Reliable Vision Application Development

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Reliable Vision Application Development

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Producing a reliable vision system is no accident. It begins with creating a strong specification that carries through to component selection to system development and finally deployment. This course will help the end user and the integrator walk through the steps needed to enhance their projects success. Individuals of all experience levels will benefit from the techniques that will be conveyed during this course.

A Little About Me

- I have been around a while
  - Back when fourtran was threetran
  - Back when we played Xbox on the Radio
  - Back when computers cost tens of thousands
  - Back when a machine vision system meant taking pictures with film, and then analyzing images by hand.
  - Back when RS-170 was the ONLY camera standard

Preaching To the Choir

- I expect ‘yall are machine vision professionals of one stripe or another.
- I expect many of you know more than I do about putting robust systems in the hands of customers.
- Maybe my value is that I know something different.

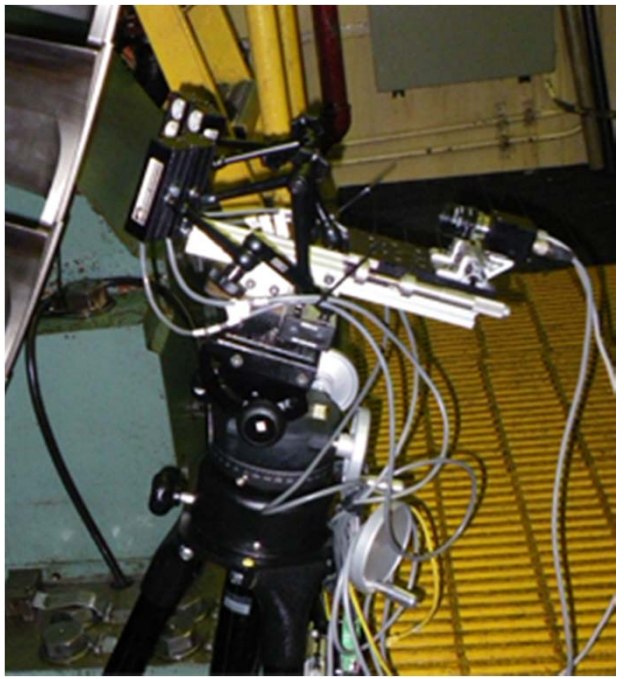
Best Practices

- Better practices across the industry means more successful installations
- Success breeds...
- I not only want to hear from you, but want those ideas to be shared
- Think about what you can share – take notes
- You can pass them on anonymously or take credit

ON with the show

Where to Start

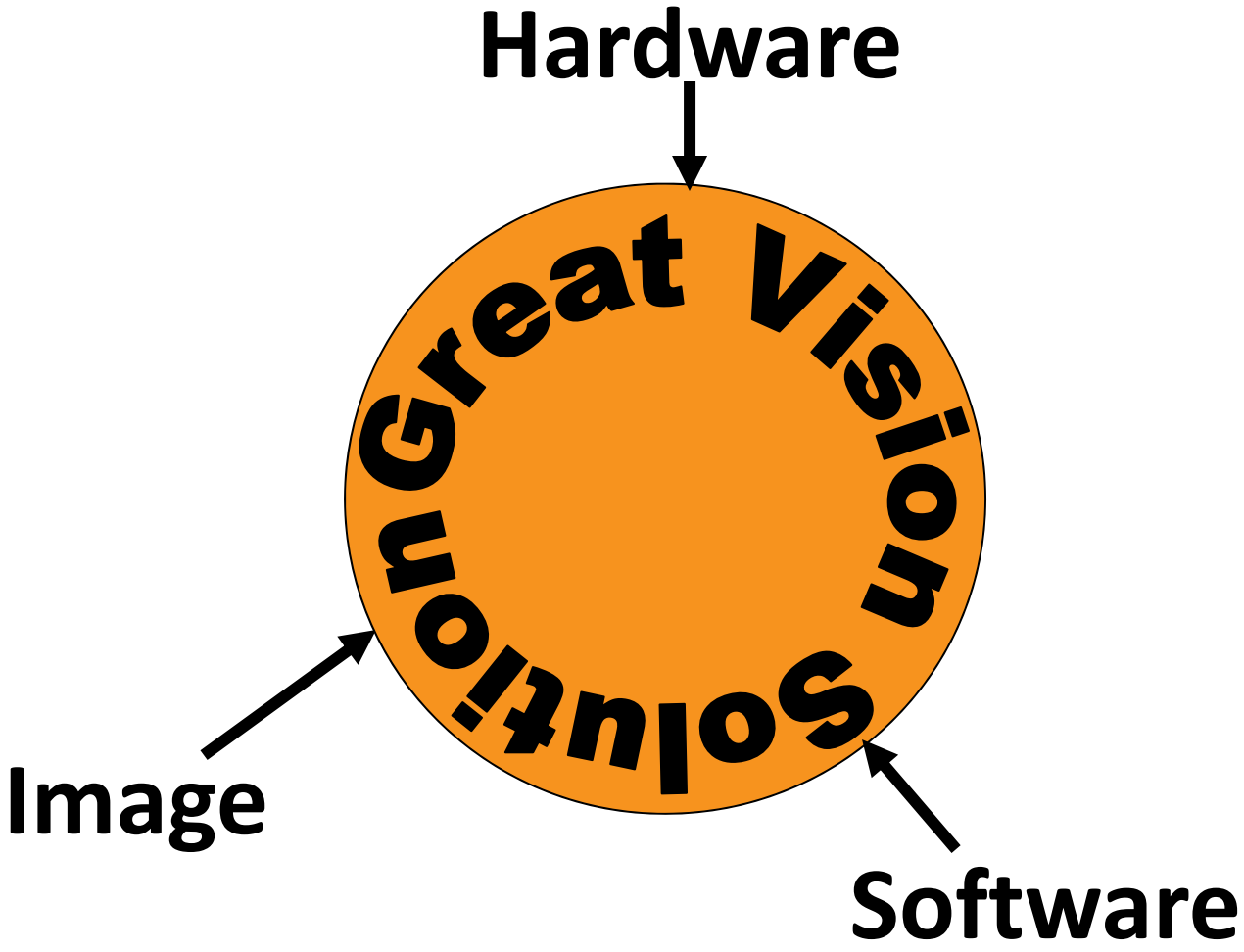
- What is a machine Vision System?



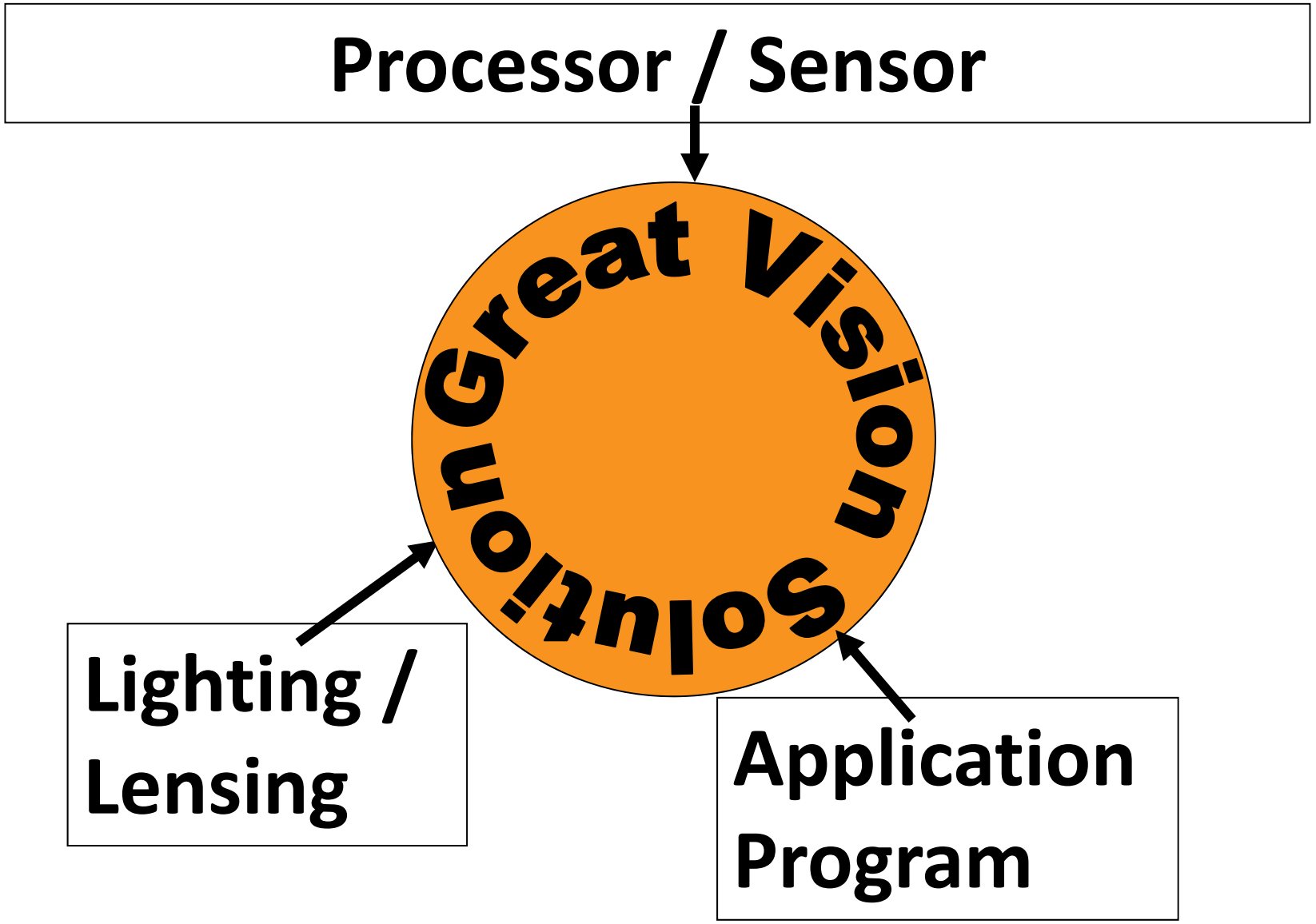
What IS a Machine Vision System?

- Just a camera connected to a computer running a program?
- A camera and a lens connected to a computer running a program?
- A camera and a lens, with lighting, connected to a computer?
- A camera and a lens, with lighting, mounted with hardware, connected to a computer running a program?
- A camera and a lens, with lighting, mounted with hardware, connected to a computer running a program that is connected to factory automation?
- A camera and a lens, with lighting, mounted with hardware that moves the subject or camera, connected to a computer running a program that is connected to factory automation.
- A camera and a lens, with lighting, mounted with hardware that moves the subject or camera, connected to a computer running a program that is connected to factory automation, and a corporate relational database?
- **And the green grass grows 'round and around'…**

The Simple Vision Solution



The Simple Vision Solution



Now to Make it Robust!

- It has to work
- It has to work well
- It has to communicate the essential information to the customer
- The guys on the plant floor have to accept it
- It has to keep working in the face of adversity
- It has to survive the production run

The Shop Floor

- The product must
  - Be easy to use
  - Be easy to maintain
  - Be easy to modify in the face of production changes
  - Run in the face of adversity

The Face of Adversity

The Ambiance

- Environmental Considerations
  - Ambient Lighting
  - Ambient Temperature
  - Ambient Pressure
  - Ambient Weather
  - Electrical
    - Spikes
    - Noise (RF, Line Carried)
    - Dropouts, Sags
    - Blackouts

The Face of the Product – The Interface

- The software is how the customer interacts with the vision system.
- For some systems the interface is invisible. The customer only sees a data stream that carries the desired information.
  - Too Big, too small, too bright, missing parts, extra parts.
- A happy customer is one who does not think of the inspection system as a machine vision system, but a sensor. Better yet, a sensor that the plant electrician can pull off the shelf in a store room, install on the line, program with a screwdriver or a pushbutton, plug into a PLC, and get on with his job.
- Since cameras are not quite that smart yet, the industry develops complex inspection systems that require a skilled operator to keep running.
  - That skilled operator will be lucky to adequately trained.
  - The interface should be easy to follow by the guy on the shop floor (not by the guy that wrote the program).

