Title:
Layout Considerations in the Manufacturing Line using 3D CAD

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Introduction:
Numerous studies have investigated techniques for representing three-dimensional (3D) shapes on computers [1, 2]. 3D-computer-aided design (3D-CAD) improves the design quality because it is a far more comprehensive process than two-dimensional (2D)-CAD, and many human errors that can occur with conventional 2D design methods can be avoided. Hence, 3D-CAD has become increasingly popular in recent years in many areas such as production facility designs and machine tools.

Many designers use 2D-CAD for layout considerations in the manufacturing line. However, it has become difficult for designers to use 2D-CAD today because the manufacturing line has become compact and efficient; moreover, robots are often employed to reduce the lead time and enhance the safety of workers. In this paper, a data structure that can handle the data of massive 3D models such as machine tools has been proposed [3]. This data structure can then be used to establish a design environment that reduces the stress on designers through its high-speed display responses. Therefore, 3D-CAD has been applied to layout considerations in the manufacturing line using the proposed data structure.

Main idea:
[Definition of problems]
First, we describe some of the problems with the layout considerations in the manufacturing line (Fig. 1). Until recently, layout considerations in the manufacturing line have been performed using 2D-CAD for two reasons: (1) it is sufficiently useful and (2) 3D models are too "heavy" for 3D-CAD to handle. However, in recent years, layout considerations using 2D-CAD have become difficult for many reasons. Nowadays machines are arranged in a closely spaced layout to reduce the spaces in the manufacturing line in order to reduce the costs, lead times, and the number of job shop processes. This closely spaced arrangement of machines has made it necessary to carefully consider the layouts of machines and robots. In addition, the working range of the robots, which arises from the robot movements on a guide rail for carrying workpieces, may have complex 3D shapes.

3D-CAD has been proposed to solve the above problems. However, traditional 3D-CAD cannot handle massive 3D models that are often required in the manufacturing line. Typically, 3D models of some of the machines in a layout are reused from existing complicated machines, instead of creating new simple models. Moreover, numerous 3D machine models are required for layout considerations because the manufacturing line has multiple processes such as roughing, drilling, finishing, cleaning, and inspection, and some of them operate in parallel.

In this study, we have attempted to apply the Ultra-Light Solid Data Structure, which has been developed for machinery design, to 3D models in the manufacturing line and verified whether designers can smoothly operate 3D-CAD for layout considerations.
[Ultra-Light Solid Data Structure]
The Ultra-Light Solid Data Structure represents aggregate surfaces in terms of planar, cylindrical, conical, spherical, and torus surfaces, which require small data sizes. The cylindrical, conical, and

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torus surface patterns are shapes that can be defined using angles, radii, and lengths. Completely circular cylinders as well as partial-arc circular cylinders, that is, cylindrical surfaces with two edges comprising circular arcs and two edges comprising straight line segments, can be represented. Conical surfaces are divided into two patterns: a cone with an apex and a truncated cone. Cones have only one edge comprising a circle or an arc and two edges comprising straight line segments. Truncated cones have two edges comprising circles or arcs and two edges comprising straight line segments. Tori are of three types: (1) without any edge; (2) with two circular edges; and (3) with four arc edges.

An example of cylindrical surface data is shown in Fig. 2. 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.

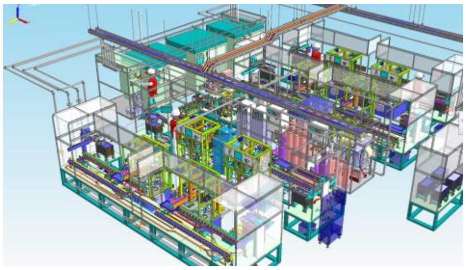

Fig. 1: A typical manufacturing line

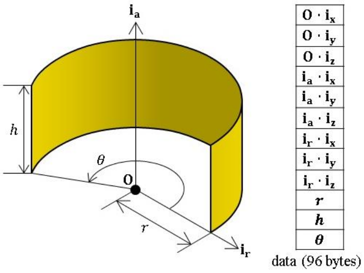

Fig. 2: Surface of a cylinder

The response time of the display process is a very important factor in interactive designs using CAD systems because the display process is performed using individual operations such as panning, zooming, and rotating. We have improved the display response time by enabling dynamic display of the data. We can easily extract the parameters of the shape features, such as the vector or radius, from the Ultra-Light Solid Data Structure. Thus, we can dynamically determine how a shape will be displayed, based on the size of the object on the screen [4].

[Evaluations]

We applied our 3D-CAD [5] using the Ultra-Light Solid Data Structure to a practical manufacturing line and evaluated the display response time. The 3D model was composed of 377,566 parts. We were able to obtain the result in less than approximately 0.2 s.

[Possibilities]

3D-CAD with the Ultra-Light Solid Data Structure offers the following possibilities to designers for layout considerations in the manufacturing line.

- ✓ Checking of interferences/clearances among robots, machines, workpieces, and traffic lines.
- ✓ Analysis of workability using human models and factory walkthrough.
- ✓ Communication of proposals to stakeholders.

Conclusions:

In this study, the applicability of 3D-CAD with the Ultra-Light Solid Data Structure to layout considerations in the manufacturing line in terms of the display response has been investigated and demonstrated. The successful application of 3D-CAD to layout considerations has expanded the domain of 3D data applications.

In future investigations, the handling of massive 3D models of an entire production facility will be realized; moreover, improvements in the display response and reductions in the data size will be investigated.

References:

[1] Okino, N.; Kakazu, Y.; Kubo, H.: TIPS: Technical Information Processing System for Computer-Aided Design, Drawing, Manufacturing, COMPUTER LANGUAGES FOR NUMERICAL CONTROL Proceedings of the second IFIP/IFAC International Conference on Programming Languages for

Machine Tools, PROLAMAT'73, edited by J. HATVANY, NORTH-HOLLAND PUBLISHING COMPANY, 1973, 141-150.
[2] Samuel, N. M.; Requicha, A. A. G.; Elkind, S. A.: TM-21 METHODOLOGY AND RESULTS OF INDUSTRIAL PART SURVEY, Production Automation Project, University of Rochester, Rochester, New York, July 1976.
[3] Matsunami, H.; Koda, A.; Odahara, N.: 3D-CAD Data Structure for Massive Assembly Models of Production Facilities, ACDDE2011 Regular Papers, Edited by L. Ma, S. Hu, B. Sheng, 2011, 108-110.
[4] Kinjo, M.; Takano, T.; Matsunami, H.: 3D-CAD Structure Based on Shape Feature for Massive Machinery Models, ACDDE1013 Proceedings, 2013, 653-661.
[5] ICAD/SX, http://jp.fujitsu.com/solutions/plm/cadcam/icadsx/, 2014.