a designer to consider the most suitable piping route because some simplified shapes suppress space. For example, a designer may think that the edge of a column is a part of a tank shape when a column is used as a substitute for a tank, and as a result, the designer cannot choose the most suitable piping route, as shown in Fig. 1.
(2) A designer may let piping interfere with a machine if a simplified shape does not include a part of the machine, as in the-case of the compressor vent shown in Fig. 2.

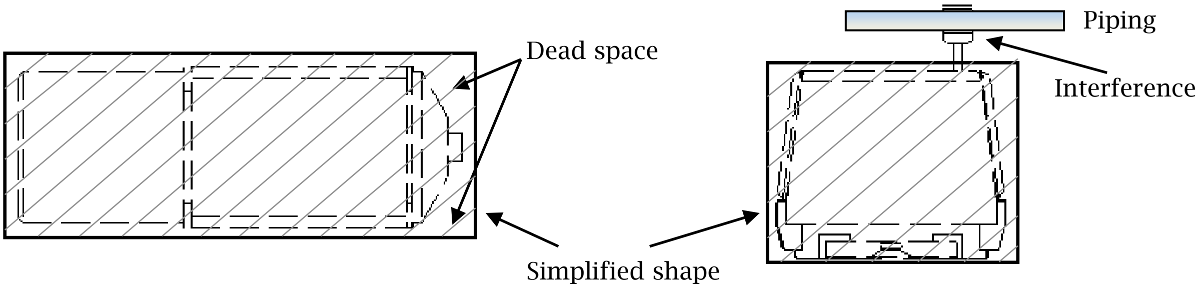


Fig. 1: Tank. Fig. 2: Compressor.

These problems occur frequently, depending on the miniaturisation and complexity of the machines.

Solution:

We think that the best solution to these problems is to use 3D-CAD to design piping with the detailed shapes of machines taken into consideration. The reason that this is the best solution is that it allows designers to change the positions of machines and the shapes of machines and piping routes at any time.

In previous research, we developed “Ultra-Light Solid Data Structure” for use in designing massive machines. In this study, we applied this data structure to piping entities to confirm that designers can use this data structure to design piping with the original 3D models of machines taken into consideration.

Ultra-Light Solid Data Structure:

The Ultra-Light Solid Data Structure represents a machine as an aggregate of surfaces in terms of planar, cylindrical, conical, spherical, and toric surfaces, all of which require small data sizes.

An example of cylindrical surface data is shown in Fig. 3. These data comprise the coordinates of the origin O; a unit vector representing the axis, $i_a$; a unit vector from the origin to the beginning point of the cylinder, $i_r$; the radius, r; the height of the cylinder surface, h; and the central angle, θ. The data size of the cylindrical surface data is 96 bytes when each value is a double-precision floating-point value.

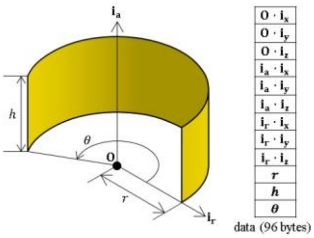


Fig. 3: Surface of a cylinder.

Application to Piping Entities:

Many piping entity shapes consist of combinations of columns and toruses.

The traditional data structure of a torus is represented by the NURBS surface [3, 4]. The data size is 2048 bytes (see Fig. 4). The Ultra-Light Solid Data Structure of a torus is shown in Fig. 5. These data comprise the coordinates of the origin O; a unit vector representing the axis, $i_a$; a unit vector from the origin to the beginning point of the torus, $i_r$; the radius from the origin to the beginning point of the torus, $r_a$; the radius of the circular edge, $r_b$; and the central angle, θ. The data size of the torus is only 96 bytes, the same as that of the cylinder. Applying the data structure, the data size can be reduced to 1/20 of that of the traditional data structure.

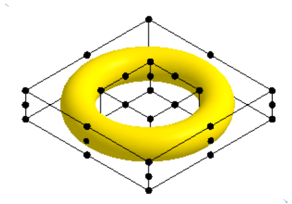


Fig. 4: Torus of traditional data structure.

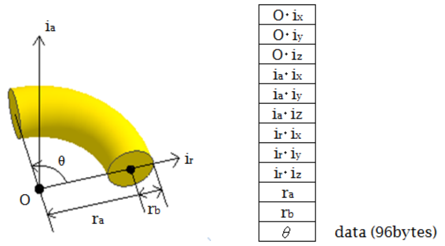


Fig. 5: Torus of Ultra-Light Solid Data Structure.

We proposed a method for improving the display response of a cylinder using the Ultra-light Solid Data Structure by reducing the display data using the features of the surface of a cylinder [1, 2]. We also propose an improvement to the display response of a torus using the features of a toric surface. We can change from the display processing of a torus to the display processing of a cylinder by adjusting the size of the torus dynamically on screen (see Fig. 6). In this way, we can display piping entities very quickly, and we can handle the 3D model of a production facility that includes many piping entities using 3D-CAD and the Ultra-Light Solid Data Structure.

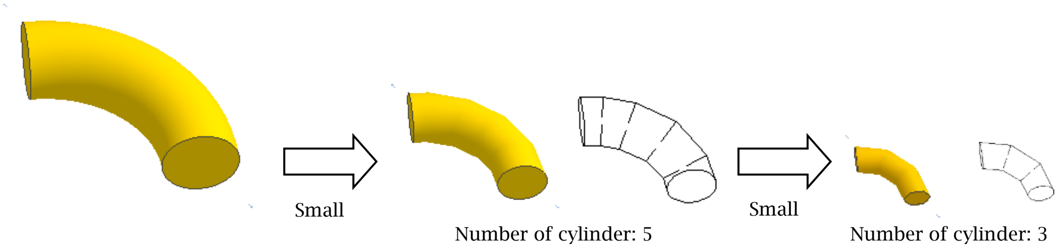


Fig. 6: Illustration of display of a torus.

Evaluation:

We applied our 3D-CAD approach [5], using the Ultra-Light Solid Data Structure, to a production facility model that included many piping entities, and we evaluated the display response time. We were able to obtain results in less than approximately 0.2 s.

Conclusions:

In this study, the applicability of 3D-CAD to piping design for production facilities using our Ultra-Light Solid Data Structure was investigated and demonstrated.

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