The Invisible Interface

- On the other end of the spectrum are inspection systems that have more in common with prox sensors than machine vision.
- They put out a few bits of data
- They talk to a PLC
- They are plug and forget
- They are just another sensor on the network

- The advent of the smart camera was the first step in turning machine vision systems into sensors, and the evolution has continued. Systems like the Cognex Checker, and the Omron ZFV are small dedicated, programmable systems that are “easy” to install and set up. They also have very limited options.

The Visible Interface

- Looking at web sites that expound the capability of a given vendors product often show an operator standing in front of a video screen with an image of a product overlaid with boxes, circles and other hieroglyphics that are meaningful to someone skilled in the art, but probably not a shop floor manager who just wants to insure product quality. Perhaps the message is that one companies magic runes are better than another's.

The Value of a Machine Vision System

- Generally, the point of putting a sensor on a manufacturing line is to drive cost out of the process, or increase the value of the product by assured quality, occasionally, public safety is driving factor.
- The investment in the sensor, whether it's a machine vision system, or a micro-switch, must be recovered in a timely fashion.
- Vision systems
  - Replace Human Inspectors
  - Enhance Human Inspectors (Aid To Visual)
  - Perform Inspections beyond human capability
  - Improve safety in harsh environments

Robust Vision System – Customer Pitfalls

- If the customer gives you good parts to train on, how do you know what a defect really looks like?
- If the customer gives you 10 defective parts, is that a sufficient sample quantity to train on?
- Will the customer tell you that (in 6 months to a year) they are changing ink color on a fiducial mark, or changing the color of silk screen on a PCB, or will they just be very upset when the inspection system rejects all of the parts from a new second tier supplier.
- Will the customer make sure their people are trained on the equipment?
- What is the REAL end goal of the customer?

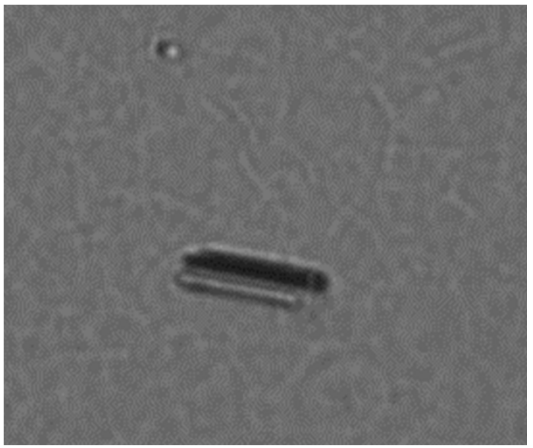
Short Case History - Plastic Sheet

- Human inspector
- Manual data collection
- Very low throughput
- Lots of escapes

- The customer was surprised when the defect rate skyrocketed with automated inspection
- They were warned
- They believed that Automated inspection would reduce defects
- In the end the product improved with the help of automated inspection

Learning From Other Peoples Mistakes

- I had a customer that wanted to find 50 micron defects in plastic sheets.
  - The system worked great.
  - It was built with close collaboration of the customer QC department.
  - The system was used to find the root cause of 50 micron defects.
  - The root cause of the 50 micron defects were eliminated by manufacturing with the help of the inspection system.
  - Now the problem was 10 micron defects.
  - Had I seen the future, I would have suggested a 10% bump in cost and a higher resolution system.
  - The system was robust, but… the customer ended up spending a lot of money to upgrade the software.
  - On the bright side the system was good enough to detect the new class of defects
- The Lesson…assume your customers needs will change, and work to build in some flexibility to meet that change.

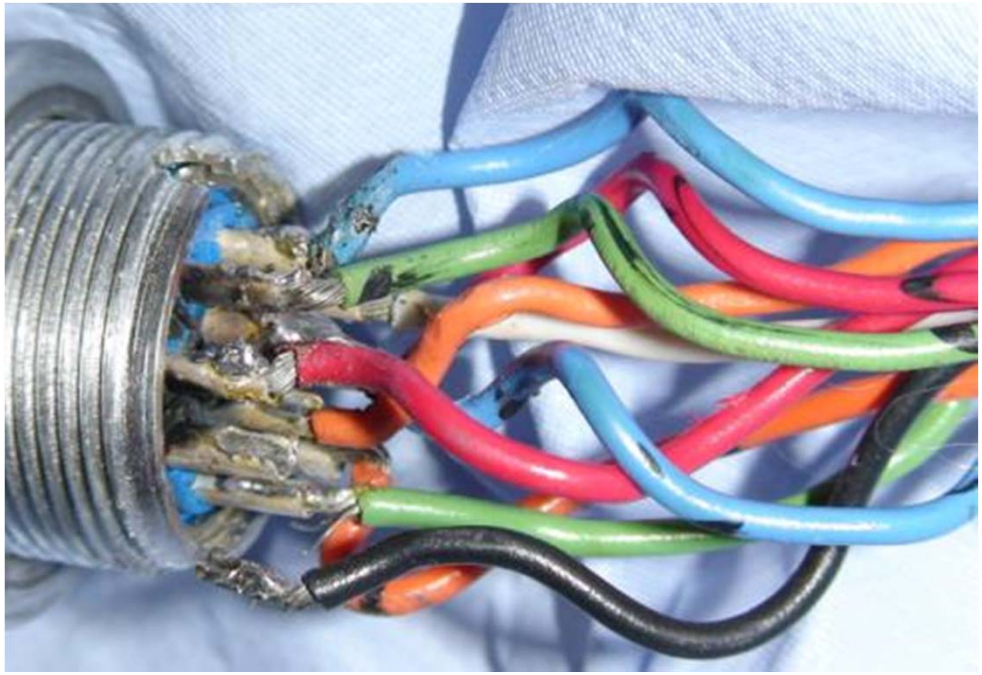


Original Defect

New Defect

Pitfalls

- Unintended consequences out of your control
- A system was installed, tested, and working fine for about 3 weeks, then… Nothing. Camera not found. Blinking lights are fine.
  - The difference between a day's lost production, and a 600 mile trip to the customer site was the right question.
  - "Is there a Firewall on the computer?"
  - Many corporations mandate anti-virus software and firewalls to reduce the speared of malicious software on a network. Sadly, it can also reduce the flow of information critical to an inspection.



Remote Support

How do you support a vision system when it's 600 miles away?

- Make sure that the customer can save "problem" images and get those to you.
- Make your you have a version of software that is functionally identical to the working version so you can test the image, and make adjustments.
- Remote log in is nice, but with viruses like Stuxnet around, it is getting less likely that customers will let you into a computer attached to their network.
- DOCUMENTATION
- TRAINING
- SIMPLE

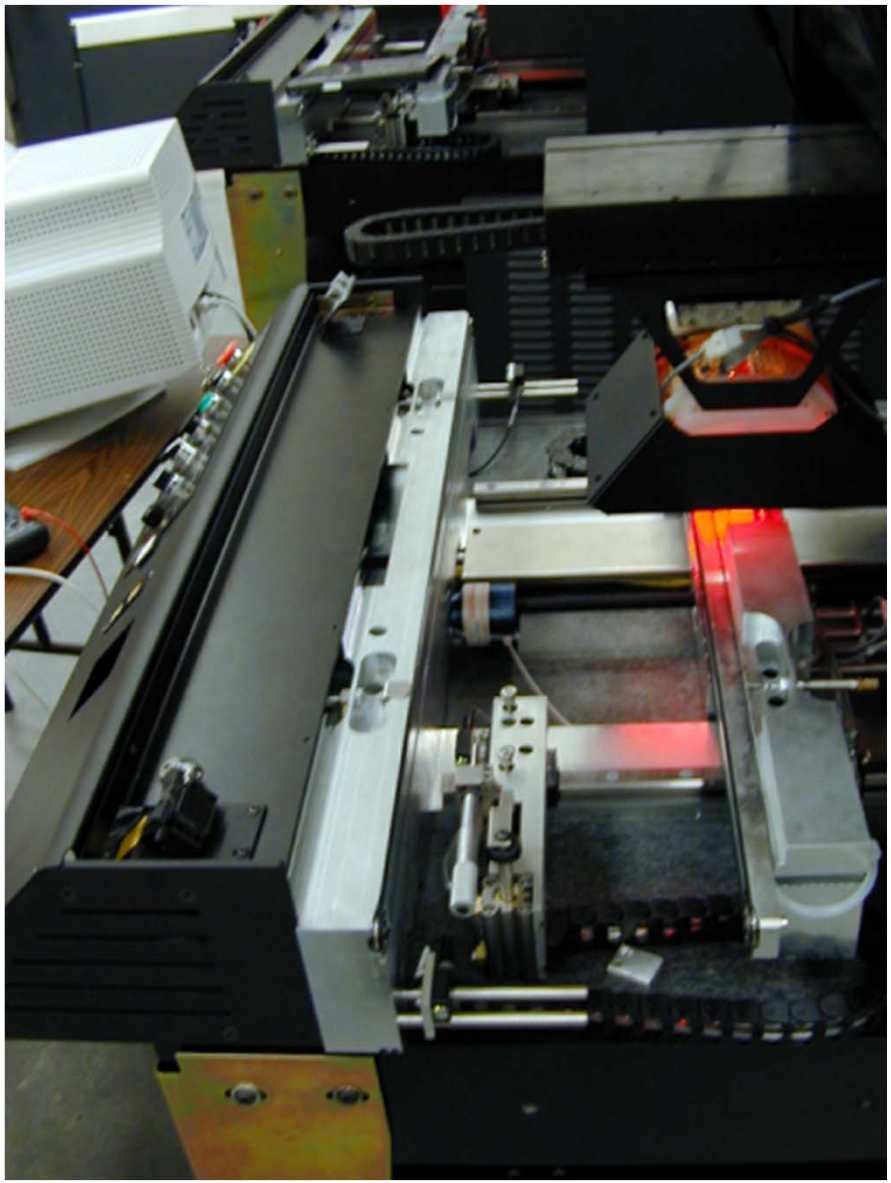
A really great vision system just works

- It does not need to be supported

Robust Lighting

- How much does it cost to change a light bulb?
- How much does the light bulb change over time?
- When choosing lighting vendors, I never paid much attention to the care the manufacturer put in to thermal management or how rugged the lights were.
- I even suggested to one company that building a light to last 10 years was silly in a world where a manufacturing cycle is typically less than 18 months.
- Then I encountered a harsh environment.
- The equipment survived.
- I was a happy customer.

