# Proverbs, Opinions and Folklore

**Bruce Batchelor,**

**Paul Whelan, Dublin City University, Dublin, Ireland**

---

The following observations, comments and suggestions are based upon the experience of the author and his colleagues. While this list is presented in a light-hearted manner, it encapsulates some important lessons that are unfortunately not universally appreciated or applied when designing or choosing a new vision system.

# General

There is more to machine vision than meets the eye.

> *A machine vision system does not see things as the human eye does.*

An eye is not a camera. A brain is not a computer.

> *Machine vision systems should not necessarily be modelled on, or intended to emulate human vision.*

Machine vision is not a scientific discipline.

> *Machine vision is not an exercise in philosophy but an engineering project.*

No vision system should be required to answer the general question "What is this?"

> *It is better for vision systems to answer more specific questions, such as "Is this widget well made?" Verification (i.e. checking that the widget is well made) is better than recognition, where few or no a priori assumptions are made.*

Intelligence $\neq$ Computing power.

> *Making the computer more powerful does not necessarily make the system smarter*.

Optimal solutions do not always exist.

> *If they do exist, optimal solutions may be too complex, or impossible to find. We should therefore be prepared to search for and accept satisfactory solutions, rather than optimal ones.*

Use a standard solution to a vision problem but only if it is sensible to do so.

> *Wherever possible we should provide standard solutions to industrial problems, since this helps to broaden the application base.*

Avoid the application of machine vision techniques for their own sake.

*It is vanity on the part of the vision engineer to do so. There are plenty of other methods of solution available. Most of them are cheaper than vision.*

Defect prevention is better than cure.

*We should consider using vision in closed loop feedback control of the manufacturing process.*

Do not rely on second-hand information about the manufacturing process and environment.

*The vision engineer should always see the manufacturing process for himself. If the customer is unwilling to let the vision engineer into the factory, it may be necessary to abandon the application.*

Vision systems need not be fully automatic.

*While it is more usual to use a fully automatic vision system, it can be used instead to enhance images for subsequent human analysis.*

# Systems

No system should be more complicated than it need be.

*This is a reformulation of Occam's Razor, which in its original form is "Entia non multiplicanda sunt." In its English translation, excessive complication is attributed to mere vanity. In colloquial use, this is often referred to as the KISS principle. (Keep it simple, stupid.) Simple systems are almost always the best in practice.*

All parts of a properly designed machine vision system bear an equal strain.

*Of course, it is impossible to measure strain in any formal sense. The point is that no part of a vision system should be made more complicated because a sloppy attitude has been adopted during the design of other parts. A particularly common error is the tendency to concentrate on the image processing, to the detriment of the image acquisition (i.e. pose of the object being inspected, lighting, optics and sensor).*

If it matters that we use the Sobel edge detector rather than the Roberts operator, then there is something fundamentally wrong, probably the lighting.

*This remark is not about the relative merits of the various edge detection operators but is a statement about the need for a broader "systems" approach. A common error is to pay much more attention to the image processing process but ignore the fact that the image contrast is low because the lighting sub-system is poorly designed.*

The following inequality is always true: Vision-system ¹ PC + Framegrabber + Camera + Software.

*To many people, these are the only components needed to build a vision system. However, this neglects many important issues: lighting, optics, systems integration, mechanical handling, ergonomics and standard industrial inspection practice.*

Problem constraints allow the vision engineer to simplify the design.

*By taking systems issues into account, it may well be possible to design a simpler, faster, cheaper and more robust system.*

Vision systems can use the same aids as people to reduce task complexity.

*For example, special optical/lighting techniques, X-rays, fluoroscopy, multi-spectral imaging, specialised sample preparation can all be used.*

Documentation is an essential part of the system.

*A vision system will not survive for long without sufficient documentation.*

# Customer

Whatever software and hardware that a machine vision system uses, the customer will want it to be different, so don't tell them.

*Many customer companies have a policy of using certain types of computer hardware / software, which will often conflict with the vision system. It is wise to regard the vision system as a closed box.*

The customer must not be allowed to tinker with the system after it is installed.

*The customer should be dissuaded from making internal adjustments to the system, since this requires rare and specialised skills (lighting, optics, camera, algorithms, systems integration).*

The customer's company just does not make defective widgets; the vision system is simple intended "to improve product quality".

