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Parametric Macro for Two-Dimensional Layout on the Auto-CAD System

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Abstract

In recent years, a number of successful nesting approaches have been developed by using the various heuristic algorithms, and due to their application potential several commercial CAD/CAM packages include a nesting module for solving the layout problem. Since a large portion of the complexity of the part nesting problem results from the overlapping computation, the geometric representation is one of the most important factors to reduce the complexity of the problem. The proposed part representation method can easily handle parts and raw materials with widely varying geometrical shape by using the redesigning modules. This considerably reduces the amount of processed data and consequently the run time of the computer. The aim of this research is to develop parametric macro for two-dimensional layout on the Auto-CAD system. Therefore, this research can be called "pre-nesting".

Keywords: geometric representation, redesigning modules, parametric macro, pre-nesting

1 Introduction

The material saving is one of the most important factors to be considered, and it is well known that a well-nested part layout can result in a substantial saving of the stock sheet. Although each industry requires different functional constraints due to its own characteristics, one common goal is to minimise the wastage of resource sheets by finding a most desirable layout of parts.

In most methods developed for the automatic nesting, the computational time has proved to be very huge(Fujita et al 1993, Ismail and Hon 1995). In recent years, a number of successful nesting approaches have been developed by using the various heuristic algorithms(Han and Na 1996, Daewoo 1999), and due to their application potential several commercial CAD/CAM packages include a nesting module for solving the layout problem. However, many of the CAD/CAM system uses an interactive editing method, and most of them depend strongly on operators experiences to produce torch path sequences for a nested stock sheet.

An important problem making the layout and the torch path sequencing difficult to handle is that the computation time required to obtain an optimal solution increases exponentially as the number of parts increases. Nesting is a peculiar engineering problem as there are no precise mathematical descriptions for the process, and there is an infinite number of possible solutions for most problem. Therefore, the nesting can be classified into the hard combinatorial optimisation problems termed NP-complete, and consequently cannot be solved exactly in the polynomial time.

This paper is a part of research field which needs to shipbuilding industry through development of Integrated Management System, which can improve quality of ship by using optimal processing and inspecting information(Figure 1). As it were, the aim of this research is to develop parametric macro for two-dimensional layout on the Auto-CAD system. Therefore, this research can be called "pre-nesting".

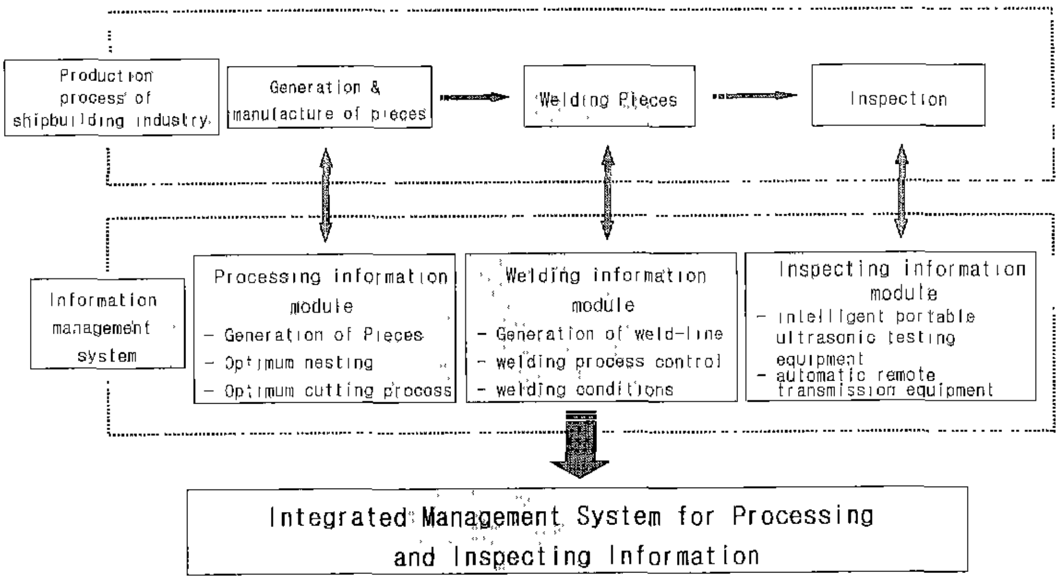

Figure 1: Schematic diagram of integrated management system for optimal processing and inspecting information.