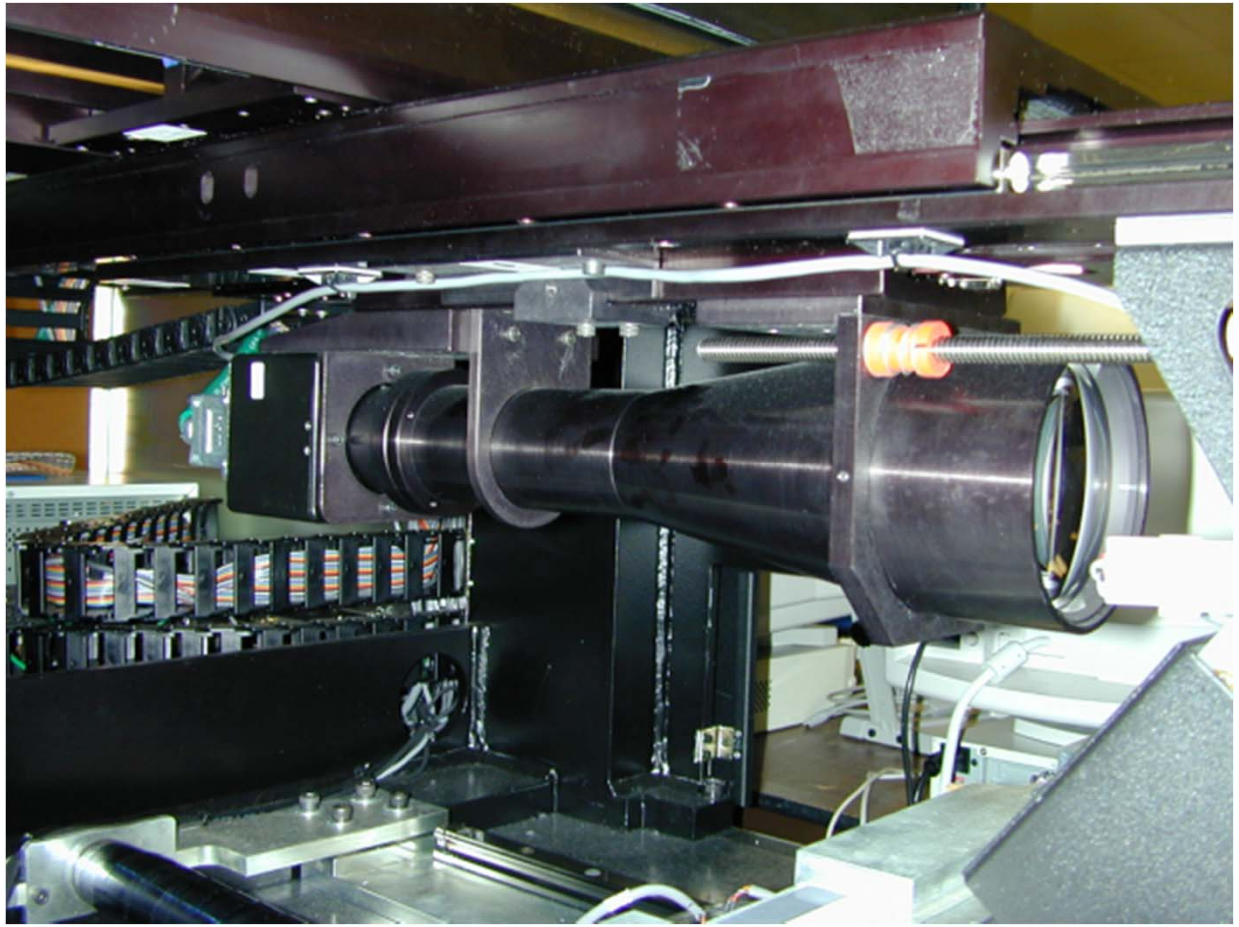
Robust Hardware



- Stone Soup
- Camera and a computer
- Add some software
- Mix in a light
- Put in a material handling system
- Add a defect marker

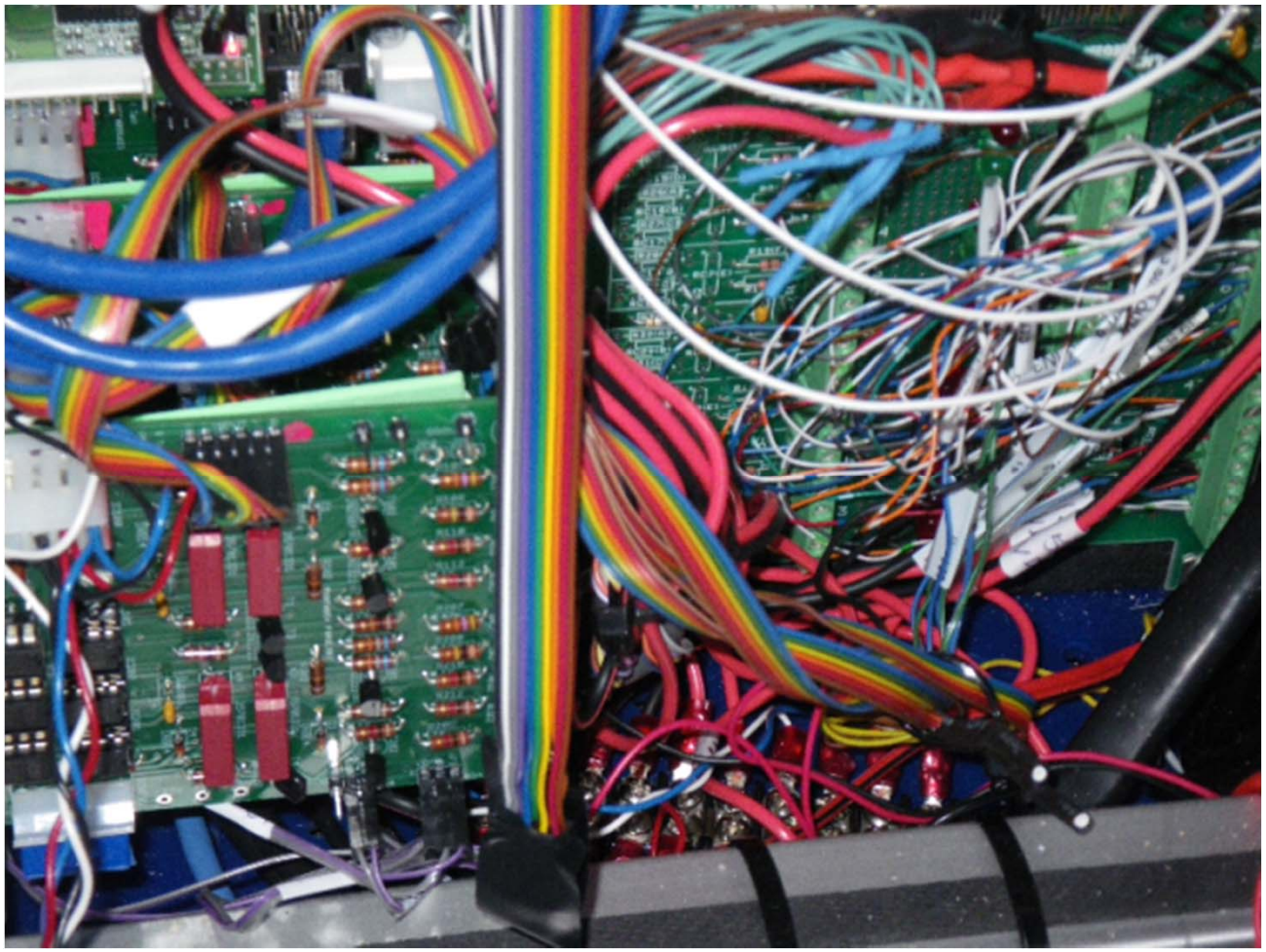
- When does it stop being an inspection system and become something else?

Savory Stone Soup



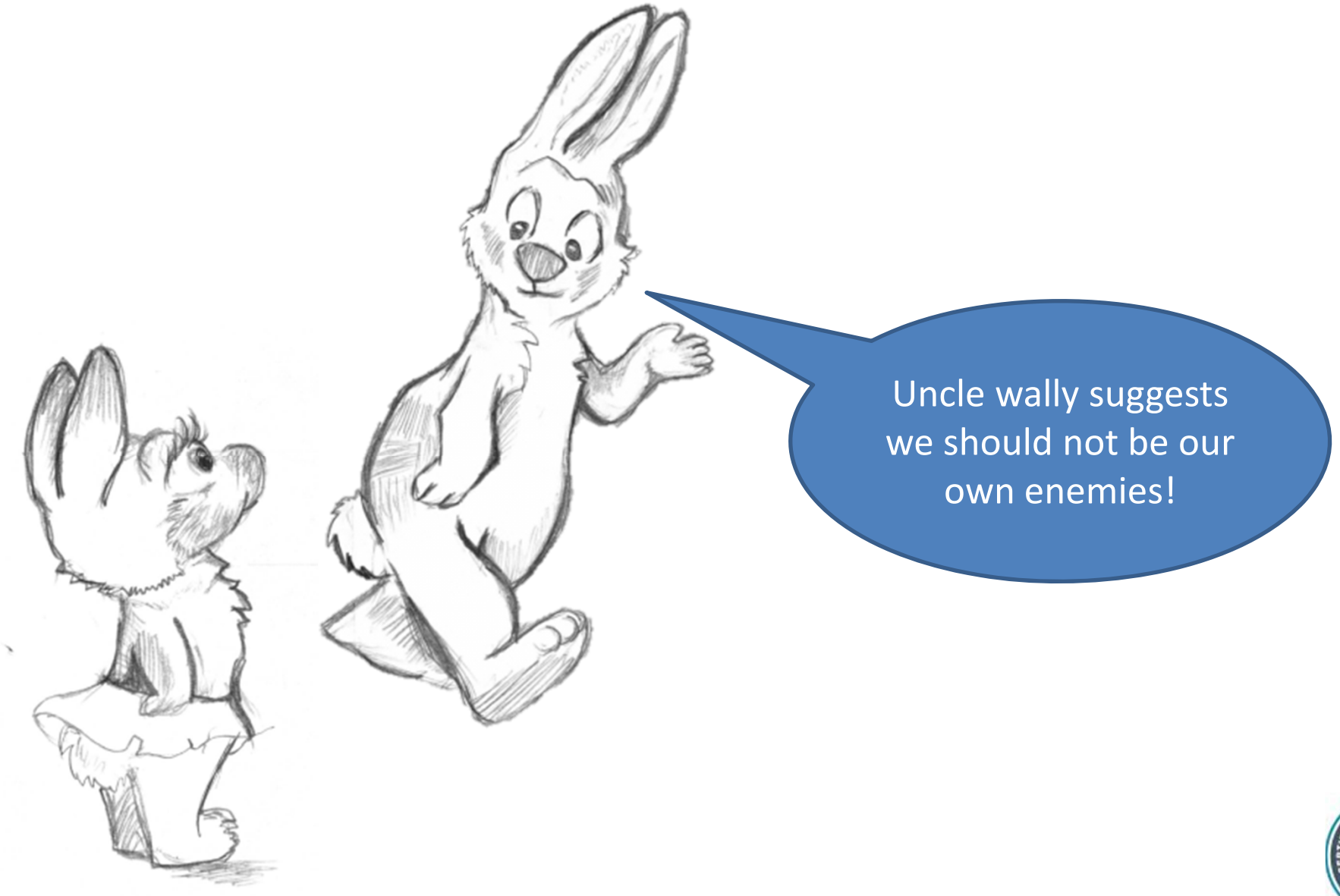
- Don’t forget a Custom Lens
- Shake and Bake
- Ship it
- See if it survived

Chef Boyardee?



