WHITE PAPER

UNDERSTANDING NESTING

STRATEGIES & TACTICS

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Choosing the best method for your operation

A nesting strategy is an overall approach or direction to be taken with processes related to nesting parts. A nesting tactic is the short term actions taken to achieve the nesting strategy.

The intent of this paper is to describe and evaluate Fifth Generation nesting strategies and different tactics used to achieve them. The discussion falls into three categories roughly following the production process. They are:

- How nesting software see part shape
- How previous and current generation nesting software create nests
- How nesting software manage part flow

"HOW TO CLASSIFY A SHAPE" STRATEGIES

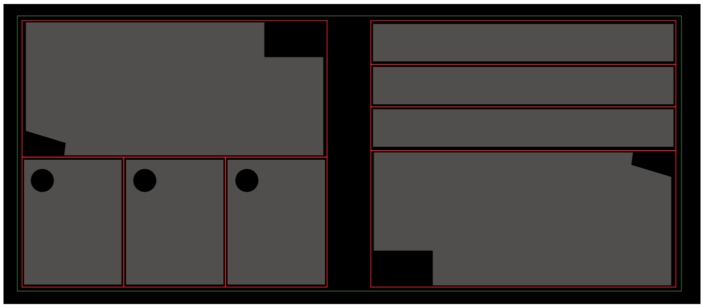
Different nesting tactics approach what seems to be natural to the human eye in different ways with varying results.

It seems intuitive that when you view a part shape, you see the shape as it is and can easily determine how the part best fits in the nest. But this isn't always the case when software views parts that are to be nested. Different nesting tactics approach what seems to be natural to the human eye in different ways with varying results.

TACTIC 1: RECTANGULAR NESTING - FIRST GENERATION NESTING

First Generation nesting software used Rectangular Nesting (see white paper describing the history and development of Nesting software.)

- What is it? Rectangular Nesting "draws" a rectangle around the part at the largest height and width. It treats the part geometry as the rectangle, not the real shape of the part when placing the part on a nest.



- Advantages. Rectangular Nesting is satisfactory if and when your parts are primarily rectangular in shape.
- Challenges. This process does not consider arcs, holes, or other non-rectangular variations in the part when nesting. Similarly, rectangular nesting does not create the opportunity for interlocking of parts. A common example of interlocking parts are two L-shaped parts, one rotated 180 degrees, locking together like puzzle pieces. Also, holes are not filled with standard rectangular nesting software.

Half Shape (True Shape) Nesting opens up the possibility of greater nesting efficiency.

TACTIC 2: HALF SHAPE (TRUE SHAPE) NESTING - SECOND GENERATION NESTING

- What is it? Half Shape Nesting identifies a portion of the actual shape of the part. It puts the shape in the lower left corner of the space available and identifies the minimum "X" and minimum "Y" coordinates where the next part can be placed. Often Half Shape nesting is called True Shape nesting because it uses the actual part boundary as it places the part. However, only half of the part shape is considered. Only the left side and bottom of the part is examined to determine how well it fits with adjacent parts. The top and right side are ignored until another part is placed next to it. In Half Shape nesting algorithms, the parts already placed on the nest remain stationary and only the newly inserted part is consider for placement and rotation.
- Advantages. Half Shape or True Shape Nesting is a more real-world approach than Rectangular Nesting, because it takes into consideration half of the actual shape of the part during placement. When the part shape is used, the nesting

tool can find greater material savings advantages by rotating the part. It also opens up the possibility of greater nesting efficiency.

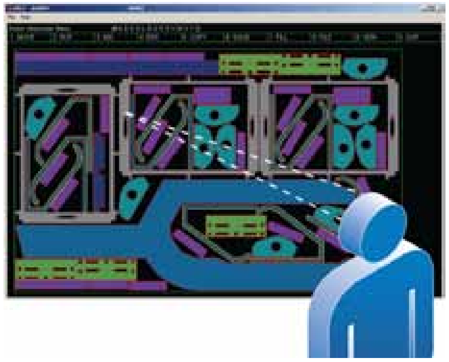
- Challenges. Half Shape or True Shape Nesting comes up short in its ability to make evaluations about the full shape of the part. Some questions it fails to answer include:
  - Is the next part the best part to select for this location?
  - What is the best orientation for a group of parts? Half of the part may fit well with existing parts on the nest at some odd orientation, but that may cause subsequent parts to cascade into a random inefficient pattern as more parts are placed in the nest.

