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Why this White Paper is Necessary

Nesting parts for today's cost-conscious and time-conscious manufacturing industry has moved on from the original concept of nesting, which was simply the geometric problem of arranging parts on a sheet to minimise waste.

In the past it may have been about filling a sheet with parts for one customer, but today it can be much more cost effective for a sheet to contain a mix of parts for different customers, and parts which are needed at different times.

Also, is the nest that optimises material usage, really the most effective in terms of the overall production process, which should take machine run times into account as well? Today's manufacturers need to consider many factors that will affect their nesting if they are to be truly efficient and get the very best from it.

Managers need to consider the effect a nest would have downstream – for example, what tool changes do the machines need, and if they minimise that are they saving more on the time the operator takes than they would be saving on materials with the nest that has the best utilisation? That's a very important factor with labour costs rising all the time.

This paper moves nesting away from its traditional roots and seeks to champion its value as an integrated part of an overall ERP or process planning system. The right type of nesting is capable of so much more than it is generally being used for – it can tie in with accurate quotations and capacity planning; and it can readily adapt to produce both standard nests and nests for a Just In Time procedure, as well as a mix of parts for different customers.

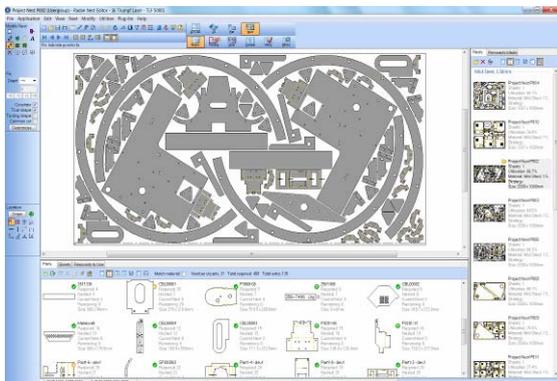
It's all about changing the way we think about nesting, and looking at the skills of the machine programmers and operators.

The Problem of Automatic Nesting

Automatic nesting has been the subject of academic research for almost as long as computing has been studied in universities, with some publications dating from the 1950s and 1960s. Nesting is mainly studied in the field of operational research. Some aspects of the problem are also studied by specialists in other fields, particularly in branches of computer science such as computational geometry.

Academic research on nesting has focused on the underlying geometrical problem rather than its manufacturing aspects. In its most abstract form the problem is this: Given a number of two-dimensional shapes called parts, and a larger shape called a sheet, a nest is an arrangement of parts on the sheet in such a way that none overlap. The goal is to arrange the parts to make the best use of the sheet, minimising the amount of wasted space.

This idealised form of the problem is purely geometrical – it does not matter whether the material is cloth, metal, wood, or anything else. The problem has a number of variations. For example in rectangular nesting the sheet and parts are rectangles and the parts must be placed with edges parallel to the edges of the sheet. In true shape nesting, the parts, and perhaps the sheet as well, have irregular shapes.



For a given sheet and set of parts there is an astronomical number of possible nests, even if rotation of the parts is not considered. The possible nests differ from each other in the sheet utilisation they achieve. Finding the particular nest that gives the best utilisation is a very difficult problem. There is no algorithm that will guarantee to find the optimal solution in a reasonable time, however fast

the computer is. The aim of practical nesting software is to find solutions that are good nests, with utilisation that is quite close to optimal, in an acceptable running time. But there is much more to nesting than that.

Let's take a hypothetical example – but just change the numbers a little and it's likely you'll be able to identify with a similar situation on your own shop floor. Your nester creates 17 different nests to manufacture 800 parts, using 68 sheets. That is a valid result and is perhaps the best that an automatic nester will give. But running 17 different programs means a lot of work on the shop floor, possibly including tool changes from one nest to another. Therefore, reducing the number of different programs to perhaps seven, can reduce the problems massively.

Nesting for Manufacturing Industry

Requirements other than raw utilisation have not been widely addressed in academic research, as they are often specific to particular industries relating to the nature of the material, the cutting technology used and the efficiency of the manufacturing process. For example, leather nesting for shoe manufacturing has several requirements that rarely occur with other materials – the sheets are irregularly shaped hides which may have areas of differing quality, and that must be taken into account when nesting different kinds of parts. The requirements of the paper industry, by contrast, are entirely different. Here the “parts” are nearly always rectangles of various sizes, and they must be manufactured by making horizontal and vertical guillotine cuts which constrains how the parts may be nested.

The textile industry has had the greatest influence on research. In garment manufacturing the parts to be cut from the cloth “sheet” are usually irregular in shape and must be placed at a particular angle to take the cloth’s grain into account. The “sheet” is a long roll of cloth, so in geometrical terms the problem is packing the part shapes onto one end of a long rectangle, minimising the length of the roll that is needed.