2 Representation of part geometry

Since a large portion of the complexity of the part layout problem results from the overlapping computation, the primary goal of the geometric representation is to develop a fast and reliable mean for performing the overlapping computation(Doi et al 1997). Therefore, the geometric representation is one of the most important factors to reduce the complexity of the nesting problem. The proposed part representation method can easily handle parts and raw materials with widely varying geometrical shape by using the redesigning modules. This considerably reduces the amount of processed data and consequently the run time of the computer.

In the geometric representation process, the part shape can be performed manually by using an interactive graphic device or automatically by using a computer algorithm. The first database structure describes the precise representation of part geometry of the input shape. This database structure will be used to describe the shape after the final placement has been decided. The second database structure contains an approximate description of the actual shape which will be used by all the optimisation procedure. Therefore, the representation of part geometry can be called "redesigning procedure".

The redesigning procedure is introduced in order to the best possible scrap ratio within a practical time frame. As the following 4 modules have an important effect to the final solution, the representation of part geometry derived from redesigning procedure is considered as a second database structure.

2.1 Enclosing

An irregular part can be represented by the Minimal Rectangular Enclosure(MRE). This technique involves determining the angles of rotation such that one or more of the sides of the shape become parallel with either the horizontal or the vertical axis. The procedure here considers those sides that connect two points of convexity of the polygon. Figure 2 is an example for the use of this technique.

The algorithm for providing "Minimal Rectangular Enclosure" for irregular polygon is a combination of heuristic and arithmetic techniques. A vertex of a given polygon is a point of "convexity" if the cross product of the incoming vector -line from vertex(x_{i-1}, y_{i-1}) to (x_i, y_i)- with the outgoing vector -line from (x_i, y_i) to (x_{i+1}, y_{i+1})- is not negative. The formulation is $(x_i - x_{i-1})(y_{i+1} - y_i) - (y_i - y_{i-1})(x_{i+1} - x_i) \geq 0$. Since vertex 5 is not a point of convexity, lines 4-5 and 5-1 are not considered in determining the potentially good absolute orientations.

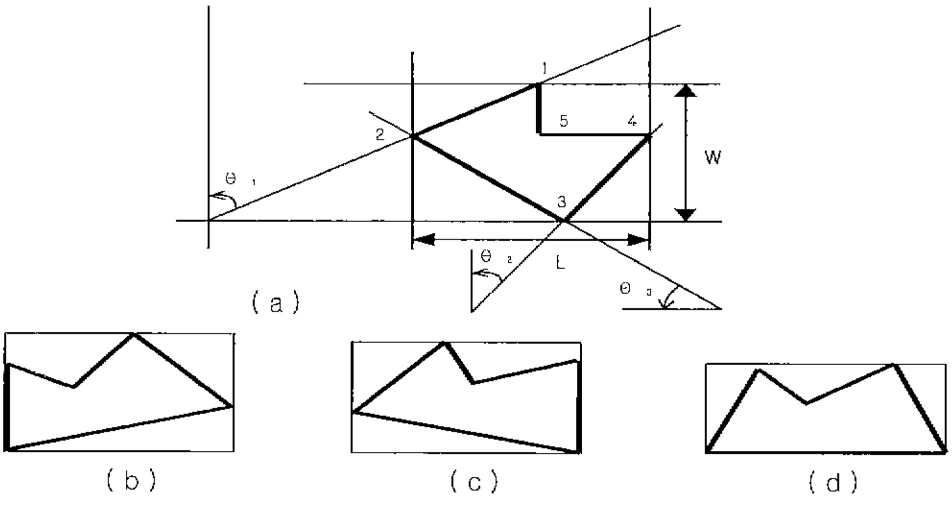

Figure 2: Rectangular enclosure at potentially good absolute orientations; original orientations(a), rotation by θ_1(b), θ_2(c) and θ_3(d)

2.2 Simplifying

The parts having complicated shapes can be formed into simplified ones, when the formation does not affect the scrap ratio negatively. Small holes, cut-out and scallop included in parts can be omitted to simplify their complicated shapes as can be seen in Figure 3. A two-dimensional shape consists of one external feature and several internal features. In post-nesting procedure, only external feature information is considered for nesting, since the internal features may not affect the nesting process. Therefore, if the internal feature information can be neglected for placement, the blank geometry representation can be applied for simplifying module.