- I see stuff like this all too often

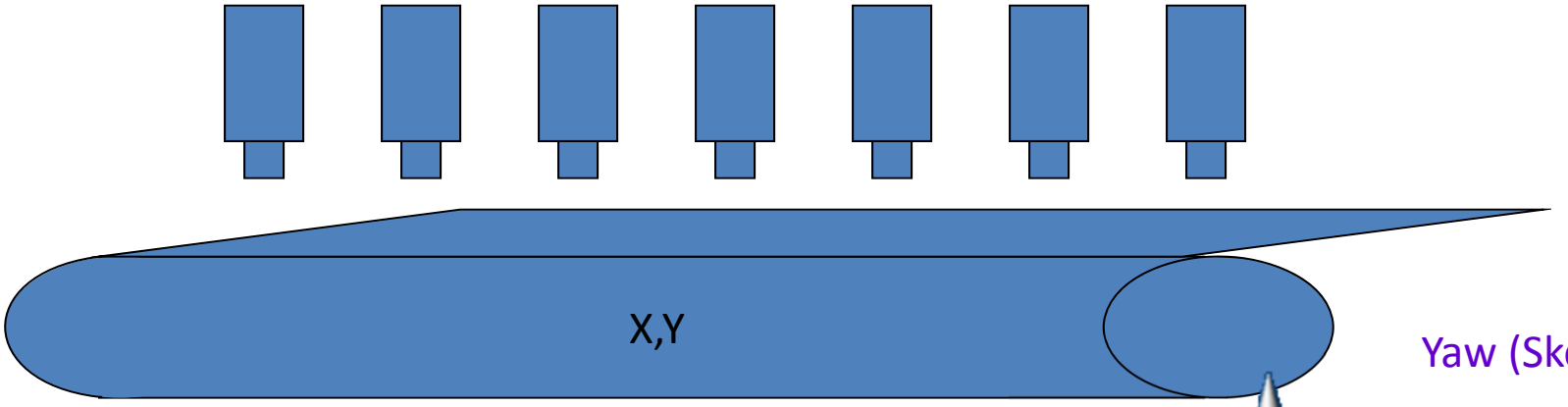
Fuzzy Bunny Page



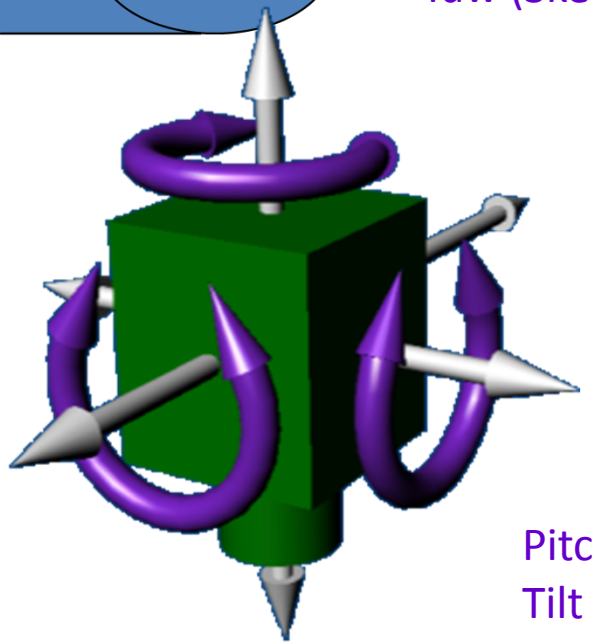
Robust Alignment

- Machine vision is used for metrology.
- This implies precision alignment and adjustment.
- **How many degrees of freedom do you need to control in your vision system?**
- How precisely do you need to control it?

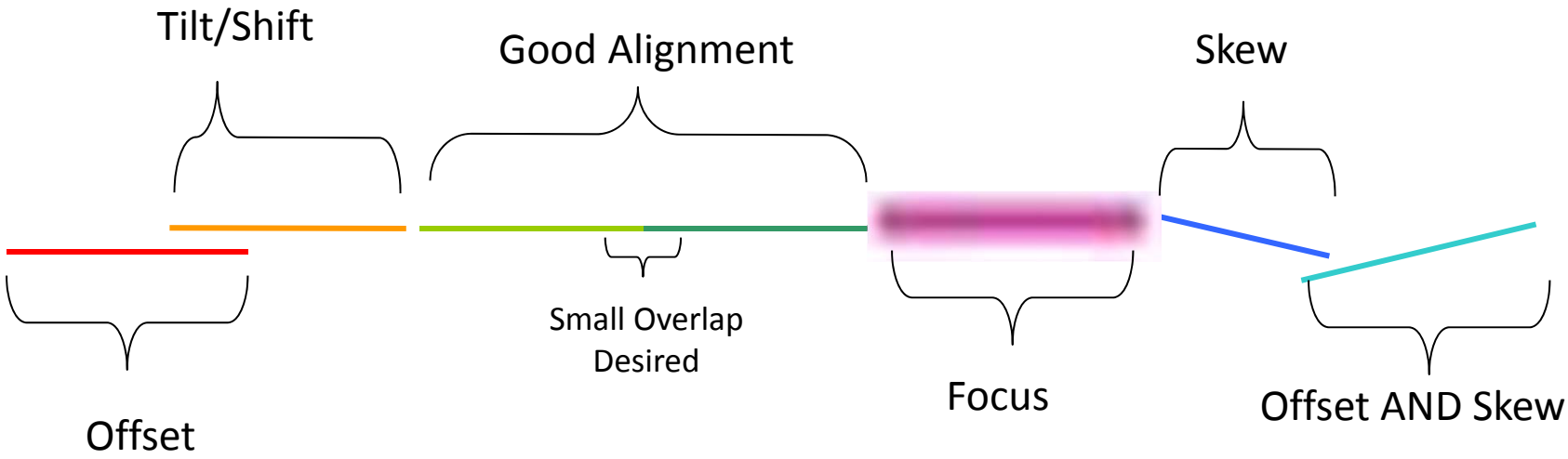
Multiple Camera Systems



- Issues with cameras
  - Skew
  - Focus
  - Rotation
  - Tilt
  - Shift



Camera View, Example of Errors

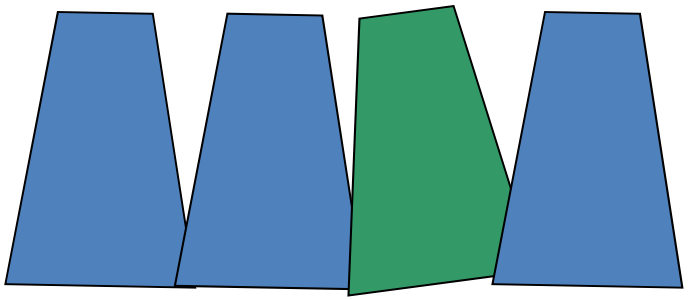


- Over time vibration may cause the mechanics of the system to drift. Essentially the camera can fall out of alignment because of shifts in roll, pitch, yaw, as well as X, Y, Z displacement.
- A calibration system will have to verify that these 6 factors are within tolerance

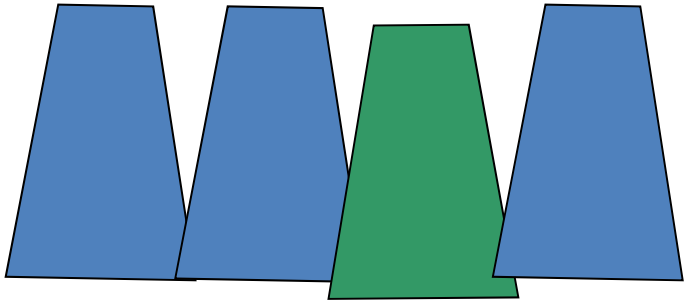
Understand the critical need to account and adjust all of the possible errors in a system

X-Z Plane Errors

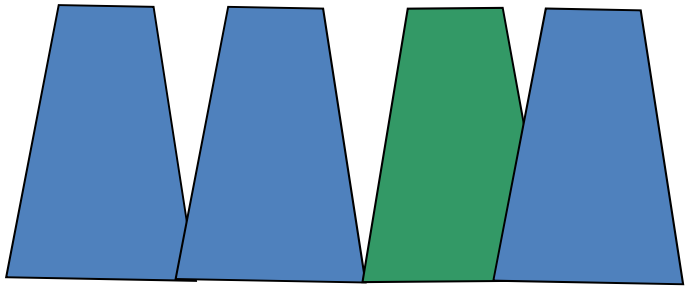
Roll



Z

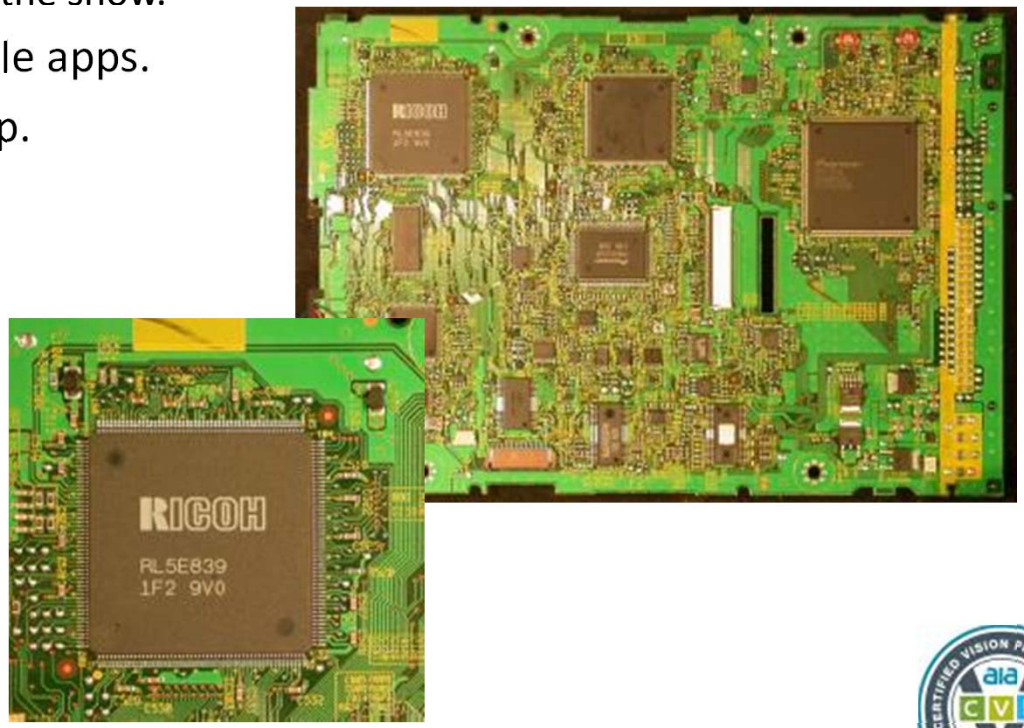


X



Don’t Waste Pixels!!!

- Taylor your lens and sensor to maximize the number of pixels that bring value to the image being processed.
- Save the customer, or your employer money by right sizing the sensor.
- Camera vendors will be happy to do the math for you.
  - Really, if you aren’t sure ask them to do the work.
  - If they are not helpful, find another vendor!
  - There are a LOT of them here at the show.
- Several have web or downloadable apps.
- Edmund Optics has an iPhone app.

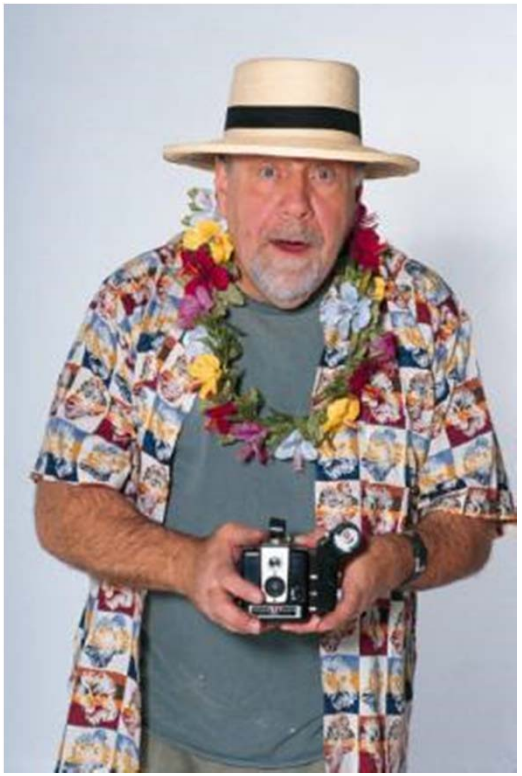


Know your image processing tools!

