

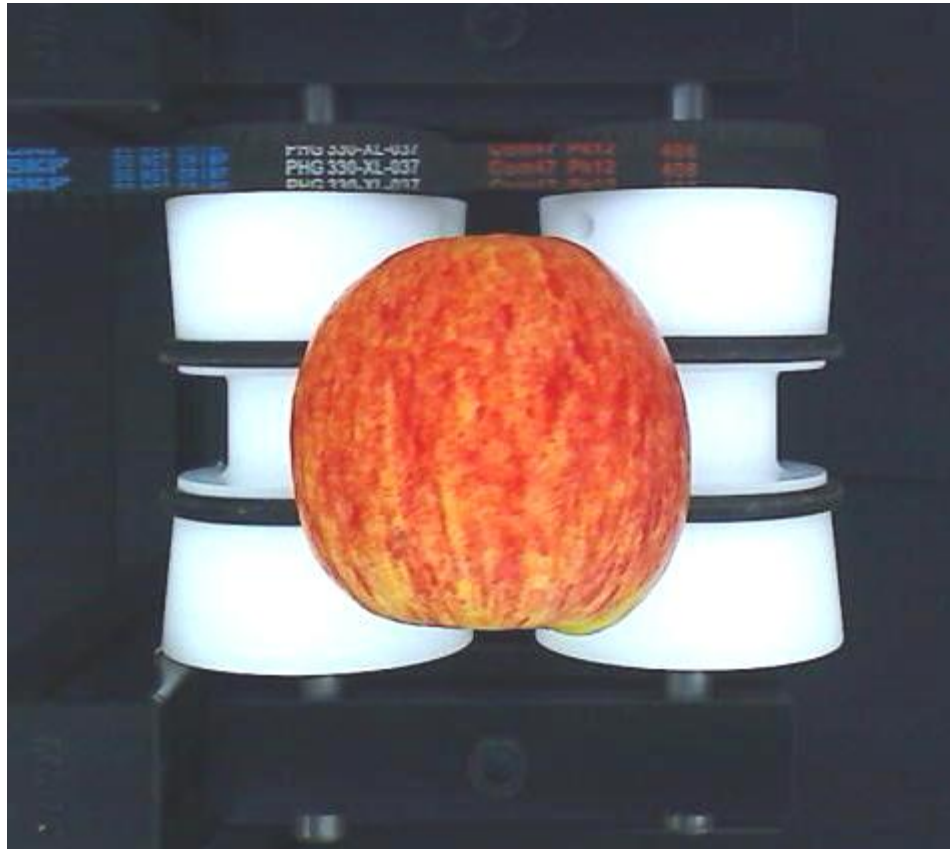
New Advances in Packing

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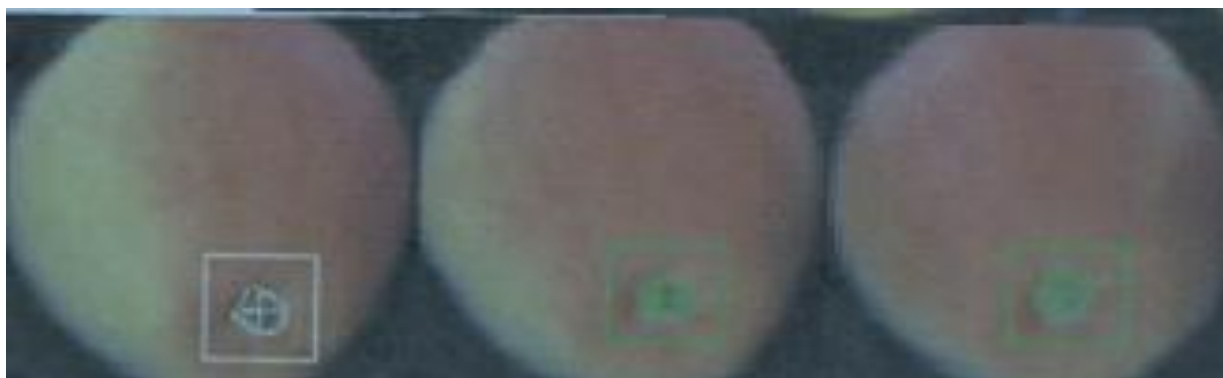
The World of Automation