The problems facing automatic nesting software for sheet metal are more challenging than in other industries. Firstly, with sheet metal there is a selection of stock sheet sizes to choose from instead of a single roll of material – although coil machining, where the raw material is a coil instead of a sheet, is something that comes in and out of fashion. Secondly, sheet metal parts are often complex shapes, and may have large holes which allow other parts to be nested inside them. Thirdly, because the metal’s grain direction can usually be ignored, parts may be placed on the sheet at any angle of rotation – certainly when using laser or plasma cutters.

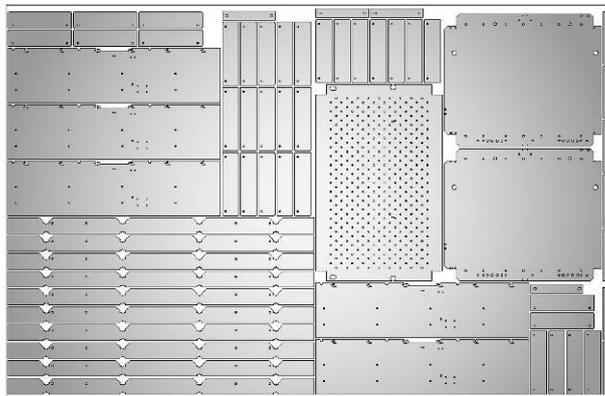


Rectangular and True Shape Nesting

There is a fundamental division between rectangular nesting and true shape nesting, and because the rectangular nesting problem is simpler, it has a longer history of research – but it is true shape nesting that is used more in the real world of manufacturing.

Rectangular Nesting:

- Ideal when parts are mainly rectangular. It treats the parts as rectangles and disregards their true shapes. If a part is not actually a rectangle then the nester places an imaginary rectangle around it. Obviously, if the parts' true shapes are very nonrectangular then this approach produces a nest with a lot of wasted material.



On the other hand, if the parts are rectangular, or nearly so, it has the advantage that specialised methods may be used to nest them extremely efficiently.

True Shape Nesting:

- This looks at the actual shape of the part, taking all its curves, angles and holes into consideration. This is particularly important in manufacturing when the material's grain and the method of manufacture do not inherently constrain the angle of the parts which can be cut. Research has focused on two aspects of the problem: firstly, methods for handling the geometry efficiently. Placing irregularly shaped parts onto a sheet so they do not overlap is easy for a human being, but difficult to program on a computer. Many approaches may take several minutes of running time to construct each nest if the shapes are complex. Long running times are not usually acceptable in practical applications such as manufacturing, and sophisticated methods must be used to reduce the time to just a few seconds or less.
- As the optimal nest is just one amongst an enormous number of possible nests, the second main area of study has been how to find it. One approach to finding a nest with excellent utilisation is to perform a search through this abstract space, generating a sequence of nests of improving quality, and trying to converge towards a very good solution. Academic researchers

have investigated many different algorithms for controlling this process, but so far this approach is not widely used by commercial nesters.

It is clear that much of the commercial nesting software on the market today attempts to achieve good material utilisation while offering features specifically for the technology and manufacturing processes involved. But the manufacturers who are keeping ahead of the game are those that seek a nester which can cope with a wide variety of additional parameters. For example, to gain and keep a competitive edge, many companies are now looking for a nester to take into account manufacturing processes, such as minimised tool changing for punching machines and common line cutting for profiling machines, which can place limitations on the freedom of a nester seeking the optimal solution.

Some nesters work by applying a set of rules which come up with a particular solution. For example, one commonly used rule is to add the parts to the nest one by one in a certain order, placing each part as far to the left in the remaining space as possible. More sophisticated nesters work by trying different potential nests in a given amount of time, so the faster a nester is, the greater the chance of finding an even better solution. This allows manufacturers to trade the amount of time they are willing to leave the nester looking for solutions against the additional material savings that can result. A law of diminishing returns starts to apply; whilst better nests can be regularly found early on (depending on the sophistication of the nester) often the result plateaus with no better nests being found after a period of time. Depending on the nester, this can be as little as tens of seconds.

A rectangular nester and a true shape nester are usually separate nesters which work in different ways. While true shape nesting's versatility and efficient performance have led to it becoming the most popular automatic nesting solution, there is a third way of nesting that is also an important aspect of modern manufacturing techniques. This is known as manual nesting.