- Simple binary threshold may work, but a an adaptive threshold will work better. You can use ratios of histogram bin counts rather than absolute bin counts; template matching based on edges or correlation rather than absolute image subtraction. Such relative measures avoid many issues with lighting and can accommodate a wide change in lighting and part finish.
- You don’t need a degree in math to use the first derivate of an edge to get the mid point of a transition. Just call up a gradient tool.
- Get to know your filters, Gaussian, Lapacian, and so on.
- Play with FFT, there are some seriously cool things you can do with FFT.

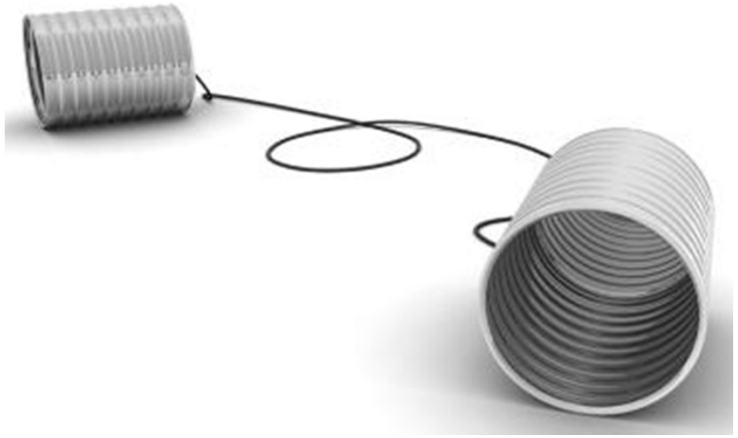
Advice to Managers / Employees

- Train your employees
- Give them some time to play
- Make a recipe book of image processing techniques



- Employees – find time to play
- Use social media
- The more skills you have…. well, it’s just better.

Talk to your Customer EARLY and Often



- If you can be part of the design team for the part, or the process line, you can suggest low or no cost changes that will improve inspection reliability.
- As part of the team you can work with the production folks to leave space for cameras at critical points, make the inspection before value added work is performed to a defective part.

Protect Your Equipment

- Factories can be nasty places. A dirty lens can alter measurements. Oil and water have optical properties that can confuse a camera. Mount the camera in a ridged fashion.
- Make sure there is a means to validate the installation on a regular basis.
  - An automatic self check is a great idea.
- Make sure there is procedure to clean the optics.
- Use solid mounts for the cameras and lights.
- Use mechanical pins or other methods in order to keep the camera and lighting where they belong.

Ask Others for Advice!

- You ask what makes a machine vision application successful. In my experience, it is one thing: reliability. I can't remember how many machine vision systems gather dust because they do not perform consistently causing false rejections and suspect measurement results…

James Campbell
Viewpoint Systems, Inc.
Rochester, NY

- Thoroughly evaluate a wide range of good, bad, and borderline parts. As you know, lighting is the most crucial part. Make sure to use the "proper light", not the one easiest to mount or power.

Perry Cornelius, PE
Terus Technologies LLC

Embrace the standards!

- GigE Vision®
- Camera Link®
- EMVA 1288
- Camera Link HS™
- USB3 Vision™
- CoaXPress
- GenICam™
- **Lens Mount Standards by JIIA**
  - Lens Mounts for Machine Vision Cameras – **NF** Mount Standard and Operational Regulations LE-003-2008
  - And more
- Manufacturing Standards MRL TRL
- Communication Standards

Stay tuned to the AIA web site
www.visiononline.org/standards

Visit some of the standards folks here at the show!

Start thinking about NF mounts.

Rules of Thumb

Make your own list.. Share!

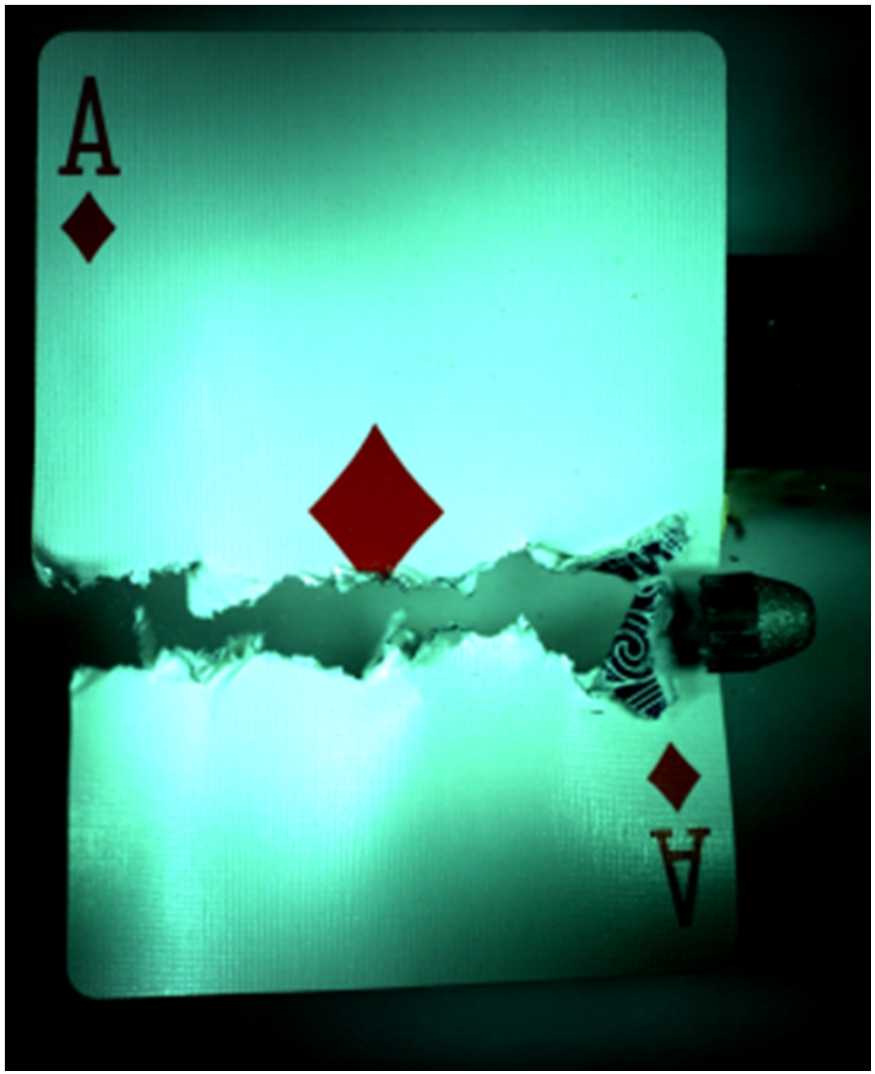
- The more the part position can be controlled, the more the resolution can be optimized. That is, the smaller the field-of-view, the better.
- Ambient light is bad. Use baffles, shields, filters, etc. to eliminate or greatly reduce ambient lighting.
- For measurement applications, have a resolution of at least 5-10 times better than the tolerance. Normally I use 10, but some applications are fine with 5.
- Realize what is really important to inspect.
- Don't take the easy road and use an algorithm just because it's easy to use.

Somebody Needs to OWN the System

- Any piece of equipment or process needs to be owned. All too often, a machine vision system is installed, and left to its own devices.
- Bad things can happen when a system is not owned!

- A person can own several vision systems in a facility, they become the local vision expert

Why I Like Strobes

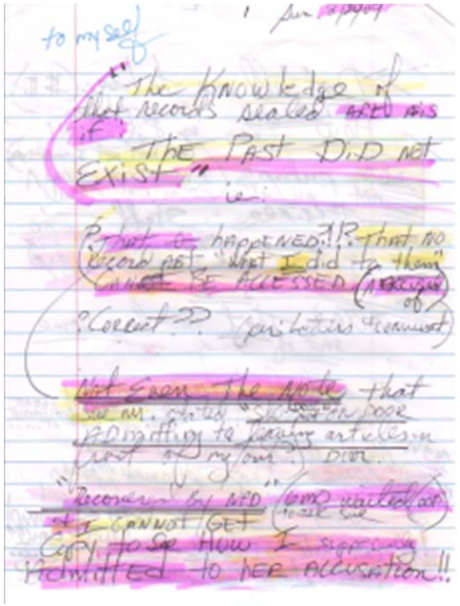


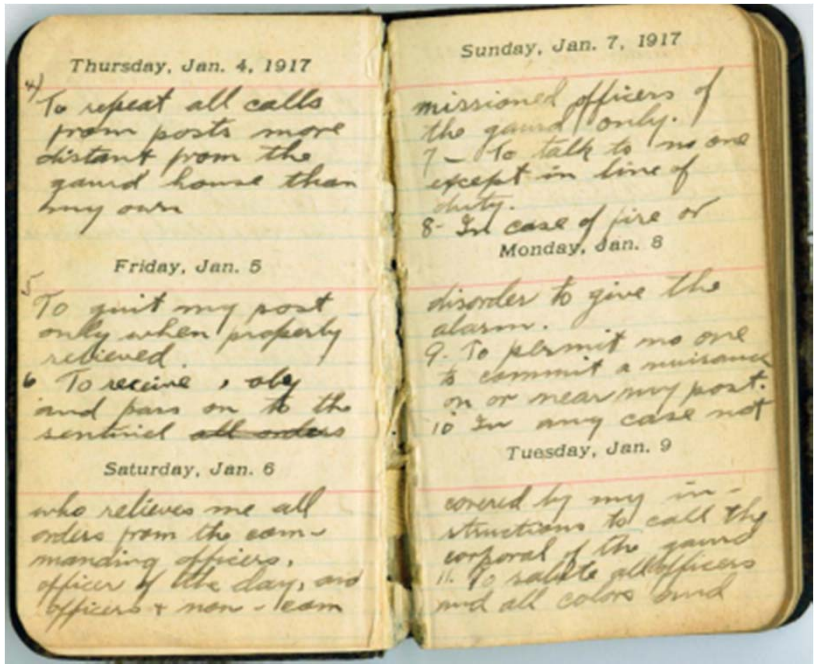
They can eliminate the effect of vibration, or motion, and strobing is incredibly effective in combating ambient light.

We should all become strobotscopotists!

Documentation!

- Keep good notes about how the system works. You may be asked to change it in a year, or two or 10. Worse yet, you may have to modify code your predecessor wrote. Better hope THEY kept good notes!