Vision Emulation helps limit the number of possible part combinations by finding the parts that best fit together.

TACTIC 3: VISION EMULATION NESTING

- What is it? Vision Emulation is a feature of fifth generation nesting technology. Vision Emulation Nesting "sees" the actual full shape of the part and makes logical conclusions about it, just as a human looking at the part would. The process is modeled after human vision and decision making.
  - Vision Emulation looks at the full shape of the part and the space available on the nest, then determines if there is an optimal fit.
  - Vision Emulation also evaluates the part to determine if and how much rotation is needed to provide an optimal fit. The actual part shape and the shape of adjacent parts is used to determine the optimal orientation. Multiple parts may be viewed on one time. A part could be rotated 123.456 degrees to achieve an optimal fit. This process eliminates the time consuming trial and error process of rotating the part in hundreds of small increments to check for fit. To understand the advancement that Vision Emulation provides, imagine putting a puzzle together in the dark. Without the ability to see the puzzle piece, you would have to try many orientations to determine if the part fits. Vision Emulation is like turning on the lights.

- Vision Emulation helps limit the number of possible part combinations by "seeing" the parts that best fit together.



- Advantages. Visual Emulation can automatically find occasions to reduce material waste by seeing parts to nest in the appropriate voids. It naturally reduces the nesting time by allowing the optimal placement to be seen – unlike previous generation nesting – by only trying reasonable shaped parts and orientations that are optimal.

"HOW TO CREATE THE NEST" STRATEGIES

Each manufacturer has a unique set of production objectives. The nesting strategy used should be consistent with and supportive of the production objectives. For the purposes of this discussion a "nest" is considered one machine cycle processing one sheet of material.

➤ In Manual Nesting, the user works with the individual parts – moving, replacing, and rotating – to achieve the optimal nest based on his priorities.

TACTIC 1: MANUAL NESTING - FIRST GENERATION TECHNOLOGY

- What is it? Manual Nesting is the process of interacting with each nest by dragging and dropping each part geometry on the material. The user works with the individual parts – moving, replacing, and rotating – to achieve the optimal nest based on his priorities. The priorities could include material use, how much time he has, and any part priorities or due

Manual Nesting offers maximum programmer control over the layout of the nest. However, Manual Nesting can be very time consuming and error prone.

dates. All choices are left to the programmer to make.

- Advantages. Manual Nesting offers maximum programmer control over the layout of the nest. He has complete discretion over the part choice, part orientation, degree of material efficiency, and programming time.
- Challenges. Manual Nesting can be very time consuming and error prone. A nest may take hours to create and still lead to such issues as the possibility of laying parts on top of parts, creating problems with the tool path, no consideration for order cohesion, or material efficiency may not be optimal. For punching operations, tool setup optimization may be compromised. Further, there isn't a quality check mechanism to insure parts can be produced or errors don't exist in the nest.

TACTIC 2: FIRST FIT NESTING - SECOND GENERATION TECHNOLOGY

- What is it? First Fit Nesting Heuristics (algorithms) create an ordered list of parts. Most often the list is ordered from the largest part to the smallest part. The First Fit Nesting heuristic places the largest part in the list on the nest first, then the next largest and so forth. If the second largest part doesn't fit, the software moves down the list to the first part that will fit; hence the name "First Fit." Additionally, when considering the part for placement the nesting tool chooses from several pre-set rotation options (90˚, 180˚, 270˚) to find the best fit. Best fit is defined as rotation that brings the center of gravity closest to the lower left corner (or other specified datum point).
- Advantages. The First Fit Nesting approach is more automated than manual nesting and can be less time consuming.
- Challenges. There are several limitations to the First Fit Nesting tactic. It is impossible to create a single list that will reflect all of the demands on the production schedule, i.e. due dates, hot parts, while maintaining a largest to smallest

part order. Nesting mathematics is very complex. Since 50 parts can be nested in more than 10^{100} alternative ways, this single list is only one of the many possible nests and is extremely unlikely to be close to the optimal solution. Another challenge is the limited number of part rotation attempted. As an example, assume a rotation setting of 10 degrees. If a part must be rotated 92° and fit, the part would be rejected as not fitting in the space available. If the software is given a large number of rotations, the time to nest the parts can become impractical. In short first fit heuristics are blind and are not able to consider multiple requirements simultaneously. Despite these limitations, the first fit heuristic is used widely by a number of nest software suppliers. The reason that this 2nd generation heuristic is used so much is that it is easy to code and easy to understand. 3rd, 4th and 5th generation nesting technology is very complex and not published in the public domain. Many 2nd generation software suppliers offer multiple variations of the first fit method which they consider different nest algorithms.