*Companies are often sensitive about the way that quality (or lack of it) in their products is discussed. This must be borne in mind when designing a vision system and particularly when reporting developments at conferences, in publications, etc.*

Everybody (including the customer) thinks that they are an expert on vision and will tell the vision engineer how to design the machine.

*This is, regrettably, one of the great truths. As a result, everybody will feel it is their right and duty to tell the vision engineer how to do his job. In many instances, prototyping tools need to be used for the specific purpose of convincing the customer that his intuitive approach just does not work reliably.*

The widgets that were provided for the feasibility study were specially cleaned and chosen by the customer for the project.

*Beware of the pernicious habit of some customers who deliberately, or through ignorance, select good quality products to show the vision company, rather than providing a more representative sample.*

Customer education is an integral part of vision system design.

*A well educated customer can help to reduce the project cost and may well help to reach a better system design.*

A little knowledge is a dangerous thing.

*The customer will suggest many changes to the system design if he is ignorant of the subtleties which led to the present design. It is best to tell the customer all or nothing. For example, the vision engineer should not tell the customer that the system uses a camera costing $5000, because the latter will know of a camera that costs only $100 but will not appreciate the benefits of the more expensive device.*

# Financial

The vision system must pay for itself in 6 months.

*The vision engineer must be prepared to argue against the simple-minded attitude which attempts to judge the value of a vision system solely on financial grounds. When a company buys a vision system, it is investing in the improvement of the quality/safety of its products.*

Component cost is not the same thing as system cost.

*By purchasing one relatively expensive component, it may be possible make the overall system cheaper, faster and more reliable.*

Only ten percent of the cost of installing a vision system is directly attributable to the requirements of image formation, acquisition and processing.

*The remaining ninety percent of the project cost is due to making the system work properly in the factory.*

$1 spent on inspection is worth $10 in improved profits.

*Investing a little in automated visual inspection can lead to significant gains in improved efficiency.*

# System Specification

The specification of the vision system is not what the customer wants.

*Do not try to take short cuts in the initial dialogue. The vision engineer should be prepared to spend a considerable amount of time finding what the customer really wants.*

The system specification must be agreed and fully understood by all concerned.

*All specifications should be in writing with negotiable and non-negotiable specifications noted before the design proper begins.*

No machine vision system can solve the problem that the customer forgot to mention when placing the order.

*Undertake a proper and complete design study for each type of product.*

The specification of a vision system should indicate its functionality and performance.

*It should not be used merely as a marketing tool.*

Beware when the customer says "By the way! We would like to be able to inspect these objects as well."

*We repeat the point just made above: undertake a proper design study for each type of product.*

Simple accept/reject labelling is easier than classifying defects by type.

*If the customer wants to classify defects, they should be made aware that this could have a major bearing on the cost of the inspection system. Detailed classification of defects can greatly increase the speed/cost of the vision system.*

It may not be possible to classify defects reliably.

*The classification process may not always be clear-cut. A certain product may, for example, have a combination of faults. The vision system supplier and customer must agree beforehand what bounds are to be imposed on the classification process.*

Specify the operating environment.

*It is relatively easy to make a system that works well in the laboratory. However, it is much more difficult to build a target system that will work reliably in a hostile factory environment.*

Defect types must be realistically prioritised.

*The ranking of defect types in order of importance can have a major influence on the approach taken, and hence the final cost of the solution. For example, it may be the case that 90% of defect types can be detected for a cost of 90% of the total project budget, whereas detecting the remaining 10% of defect types would cost another 90%. (This is an example of the 90:90 rule.)*

# Choosing Inspection System Design Samples

Maximise the number of product samples.

*The feasibility study, the target system design process, the testing and evaluation of the target system and any demonstrations to the customer should all be based on a large number of representative sample parts. These samples should cover the full range of part variability.*

Choose design samples following proper statistical sampling techniques.

*Their selection should be made according to a carefully planned and agreed protocol.*

If necessary, choose inspection samples manually using agreed criteria.

*If samples are chosen manually they will need to be cross-checked to ensure that the variation found in manual inspection is minimised. It is critical that the vision engineer establishes a reliable training set.*

The customer said his widgets were made of brass. He did not think to state that they are always painted blue and oily.

*To the vision engineer, the surface finish is more important than the underlying material. This contrasts sharply with the customer who often regards surface finish as being of mere cosmetic value.*

Classify sample defects.

*There are many different ways in which a product can fail to meet its criteria. Any specific application knowledge that the customer can add concerning the type and origin of the fault, will be useful in the design process.*

# Vision Company

A sales-person who says that their company's vision system can operate in uncontrolled lighting is lying.