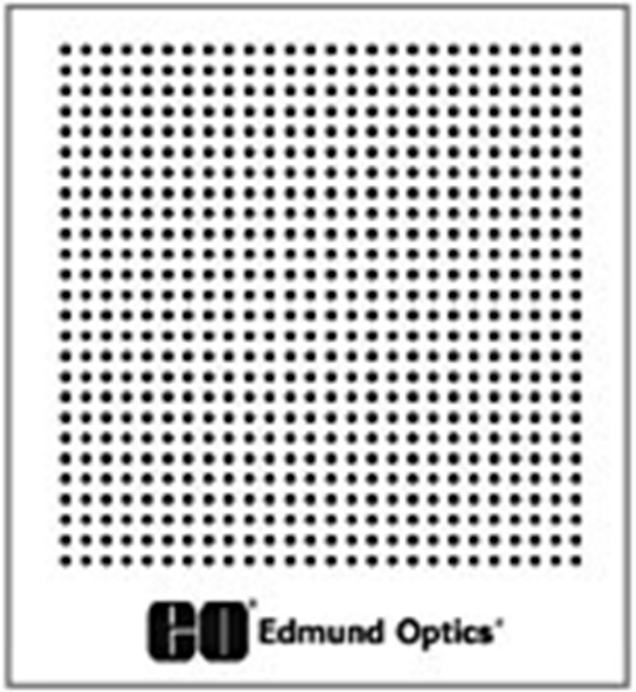


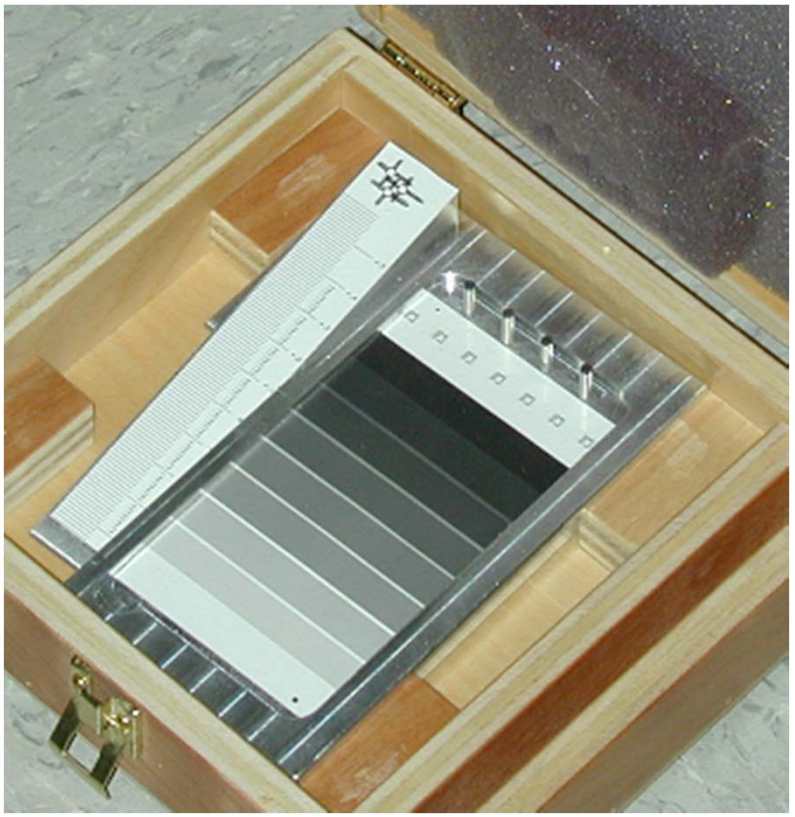
Make sure your customer has adequate documentation to keep the system running and make any user adjustments. Specification and limitations. Include in Index.

FIND AN ENGLISH MAJOR, or better yet, use a TECH EDITOR!

Calibrate

- If you need real world units, need to account for geometric distortion, or subject brightness, calibration is essential.



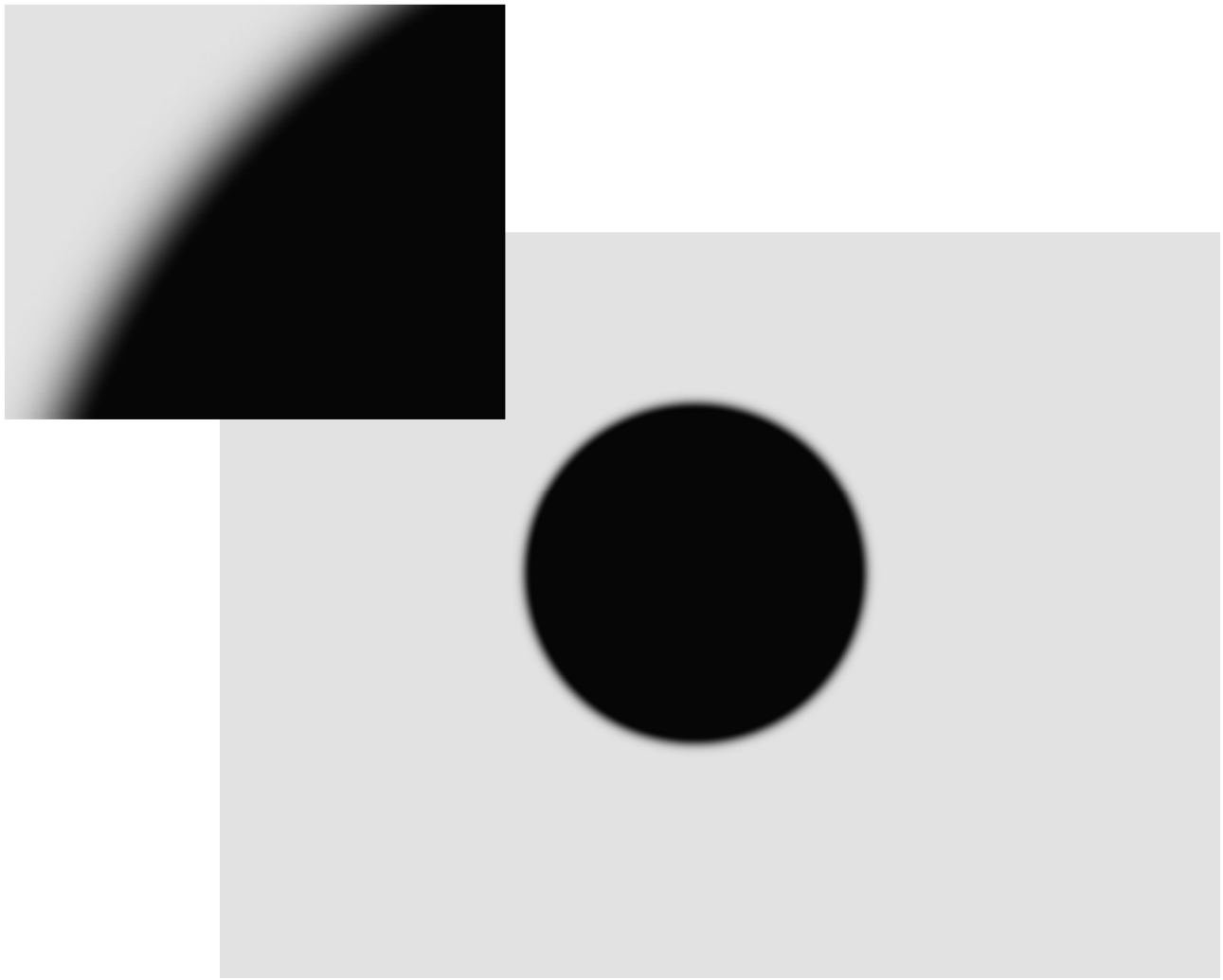


The Fuzzy Kitten Page

Real World Example – Measure a Spot

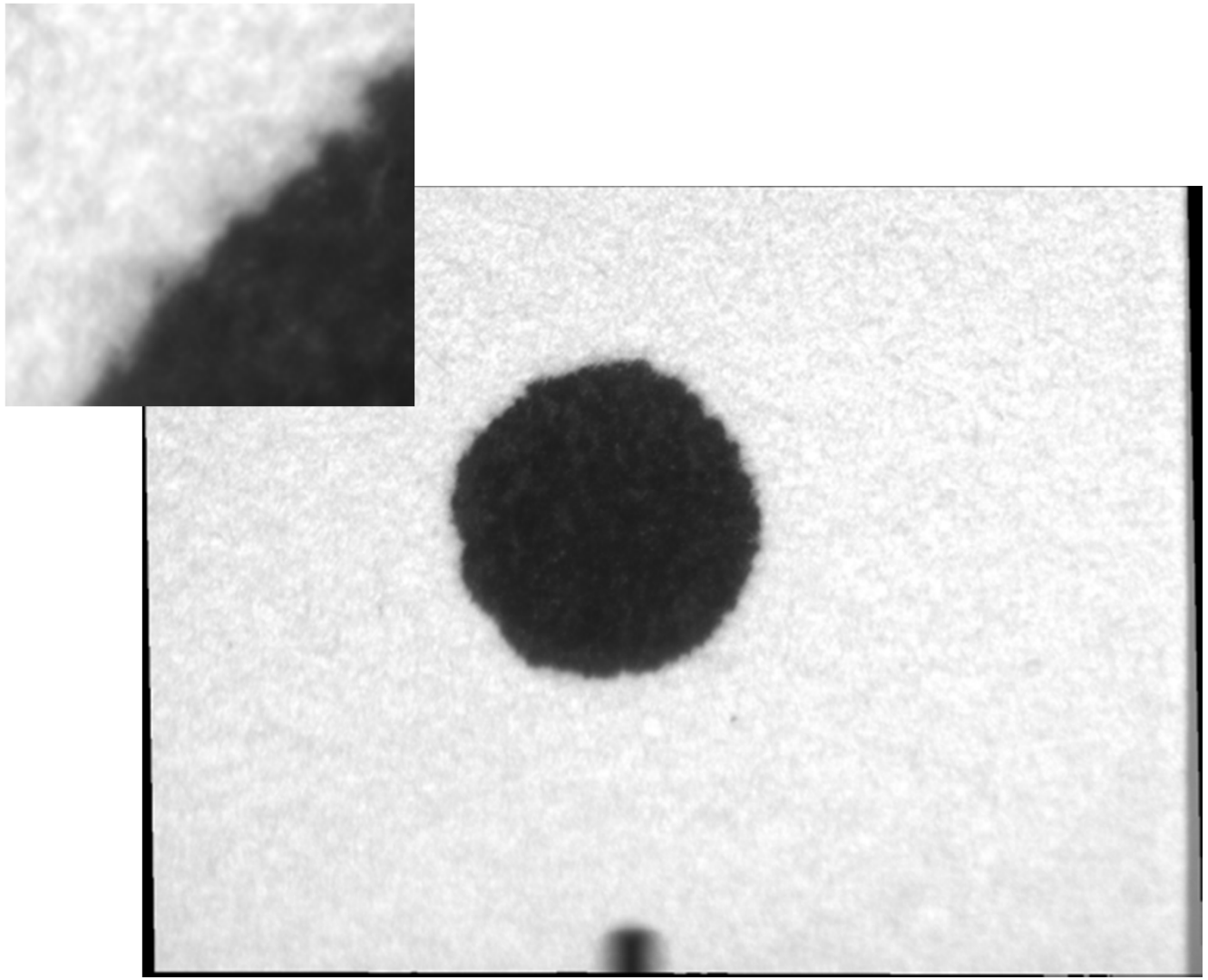
- How hard can it be? It's just a Spot!
  - Better make sure that your customer knows what YOU think a spot is.
  - How do you handle the spot (or are you lucky enough to just hang a camera from a fixture in the plant)