TACTIC 3: MULTI-DIMENSIONAL COMBINATORIAL NESTING - THIRD, FORTH AND FIFTH GENERATION NESTING

- What is it? Multi-Dimensional Combinatorial Nesting is another automatic nesting technique. The software uses mathematical fathoming to eliminate alternatives that do not need to be considered. See the Flash presentation at http://www.optinest.com/VE.swf for a full explanation of fathoming. The nesting software automatically and intelligently considers only those part combinations (nests) that take into consideration machine efficiency, schedule demand, order completion, material efficiency and many more real world requirements. Part layout solutions that are outside of the optimal solution set are simply not considered. In this approach, the production priorities are part of the expert knowledge base in the nesting software enabling it to

See the Flash presentation at http://www.optinest.com/Vision_Emulation_Flash_Demonstration.htm for a full explanation of fathoming.

make intelligent decisions. Due dates, hot parts, machine efficiency, material cost, part attributes and more are evaluated then optimized into a nest or series of nests that the optimal solution to the user's requirements.

- Advantages. This method significantly reduces programming time and retains the best possible results for all considered factors – schedule, material, order completion, etc. Benchmarks show 8% to 16% higher material utilization over other methods.
- Challenges. While the technology can be simplified and used in any environment, the expert system technology can best be leveraged by fully integrating the system with other manufacturing systems such as ERP/MRP, CAD and other common manufacturing tools. Training and a good support system is necessary to gain the maximum benefit from the technology.

➤ Effectively managing the production schedule and the efficient flow of product is at the core of meeting manufacturing goals.

"HOW TO MANAGE NESTING PRODUCTION" STRATEGIES

Really, creating the nest is only part of the task of producing parts. Effectively managing the production schedule and the efficient flow of product is at the core of meeting manufacturing goals. First consider your production objectives – material efficiency, labor efficiency, part flow, throughput, flexibility, dynamic machine loading, setup costs, and overhead conservation – then look to these strategies to determine the best fit.

TACTIC 1: STATIC NESTING

- What is it? Static Nesting is the process of cutting multiple sheets of material with the same nest or part layout. The parts, the part quantities, the orientation of the parts, and the part layout all remain precisely the same on each sheet of metal cut with the static nest.
- Advantages. There are a couple reasons why a fabricator may turn to Static Nesting. First, if they are producing a very

large volume of the same or same set of parts, such as the case with a kit or product assembly, it may be cost-efficient to spend the time to create one single nest (interactive or automatically) with the best possible material utilization, then cut the same nest repeatedly. Often this process will result in a custom size of material for each static nest. This tactic achieves material efficiency while minimizing programmer time in creating the nest. The part cost and cycle times could be determined from past experience and be the basis for future estimating. Often manufacturing cells are designed to eliminate setup and accomplish single kit flow.

- Challenges. Static nests are only useful when the nest can be repeated a large number of times. The biggest challenge with static nests is the lack of same part volume and that some high volume kits make poor nests. If a part design changes or a produced part needs to be re-created quickly, it is generally impractical or impossible to incorporate the new part into the static nest. Unless the new part is 100% geometrically the same or smaller than the part it replaces in the nest, a new static nest will need to be created. Hot parts are handled independently often at a high labor and material costs. Because of the normal changing demand on most shop floors, static nests are often only used for special kiting requirements.

➤ Automatic Single Nest Creation affords the user the multiple advantages of automated nesting and the control of “final approval” or “final editing.”

TACTIC 2: AUTOMATIC SINGLE NEST CREATION

- What is it? Automatic Single Nest Creation is the process of creating nests automatically, one sheet layout at a time. Each nesting action is cued by the programmer. The nesting software creates the nest, assigns lead-ins, tooling, manages order priorities, and creates the tool paths automatically, without user intervention. When the automatic nesting process is complete, the programmer can review and/or interact with the nest if needed. The order information or pool of parts from which the automatic nests are created remains constant until it is updated.