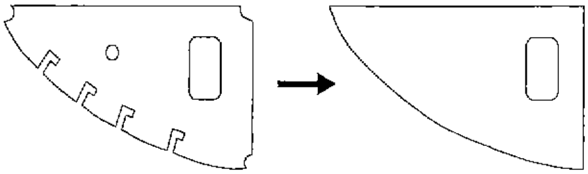

Figure 3: An example of simplifying

The simplifying module is considered as follows:

- o When there ar esmall holes in a hull structure part and no other parts can be placed in the holes, they are omitted from the part's shape.
- o Cut-out and scallops forming a hull structure part are omitted from the part's shape unconditionally.
- o Arc are replaced by straight lines, when they are included in geometrical elements of a part's shape. Since this "Simplifying" technique has reduced database during nesting procedure, it is expected to be effective to shorten the calculation time

2.3 Pairwise clustering

When there are two similar parts or their shapes are alike such as a triangle or L-type, they are regarded as a pair. Two similar trapezoidal and triangular brackets are regarded as a pair, and can be treated as one part(Figure 4).

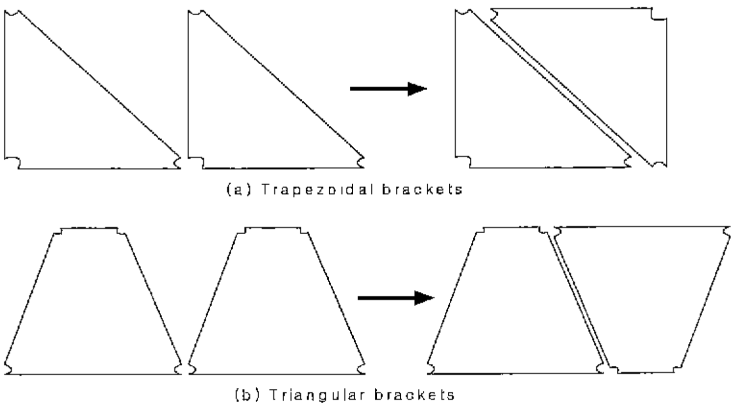

Figure 4: An example of pairwise clustering

The "Pairwise Clustering" is considered as follows:

- o Candidate parts for pairing are selected by their pairing ratio which is defined as the ratio between the area of 2 parts and the minimal rectangular enclosure which surrounds 2 parts.

- When the pairing ratio of two parts is higher than a fitness level, the parts are placed as one part.

The "Pairwise Clustering" is expected to be effective to shorten the calculation time and to improve scrap ratio.

2.4 Grouping

Hull structure parts, including pairing parts, with rectangular shapes or with the same height or width are regarded as one group and the parts in a group are placed on the raw plate. The "Grouping" is expected to be effective to improve the scrap ratio.

3 Parametric macro

The parametric macro, which is surrounded by box in Figure 14, have developed to manage optimal processing and inspecting information on the Auto-CAD system. These macro for manual-nesting has developed in current paper, and is achieved its own task by click each of icons and POP menu bar. The functions of these macro will be briefly mentioned in the following chapters. Here, the some of results derived from these macro are shown as examples.

3.1 Generation of piece

Unload current programme.

Setup global input variables.


Decide entity-direction of outer-contour, hole and marking line of piece, and verify detailed drawing of designed piece.


Save piece drawn on Auto-CAD.


Call piece from D/B.


Delete piece.


Find Minimal Rectangular Enclosure(Figure 5).


Simplify piece.


Make Pairwise Clustering.


Group pieces with similar shapes(Figure 6).

Register X-Data or information for piece and raw-plate(Figure 7).

3.2 Nesting procedure

Draw new raw-plate.