What the Customer Described



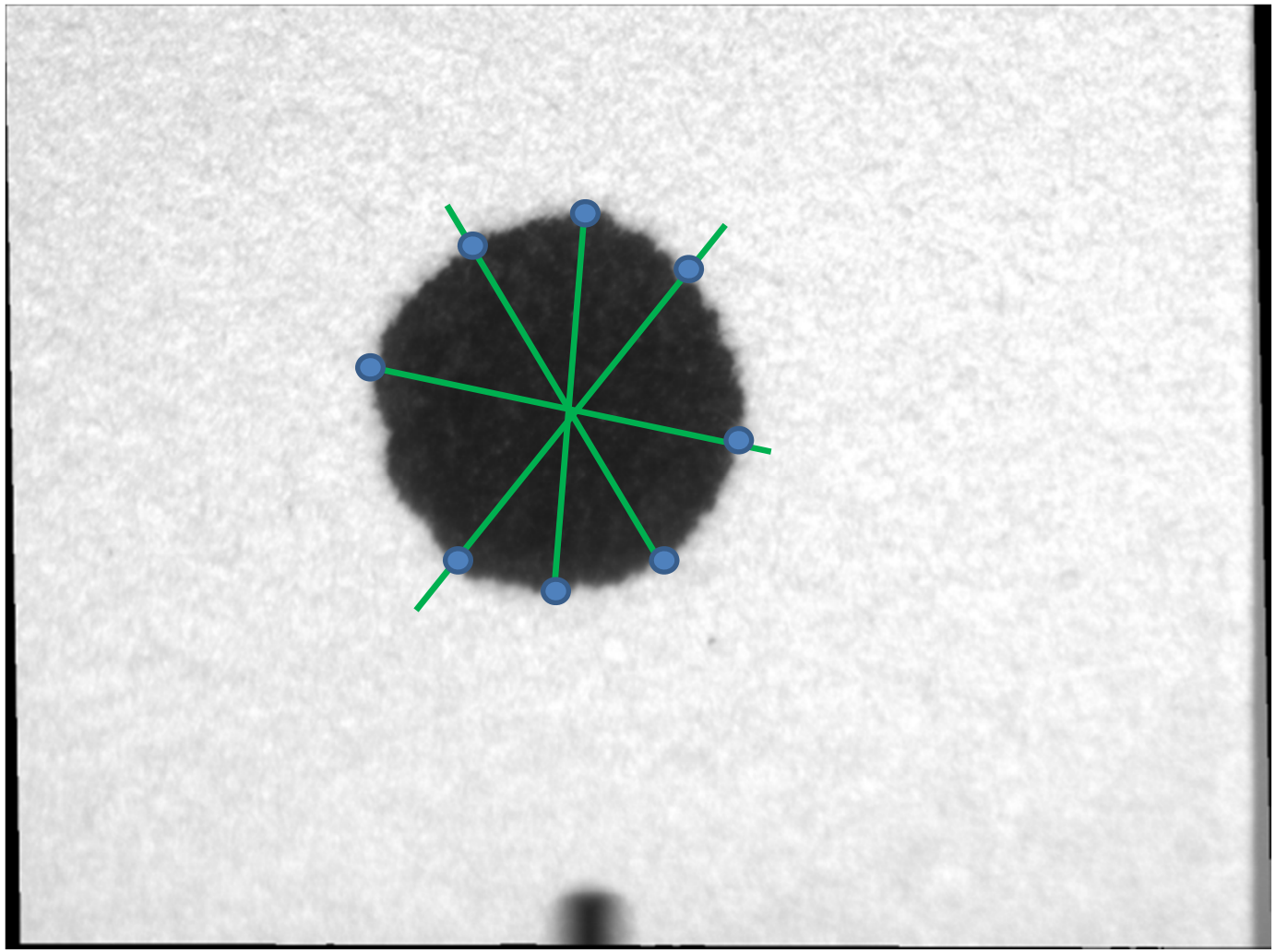
- Ah...The perfect spot.
- Nice even background
- Excellent edge Definition
- Subpixel interpolation will work
- Nice and round
- It’s fake

What the Customer Showed Us



- Not too bad.
- Sort of round
- Good Contrast
- Background a little noisy
- Spurious object in the frame
- It's what the customer showed us

What the Customer was Doing Before by Hand – with a Ruler

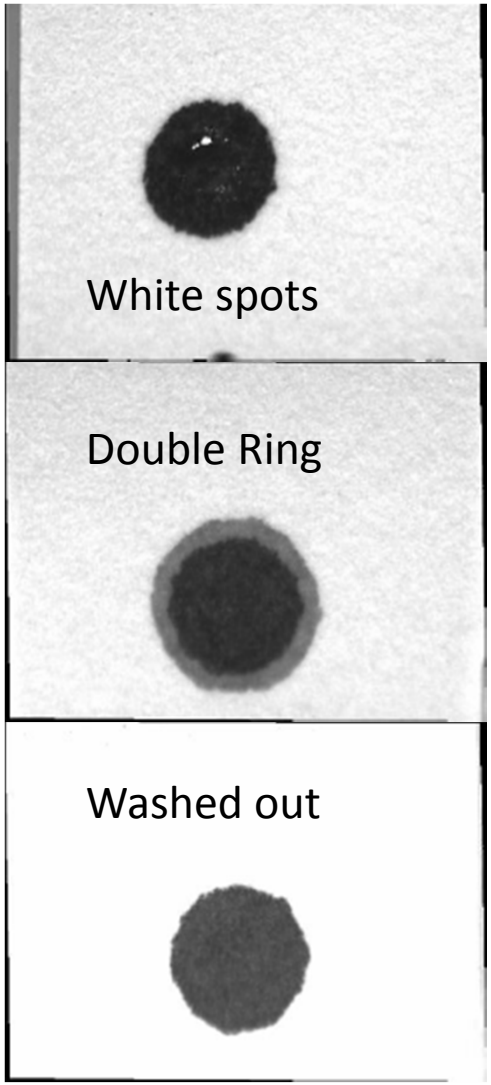


What the Customer Wanted to Know

(along with an automated version of the manual measurement)

- How round is it?
- How shiny is it?
- How fast does it grow?
- How smooth are the edges?

Lots of Samples (variations)!



Some of the variations are real, others are simulated in anticipation of what might happen.

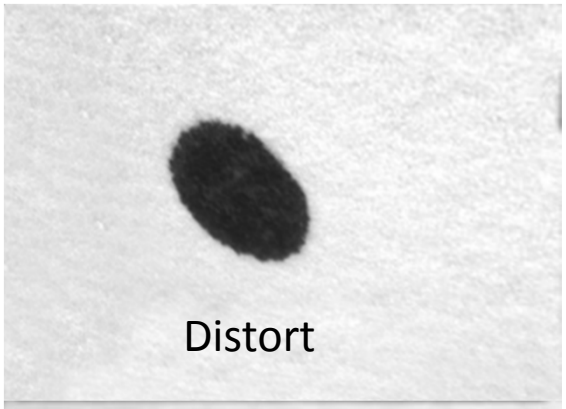
Don't even get me started about color.

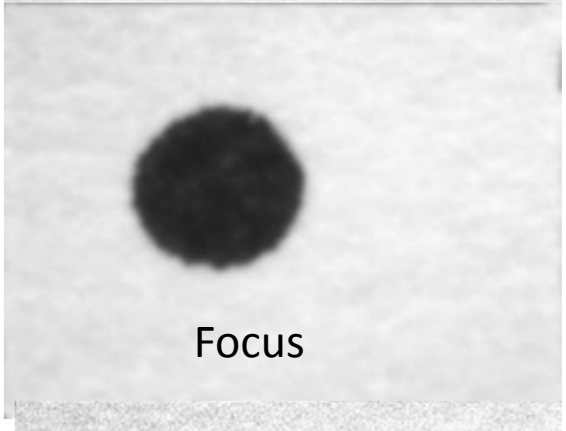
You young kids have it so easy today. LEDs last for years with very small drift in intensity and color change, high tolerance to electrical spikes, and generate less heat.

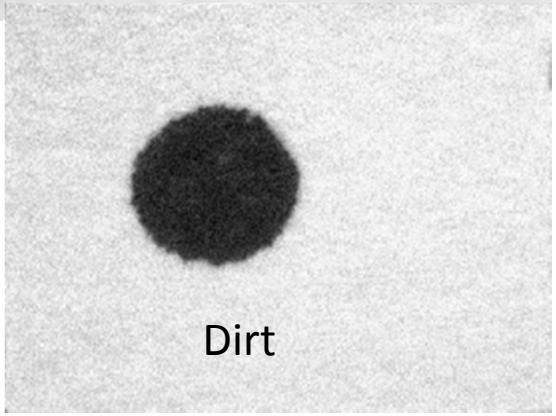
!

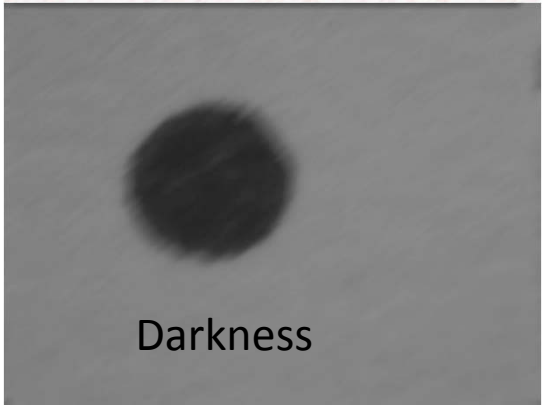
Build testing into the software. Create an offline tool to work with real and simulated images.