- Advantages. This tactic affords the user the multiple advantages of automated nesting and the control of "final approval" or "final editing." Advantages include, but are not limited to: reduced programming time, optimal material efficiency, error checking, increased throughput, and overhead conservation. An intelligent nesting tool will be able to produce the nest in a matter of minutes, if not seconds, far faster than most machine cycle times, so keeping ahead of the production pace is typically not an issue.
- Challenges. The programmer is responsible for maintaining a fluid cue of nests for production. If problems arise in programming, a production bottleneck can be created. Often programmers work on a single shift while production can have two or three shifts. Production problems in shift two and three can cause delays and increased cost because the programmer is not available to correct the problem.

TACTIC 3: BATCH NESTING

- What is it? Automatic Batch Nesting creates multiple sheet layouts or nests with a wide variety of parts for a specific material in a single process. Unlike Static Nesting, it creates any number of nests required – some replicates, some unique. It looks at all part orders for a given time – a shift, day, week – then creates nests optimizing the material efficiency, order cohesion, and part due date.
- Advantages. Automatic Batch Nesting is designed to achieve maximum material efficiency through an automated nesting process using minimal human interaction or limited programmer time. An entire batch of nests, for example 2nd shift's production, can be created in a few minutes and ready for the machine operator to download and produce. If, after the batch is complete, changes in demand occur, such as a "hot part," the entire batch of nests can be discarded and re-run with automatic batch nesting affording far more flexibility than manual or static nesting. Production is able to see the demand that is in front of them and can better plan

Batch Nesting looks at all part orders for a given time – a shift, day, week – then creates nests optimizing the material efficiency, order cohesion, and part due date.

manpower.

- Challenges. Automatic Batch Nesting does not reflect changes in demand over time. If a batch nest run is created and downloaded to a machine with the intent of running the batch over an eight hour period, changes in the schedule are not able to impact the production results during that shift.

TACTIC 4: AUTOMATIC JUST IN TIME (JIT) NESTING

- What is it? Similar to Automatic Single Nest Creation, Just in Time creates one nest (sheet layout) at a time automatically without a programmer. The nest creation is triggered by the machine operator asking for the next nest. This allows the JIT nest to be created at the last possible time it is needed. The nest is then automatically generated without human interaction using the most recent order information. The next nest always reflects the current order demand. Hot parts and schedule changes are responded to with each machine cycle. Multiple machines are automatically load balanced; providing optimal use of your capacity on the most important items to be produced.
- Advantages. Automatic Just in Time Nesting has all of the advantages of Automatic Single Nest Creation – material efficiency, reduced programming time, increased throughput, and overhead conservation. The distinctive advantage JIT Nesting has is the user is ensured that all "hot parts" or any order demand changes will be reflected in the next nest. Additionally, workload is automatically balanced between machines by redirecting nests among machines as they become available. Inherent to JIT system is the optimal flexibility to react as production requirements change, machines become inoperable, or order requirements vary. Human nesting time is eliminated; freeing your most knowledgeable employees to support the JIT process. Material efficiency is greater because there are always more new orders waiting to be nested and there is no tail-off caused by running out of parts. Often unused material

➤ The distinctive advantage JIT Nesting has is the user is ensured that all "hot parts" or any order demand changes will be reflected in the very next nest.

remnants can be completely eliminated. Kanban or other demand pull system are a perfect fit for JIT nesting. These real time production planning systems require maximum flexibility to an ever changing demand.

- Challenges. JIT nesting requires a very intelligent 5th generation nesting system. Simple single-dimensional 1st or 2nd generation nesting systems will fail to make the correct decisions in an rapidly changing production environment. JIT nesting is a new paradigm for most production employees. The new methods must be learned to gain the maximum advantage from the system. Support systems such as MRP/ERP, Kanban or Demand Pull must deliver reliable production plans or the JIT nests will produce the parts based upon an erroneous schedule.

ABOUT OPTIMATION®

Optimation® delivers economic performance for fabricators through advanced nesting software. Optimation® develops and supports nesting and CNC part programming software for fabrication processes, which include punch, laser, plasma, Waterjet, router, and CNC knives. We cover the range from single-machine sites to sites with hundreds of machine tools with the highest possible automation.

Our automated approach to manufacturing solutions dates back to our beginning more than three decades ago. It is our belief that routine - and even not so routine - nest technology fabrication can be best achieved through a rules-based system that reduces not only material waste but programming time and error and keeps the manufacturer in control.