*No. We are not exaggerating. The human eye cannot. No machine can either.*

A happy vision team has (at least) seven players.

*This consists of engineers who specialise in mechanical handling, lighting, optics, video sensor technology, electronic hardware, software, vision system integration.*

# Alternative Solutions

What a person cannot see, generally cannot be detected by the machine vision system.

*The human eye is remarkably adept and versatile. In contrast, a vision system is clumsy and unsophisticated, although it may be faster and more reliable. It is a good maxim to admit defeat sometimes as this will gain customer confidence, in the long term.*

It may be cheaper to hire a person to inspect the widgets.

*However, a machine may be faster, more consistent and reliable. Be prepared to argue this point with the customer.*

Machines can do some things better than humans.

*Machines can sense outside the visible spectrum (X-rays, IR, UV). Line-scan cameras and laser scanners can produce high resolution images that cannot be seen directly by the eye. Depending on the technology used, a machine vision system would be expected to achieve a substantially higher inspection efficiency, and it can theoretically do this for 24 hours a day, 7 days a week. Machine vision can also be useful at detecting gradual changes in continuous processes that appear over long time periods. For example, inspecting gradual colour variations in the production of web materials. Such a gradual change in colour is unlikely to be detected by a human operator.*

People can do some things better than machines.

*So far, no machine has been built that can reliably guide a car through busy traffic, safely and at speed. No machine can yet judge the aesthetic qualities of a person's dress or a fine painting.*

Even the best human inspector is only 70% efficient.

*This is one of the best arguments in favour of using machine vision. A person is easily distracted, for example by a good-looking member of the opposite sex walking past. The performance of a human inspector falls as a results of boredom, dissatisfaction with employment, distress due to a recent argument, illness, fatigue, hunger, discomfort, pain, alcohol and drug ingestion.*

Machines can work in situations that people cannot tolerate.

*Machines can work in radioactive, chemical and biological hazards, where there are high levels of noise, IR, UV, X-ray and microwave radiation, or it is very hot. Machines can tolerate flashing lights, which would induce epileptic fits and migraine attacks in people. A camera can operate under very high, very low, or suddenly changing pressure, and can also be used safely where there is a danger of explosion, or brittle materials are likely to shatter suddenly. A camera can be placed close to a laser cutter, which would be dangerous to a human being. A person cannot inspect the inside of a working jet engine, nor even a drain pipe.*

Human inspection often comes free.

*Packing and assembly operators can inspect objects without adding (significantly) to the overall cost of the manufacturing process.*

Neither a human inspector, nor a fully automated vision system, will always get the best results.

*It is sometimes better to employ a person working in symbiosis with a machine vision system.*

# Mechanical Handling

However deformed the widgets are, they must all pass through the inspection system without jamming.

*If the full range of defective widgets cannot be fed properly through the inspection system, then it is of no use whatsoever. It is an irony that one of the main aims of automated visual inspection is to preventing jamming of a mechanical sub-system, such as an assembly machine.*

If the parts feed mechanism of the inspection system can go wrong, it most certainly will and the camera will be crushed.

*Be prepared to sacrifice the camera, lighting and/or optical sub-systems, in the event of a failure of the feed mechanism. Design the system accordingly.*

# Lighting and Optics

Many hands make light work.

*... but not very well. However, some people do apply proper engineering principles to the design of the optical sub-system and inevitably obtain better results.*

The lighting is not constant.

*Lighting is never constant in either time or in space.*

Never use software to compensate for a poor lighting system.

*It is not cost effective and will result in a poor system design.*

It is cheaper to add a light-proof shroud to keep sun-light away from the object under inspection than to modify the software.

*Another universal truth which is often forgotten.*

Nothing exceeds the speed of light.

*Any processing that can be done optically will save a lot of computer processing later.*

It is all done by mirrors.

*Wishful thinking, in view of the previous remark.*

# Image Resolution

Any feature whose diameter is equal to 0.1% of the width of the camera's field of view, requires an image resolution better than 2000x2000.

*Nyquist's Sampling Theorem places a fundamental limit on the image resolution. This is often forgotten / ignored by advertisers on broadcast television, who frequently place disclaimer notices about their products on the screen, using printing that cannot be read properly because it is too small The same principal applies to machine vision.*

A (100x100) picture is worth 10000 words.