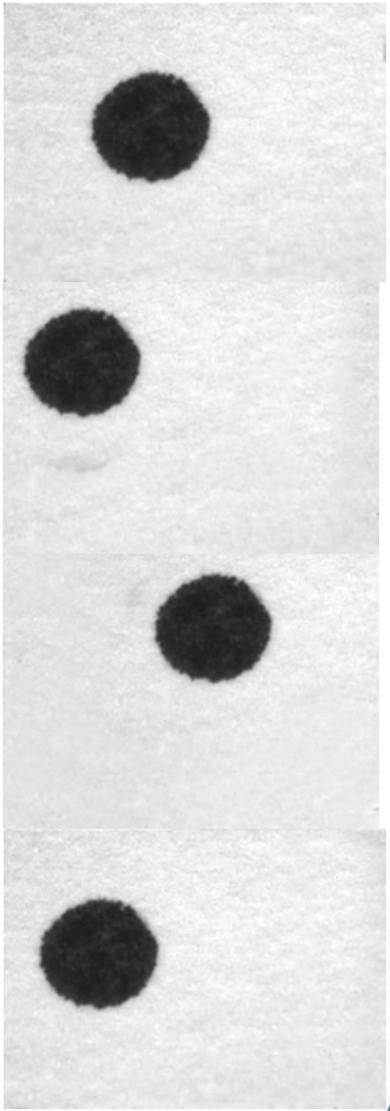
Simulate failures





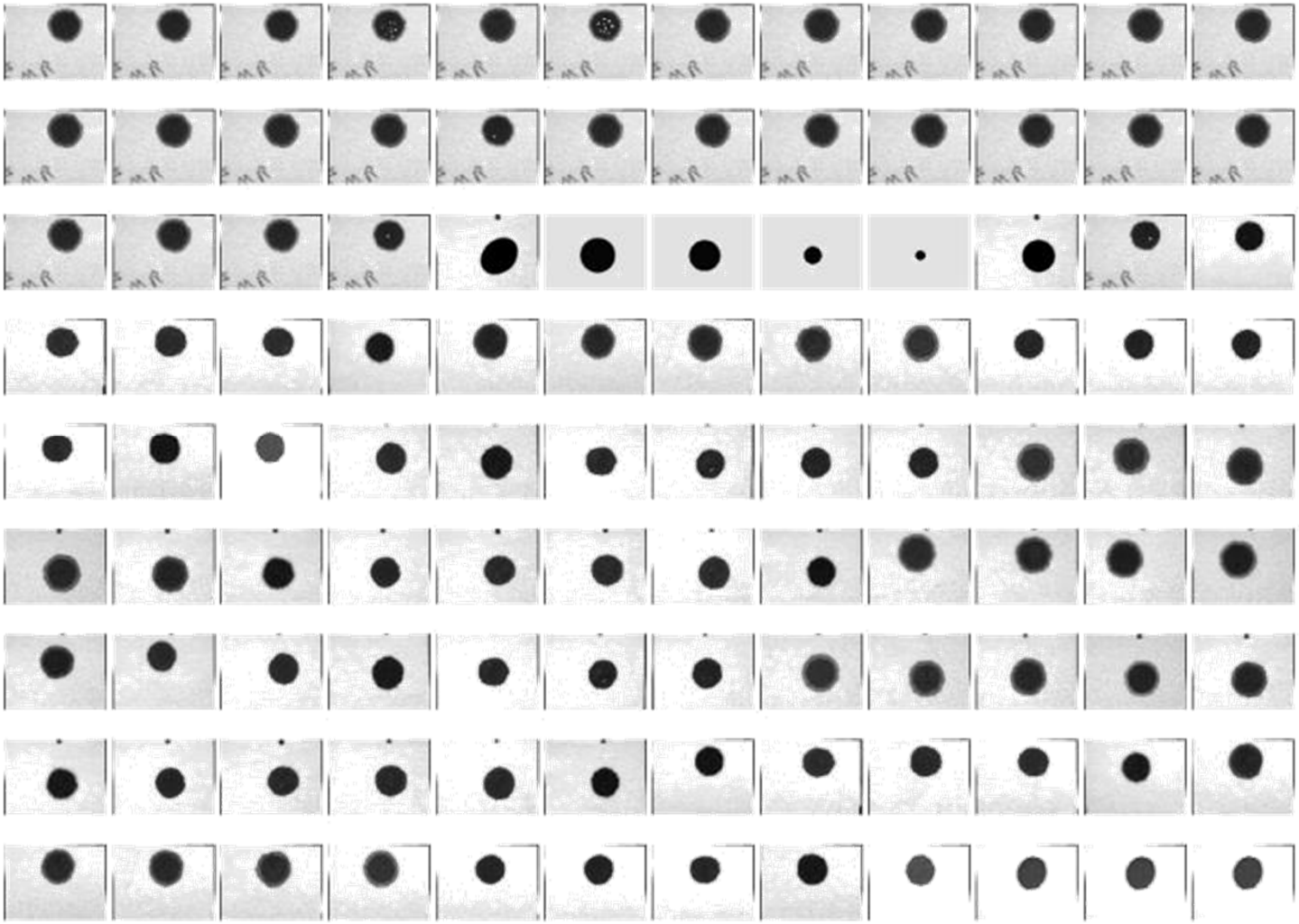






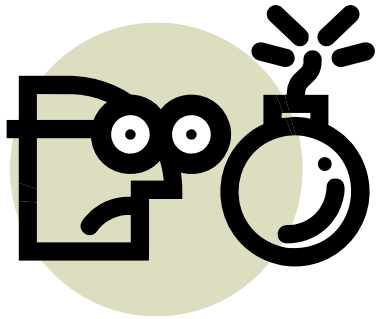
Hokey Pokey

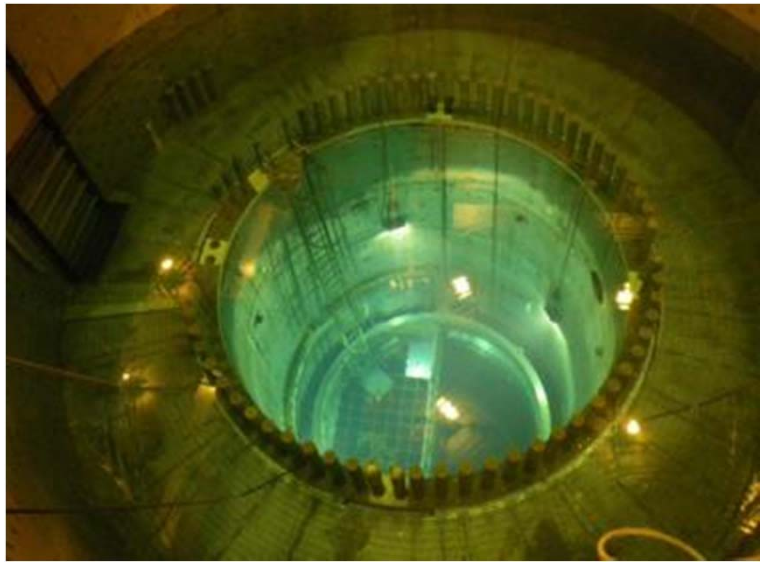
Take the set of known defects and good parts and run them through the system. Until the results will satisfy the customer!



Fault Tolerance / Recovery

- Idiot Proof! Idiots are darn clever.
  - All too often they are smarter than I am.

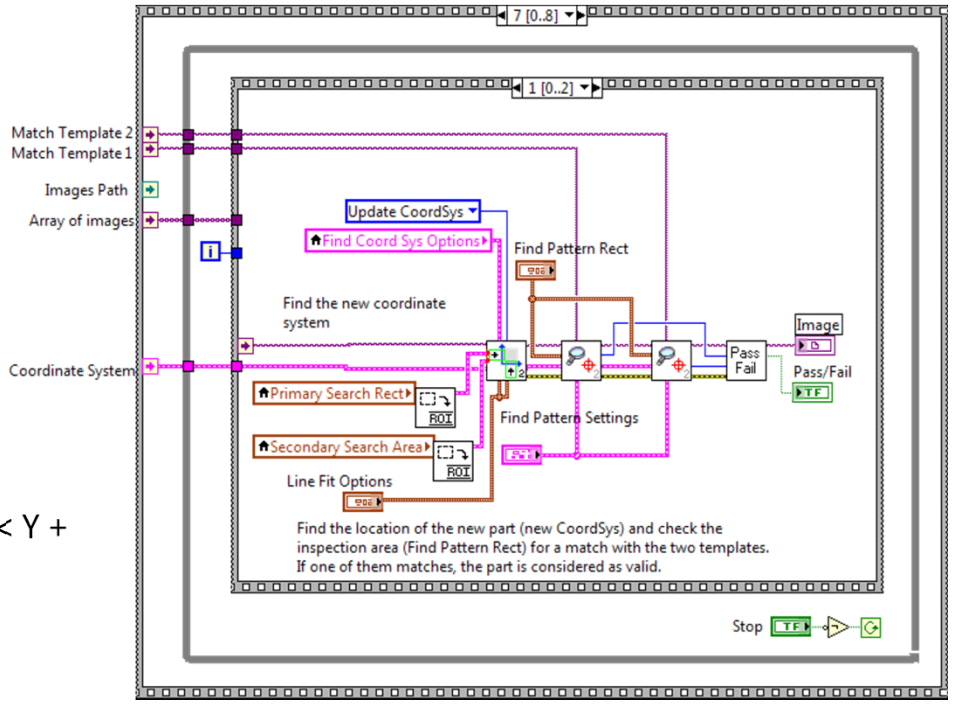




  - Fault Tolerance
    - How does your system respond to different failure modes?
    - Let a total stranger run the inspection system. If you ever have to say "don't do that", there is something wrong!
    - What happens if the power plug is pulled?
    - What happens if the hard disk fills?
    - What happens if ….

Software- Do it Right and Document

- window_size = window_size0
- scale = 1
- faces = {}
- while window_size ≤ image_size do
- classifier_cascade = classifier_cascade0 scaled by scale
- dX = scale
- dY = scale
- for 0 ≤ Y < image_height – window_height do
- for 0 ≤ X < image_height – window_height do
- region_to_test = {0 ≤ x < X + window_width; 0 ≤ y < Y +
- window_width}
- if classifier_cascade(region_to_test) == 1 then
- faces = faces ∪ {region_to_test}
- end if
- X = X + dX
- end for
- Y = Y + dY
- end for
- scale = scale × C /* C – some constant, e.g. 1.1 or 1.2 */
- end whil



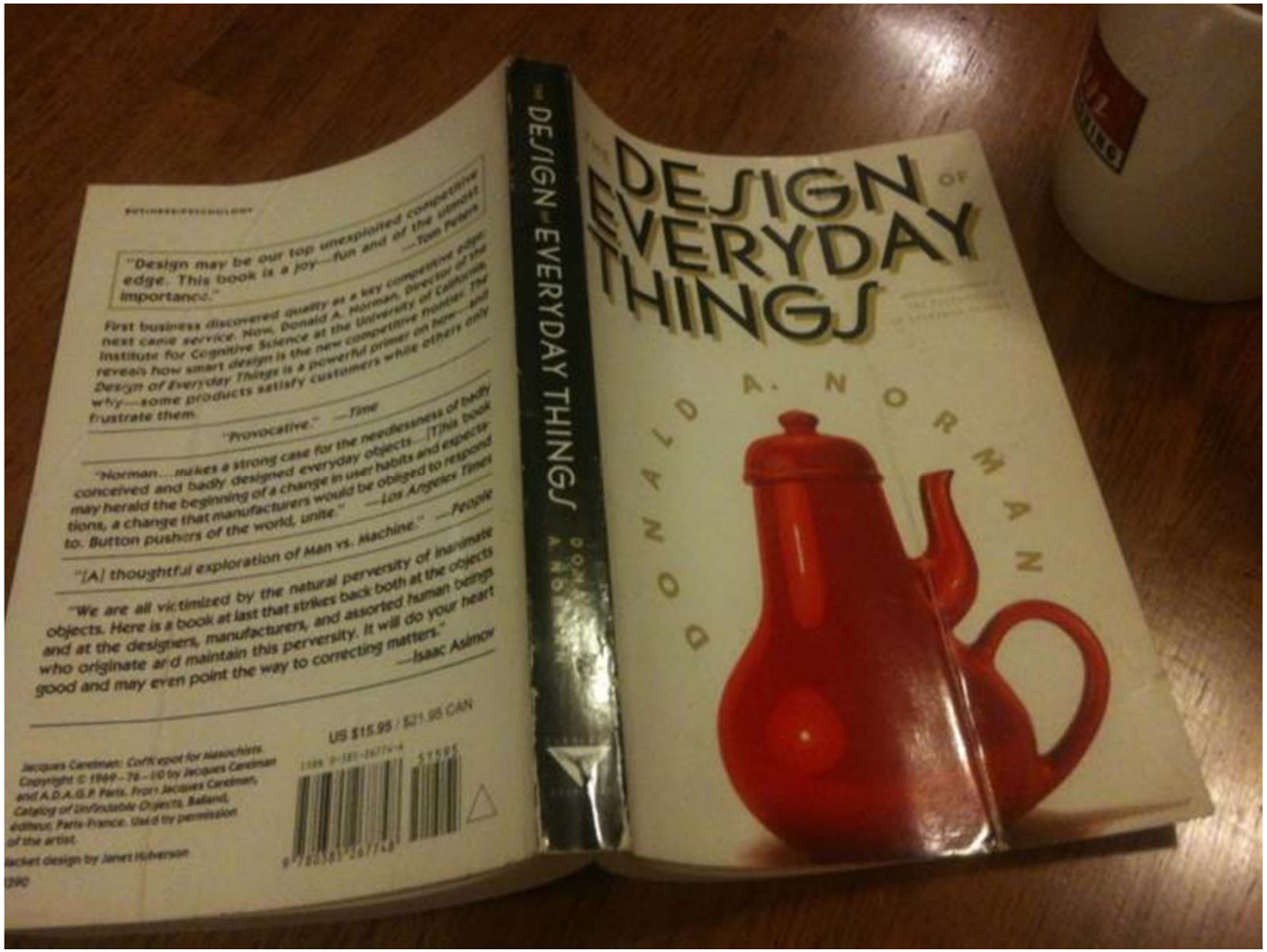
Use Social Networking

- Tweets
- SMS
- LinkedIn
- Google Plus
- User Groups
- Listservs

Disciplines of a Robust Vision System

- Mechanical Engineering
- Design Engineering
- Software engineering
- Vision Engineering
- Lighting Engineering
- Sourcing
- Technical Writer

Recommended Reading



Share Best Practices

- Hardware
- Software
- Documentation
- Training

The Zen Buddhists are the Best Customers

(Obligatory Closing Joke)

- They listen quietly and don't interrupt your pitch
- They are thoughtful
- They see the big picture
- They are willing to commit
- They are motivated
- They are willing to work with you
- They can change their own light bulbs
- They are accepting of new ideas
- They are open to new technology and features.
- They never lie about paying

- So I was delighted to hear the head Monk's response to the list of all the options…

Thank You!

Share your thoughts
Keep in touch

Somebody out there start a
Robust Vision System Blog -
let me know.

Still searching for answers

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Lighting

- About 1000 LEDs in hood.
- Draws 4.6 Amps
- 100% Power = 18V
- Boost Voltage = 21 V

Heisenberg principle

- Success in machine vision image processing often comes with a tradeoff between speed and robustness