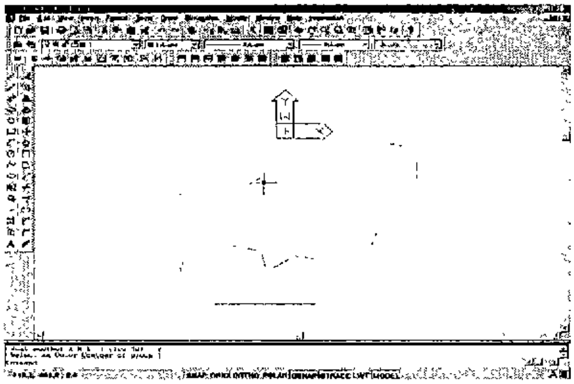

Figure 5: An example of Enclosing

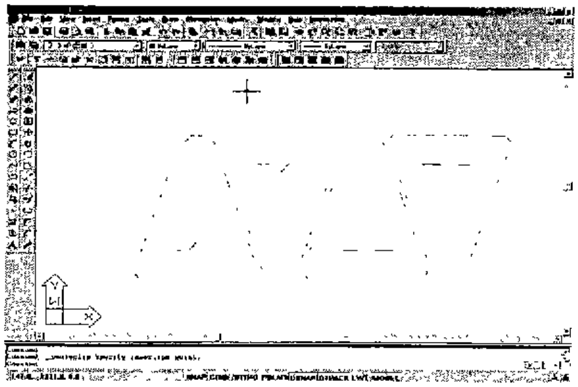

Figure 6: An example of Grouping

 Array pieces over the raw-plate(Figure 8).

 Move piece(Figure 9).

 Rotate piece(Figure 10).

 Bump piece in any direction(Figure 11).

 Mirror by horizontal axis(Figure 12).

 Mirror by vertical axis(Figure 13).

3.3 POP menu-bar

This POP menu bar consists of five items for optimal processing and inspecting information as follows:

(1) Piece information menu bar
(2) Nesting information menu bar
(3) Cutting information menu bar
(4) Weld-line information menu bar
(5) Flaw information menu bar

4 Results and conclusion

Figure 14 is a result of manual-nesting with several pieces using programme which is developed by the current author. Here, since the current research is a part of final project, which is "Integrated Management System for optimal processing and inspecting information". the comparison of efficiency between current programme and another nesting programme is not mentioned. As it were, the current programme will be joined with further work to find artificial intelligent nesting and cutting path planning by using FEM.