*The ancients were very astute when they realised that a digital image requires the storage and processing of a lot of data.*

One high-quality image is better than 5 fuzzy pictures.

*Few people would dispute this point.*

Five fuzzy pictures are better than one high-quality image.

*No! This does not conflict with the previous proverb. It may be cheaper and easier to obtain the required information from a small set of low-resolution images than to process one very high resolution image. For example, it may be necessary to see several small features within a large scene. In such a case, it might be appropriate, say to use 5 low resolution images (e.g. 256*256), rather than one image of much higher resolution (e.g. 2000*2000).*

# Related Disciplines

Machine Vision $\neq$ Computer Vision.

*Machine vision is concerned with Systems Engineering and the solution of practical problems, such as guiding industrial robots, inspection and process monitoring. On the other hand, Computer Vision concentrates on the concepts and scientific basis of vision . The latter is concerned with generic issues and takes inspiration from and is often used to model human and animal vision.*

Machine vision research is not a part-time activity for workers in Image Processing, Pattern Recognition, or Artificial Intelligence.

*Some people think it is, unfortunately. The solutions they offer to industrial inspection problems are, at best, unreliable and over-complicated, because they are unaware of the broader "systems issues", such as image acquisition, QA practices, industrial engineering etc..*

# Environmental Protection

Protect the machine from the work place.

*A factory is a hostile place, with lots of dirt, tampering fingers, etc.*

Protect the work place from the machine.

*Protect eyes from flashing lights, lasers, etc. Make sure that the inspection machine does not shed bits, such as nuts, bolts, etc. to contaminate food products, pharmaceuticals, etc.*

It is cheaper to pay for a shroud to enclose strobed light than to pay compensation for causing epileptic fits.

*Flashing lights can trigger epileptic fits and migraine attacks.*

The lens may not fit the workman’s camera at home, but he thinks it will.

*Be aware of light fingered workers causing damage by removing pieces of equipment.*

"He is a good worker and likes to keep things clean - he washes down all of the equipment using a hose-pipe, every afternoon".

*This is quotation from one factory manager about a dedicated, but uninformed worker who did not realise the potential damage and danger his actions could cause. It is imperative therefore that the vision equipment be made safe and robust.*

Adjustment of the camera is achieved using a 1kg hammer.

*Vision engineers will be horrified at this prospect but it may happen.*

Factories are dirty places.

*The electrical power supply is noisy. The air supply, for pneumatic equipment, also carries dirt, moisture and oil. Dirt, dust, moisture, fumes, spray, etc. all abound in the local atmosphere.*

# Proving and Working with the System in the Factory

Do not assume that the factory workers are computer literate.

*Software should be designed in such a way that it can be used with minimal computer skills.*

The people who will make sure that the machine will not work are standing beside it.

*So, the vision engineer should try to persuade them that it is actually in their best interests (as well as his) to work in co-operation with the treasured vision system, not against it.*

A picture is worth ten thousand words.

*Give the workers a television program to watch. A visual display, showing performance statistics of the vision system and explaining its operation is well worth having, even though it may not seem to be essential.*

People "understand" pictures.

*A visual display is a useful way of building the confidence of factory personnel. It is also a valuable diagnostic tool: a person can easily recognise whether a sequence of images, showing the operation of the vision system is being repeated properly.*

The service schedule of the vision system should be compatible with the production line.

*If it is not, the vision system will not fit into the factory environment properly.*

For every hour you spend on inspecting products, your smarter competitor spends 10 hours improving their process.

*Automated inspection is not always the best way to get the desired results.*

Document all experiments to validate the system.

*All laboratory and on-site trials in the customer's premises should be fully documented. This should include details about the hardware and software used, parameter settings, optical and lighting set-ups, lens* *distance, aperture settings and mechanical handling features, how the products were selected.*

Quantify the system performance.

*The ability of the system to perform to the agreed specification should be demonstrated and quantified. Accuracy, repeatability, robustness, feature delectability and tolerance of product variation should all be measured and recorded. All demonstrations should be attended by the vision application engineer(s) who are ultimately responsible for the system design and implementation.*

Results may not be reproducible.

*Wherever possible, the results of all system performance tests should be reproducible and statistically characterised as to repeatability. In certain applications, for example the inspection of natural products, the variation in product characteristics make it difficult to implement this approach.*

Align, calibrate and then test the system before it is used.

*A badly aligned system, or one which has not been calibrated, is likely to produce erroneous but seemingly reasonable results.*