Nesting Solutions

Manual Nesting is where the thinking is manual, but the process is semi-automatic. The operator constructs the nest interactively with the help of the nesting program. Good manual nesting software allows the operator to position parts on the sheet while ensuring that manufacturing constraints are not violated. For example, each part may have to be separated from the other parts in the nest by a certain minimum clearance. Using manual nesting in combination with automatic nesting is an extremely useful system for today's intense manufacturing processes, because while the computer gives an excellent nest automatically, the operator is able to optimise it even further. The human adjustments can take numerous

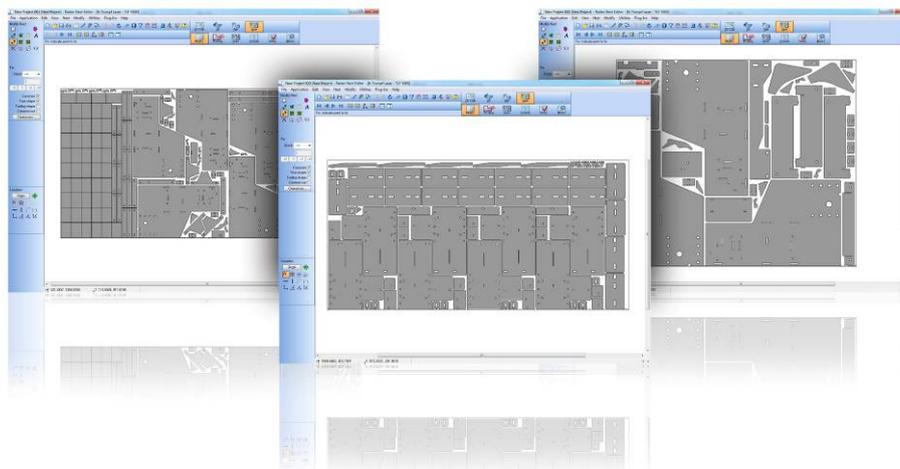
production requirements into consideration, which may be difficult with an automatic nester. For example, the operator can specify that certain parts come off the first sheet because they are needed for prototyping or quality assurance.

Static Nesting. This is where considerable time is taken arranging groups of parts which are likely to recur in the future. The nest is then saved, and there is no need to generate another nest for those parts. If an order comes in for a further hundred of those groups, the nest is already there and nothing else needs to be considered for it. Companies spend a lot of time optimising these static nests which will be used regularly, perhaps for several years.

Automatic Single Part Nesting is a logistical approach to produce a nest for a certain quantity of one particular part. It will usually be for a large series and is especially popular on punching machines. It is a simple procedure because it is generally for one customer, and only one set-up is required for the production run.

Project Nesting is organising a run of nests for manufacturing large quantities of parts in a time frame of a few days or weeks. It is particularly useful when a machine would otherwise not be running, either for a day or for a proportion of a work shift. It gives the operator the opportunity to consider regular orders and to anticipate what will be required next week. The run could be specific to a machine tool or a customer order, and can be completed before the machine is needed for anything with a more pressing deadline.

Automatic Just In Time (JIT) Nesting. This is similar to project nesting but with a greatly condensed time scale. The operator looks at what needs to be going out today, and focuses on nesting those parts alone, instead of optimising the entire production process. JIT nesting could be as simple as producing a single nest for a single machine, and may complete its run in a short time – maybe as little as half an hour.



The Future is Here Now

The future is here now – in two ways. First, manufacturers who only look at today's needs are unlikely to get the best from their nester in the long term. The solution is to carefully analyse what you are doing now, along with your aspirations for the future, because a nester that looks to be absolutely perfect for a manufacturer now, will almost certainly not be suitable for where that company wants to be in a few years' time.

Analyse Now, and the Future

Look carefully at what your processes are now: do you need to make hundreds of the parts or not so many? Are orders coming in for JIT production, or do you manufacture mainly for stock? Confirm where you want to be in six months time and ensure that the nester can be used for your requirements now, that it is capable of growing with you, and can adapt to any changes you make in the future.

Then consider the long-term future – and this is really the most vital step when purchasing nesting software. Ask yourself the following questions revolving around where you want to be in five years time:

- Do I want to increase my output?
- Do I want to have fewer people?
- Do I want to be more automated?
- Do I want customers to log on to my website and upload files?
- Do I want to run my production without tying staff down to look at it?

If you answered yes to any of those questions, you need to be extra vigilant about the quality and capabilities of your nesting software. It must be capable of changing with you to accommodate JIT production in a highly automated, error-free environment.

Ask your potential supplier to take you through that full analytical process to ascertain what your nesting requirements will be in the future, and to tell you in detail how the nester can be used now, during the transition, and after the change. You may find that while the nester you were considering may be right for you now, it is less suited to your future requirements.

An easy benchmark for nesting products has always been material utilisation and speed, but a sea change is coming where nesting best practice will move towards integrating it fully into the whole production process. With series runs getting shorter as parts change and new innovations are brought in, manufacturers will need to optimise their parts and change to a more Just In

Time process. So the new benchmark is going to be how a nester fits into a regularly changing scenario that has different demands on it, such as the manufacturing process, the materials, full adaptability, and the constraints of the machine.