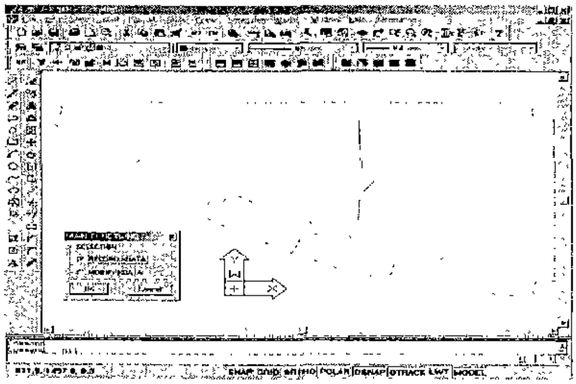

Figure 7: An example of registration and modification of X-data

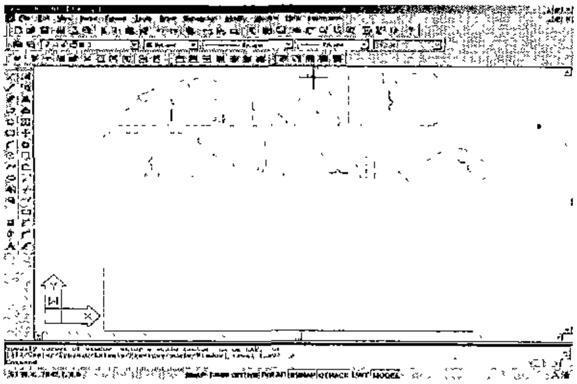

Figure 8: An example of arrangement list of the pieces for manual nesting

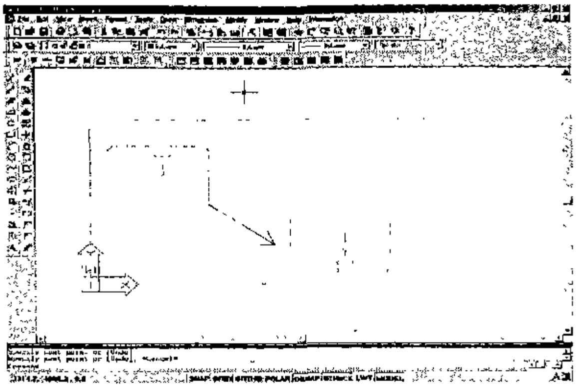

Figure 9: An example of moved piece

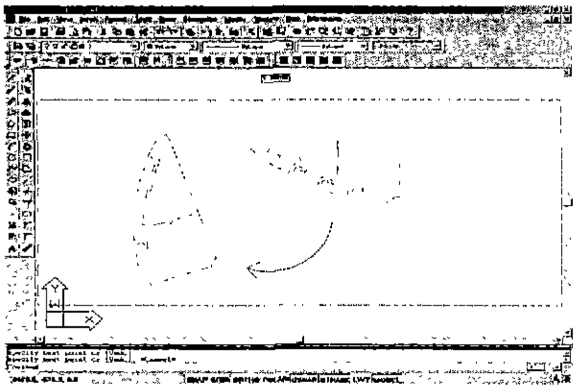

Figure 10: An example of rotated piece

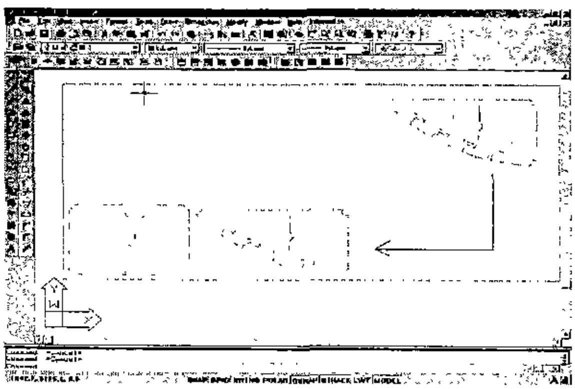

Figure 11: An example of bumping piece

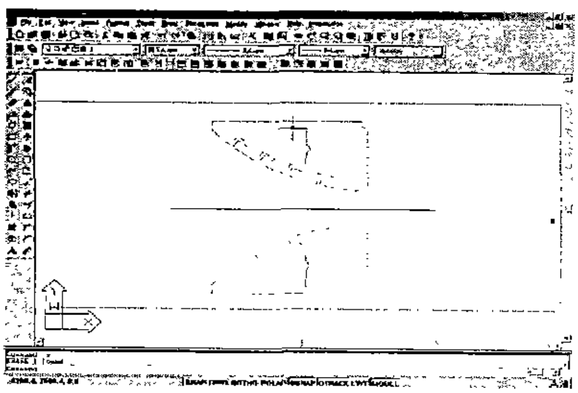

Figure 12: An example of mirror along with X-axis

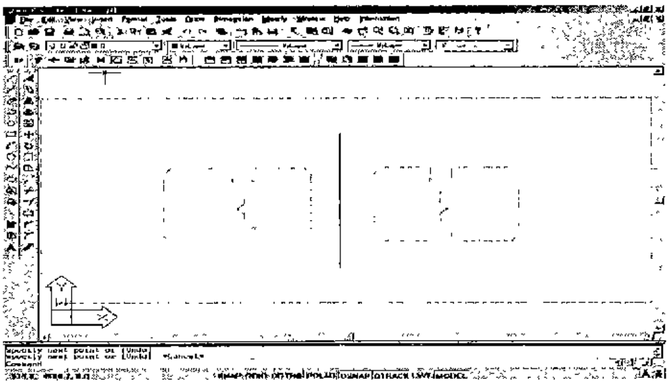

Figure 13: An example of mirror along with Y-axis

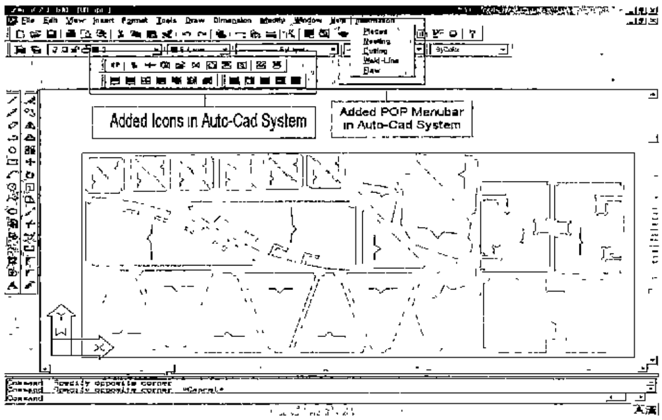

Figure 14: An example of manual nesting using parametric macro

Acknowledgements

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