It is a difficult choice to make without being fully knowledgeable about how an individual nester can meet your specific requirements, because you may be producing JIT, or you may be producing something because your stock levels are low.

Multi-Threaded Code

And secondly, the future is here now in the form of the latest generation of nesters which encompass multi-threaded code. This is fast becoming an absolute pre-requisite for nesting software, as computers have multiple processor cores. Recent computers have two or even four processor cores, whereas traditionally they have had only one. In order to exploit that, nesting software must be capable of scaling up automatically as the hardware running it gets better.

Over the years CPUs have been getting smaller and faster. But there are physical limits on that, because the smaller and faster a computer is, the more heat it generates, and we would eventually reach the stage where the processor melts. So instead of making the parts faster, computer technology has developed the technique of having several CPUs on one chip, so even today's basic PCs have two processor cores, and it's getting increasingly common to have four. In the not-too-distant future, developments are likely to lead to computers having eight cores, then 16, then 32, so nesting software must exploit this with multi-threaded code which subdivides the problem. For example, software without multi-threaded code is only utilising half a two-core computer's resources, and where computers have four cores it would only utilise 25 per cent. Clearly not efficient.

While the market leading nesters are already incorporating multi-threaded code, there is a growing market requirement for this, so the nester can utilise multiple processors running at the same time.

Other Possible Trends

The limited use of multi-head nesting may change dramatically in the near future with the development of fibre-optic laser cutters. In the past, multi-head nesting was mainly used by specific markets such as heavy plate, ship building and raw material production. The laser head in traditional CO₂ lasers has always been fragile, and it has been difficult to get the focussing and the beam absolutely right. So adding extra heads would simply compound the problem. But fibre optics overcomes these difficulties with the light source, and duplicating that into a second head is becoming equally simple. If multi-head machines become more popular, multi-head nesting will also become a widespread requirement.

Nesting Farms are also likely to become commonplace. This is where nesting is taken beyond multiple processors on just one computer. Where other computers in the company are standing idle, some of the nesting work can be farmed out to them. This approach has the potential to dramatically increase the computing power targeted at the nesting problem. It may be that some companies offer the resources of arrays of processors for a “pay-as-you-go” approach to nesting.

Integration with MRP / ERP

To fully utilise the power of a nesting program in a modern manufacturing environment, integration with an MRP or ERP system is vital. Knowing what needs to be cut, and when by, is the most basic requirement. Of course, this information can be entered into nesting software manually, but it is far better if the link is electronic and automatic. Closing the loop so that the nesting software, together with the CAM system or even the DNC software, feeds back to the MRP software what parts have been nested, and on what sheets, is also highly important. Managing sheet stock (both standard size and, for higher value material, remnants), in a way that makes sure the nesting software is using material that is both available and most efficient, can save money and time, and make sure that ordering and organising sheets is as painless as possible.

Dealing with “emergencies”, whether caused by urgent orders or re-work required because of parts being scrapped in a downstream process, can be handled in an ad hoc way with the operator using the nesting software manually. But it is better for this to be dealt with properly by the MRP system and the required re-nesting to be done in a way that both allows the new parts to be dealt with swiftly, and also ensures that the episode is captured so that any causes for re-work can be properly monitored and improved upon.

Another potential benefit is in improving the speed and accuracy of estimates and quotations. A properly integrated system can accurately gauge how much material would be used to fulfil an order, and also predict delivery times given the machine loadings already committed to.

Before You Buy

With the sea change in what nesting can do for companies, and how it can be fully integrated into the complete production process, enabling manufacturers to take their businesses to the next level, it is vital that you make the correct decision about your nesting software.

To gain that valuable competitive edge, it is no longer enough just to look at nesting as a purely geometric solution. With the development of algorithms meaning that the nesting program *that is*

absolutely right for your business can give considerable added value, the power of the nester touches an increasing number of aspects of a manufacturing business.

When considering investment in nesting software, some key considerations are

- The difference between JIT and manufacturing for stock
- The ability to prioritise based on due dates
- Whether machine set-up times are important (e.g. keeping tooling changes to a minimum on a punch press)
- The degree to which integration with ERP / MRP will be utilised.

Therefore, it is essential that your potential supplier undertakes a full analytical process with you about your current requirements along with your requirements in five years time, and demonstrates fully how the nester you are considering will handle your manufacturing processes currently, during the change, and when those changes are fully operational.

There are many nesting programs with varying degrees of capability, so it is essential that manufacturers understand what they need their nester to do -- not only today, but in the future, too – what is available, and how their particular nester will give them a competitive edge.

Fully integrating the nester – and indeed the complete CAM system – into a company's ERP or process planning systems will ultimately become standard. The opportunities are available to have that future standard, today.

MODERN NESTING

Changing the way you think about nesting