- Mature automation costs much less than the product – so the cost of the product is mainly the raw materials
- In packing fruit, the automation/labour cost is significant
- ISO 9001, the standard for mature automation, permits 1 baddie in a million
- Current packing practice permits 250,000 baddies in a million (Knee et al - 2004), primarily from bruising
- This is because packing is so expensive and it's a reasonable trade-off and everyone is doing it so we can get away with it.
- The bar is going to be raised and the industry will have to move on to higher performance. Mature automation will arrive sooner or later.

Computer vision and your basic apple



In the trenches of Inspection



Life and times of computer vision

49 45 126 244 63 135 174 230 35 235 137 124 45 173 229 197 127 116 154 198 89 144 137 111 60 142
127 152 80 147 61 207 153 45 74 91 32 91 191 60 243 184 92 139 219 195 50 94 164 227 159 236
181 40 12 28 108 237 66 40 120 114 247 129 67 203 250 137 56 9 48 100 120 21 226 254 206 223 9
12 84 188 249 79 216 145 153 87 74 223 11 53 95 209 217 17 50 110 10 180 240 118 99 145 213 14
4 89 52 206 177 102 218 179 183 115 150 28 240 174 107 72 169 7 32 53 1 234 242 121 63 85 139
57 65 46 212 202 152 203 75 180 51 54 158 67 37 190 39 130 35 219 212 174 65 215 22 140 1 199
45 243 67 24 71 220 30 2 80 167 79 0 224 153 209 178 101 123 29 60 196 168 238 245 68 101 76
202 159 129 47 214 187 168 128 205 89 138 234 158 250 172 173 25 126 136 44 166 251 224 240 54 2
128 232 39 117 31 83 79 4 161 132 208 125 118 128 175 169 217 224 47 140 76 120 230 49 64 54 2
161 182 12 64 51 22 236 220 222 210 186 163 56 254 210 206 160 69 189 15 26 114 171 43 90 52 2
134 208 20 17 54 35 52 172 176 11 179 199 213 121 17 244 187 184 188 244 245 162 124 133 22 16
27 54 167 127 30 187 169 253 82 78 161 68 55 194 33 110 3 192 68 244 221 33 137 47 81 154 224
03 109 130 253 202 86 206 67 181 155 38 6 85 74 179 211 203 135 83 39 120 202 245 61 119 72 72
44 157 113 171 78 33 101 146 144 188 178 139 66 11 217 36 142 32 236 54 185 190 242 186 166 204
00 133 123 73 68 216 120 173 68 143 108 202 66 209 46 44 109 162 5 9 239 19 16 24 115 181 228
246 252 24 110 226 212 254 172 138 234 202 91 141 246 167 2 33 232 20 54 83 31 68 110 150 218
59 67 108 218 191 178 98 108 241 168 28 168 69 213 92 210 63 190 96 201 146 88 29 59 136 212 1
247 234 174 251 247 72 185 174 157 85 209 230 187 236 122 227 30 246 5 131 191 212 100 191 62
0 190 82 5 17 43 16 249 229 207 249 246 252 164 114 230 100 11 167 76 100 189 186 213 190 5 32
55 118 52 66 175 78 167 45 90 75 255 121 188 148 20 173 13 25 104 76 152 128 85 98 8 97 100 92
80 239 49 119 57 43 223 143 195 81 87 166 70 177 190 25 60 39 147 57 61 62 65 149 46 151 244
44 13 230 163 125 235 30 193 16 170 189 143 230 170 115 144 196 176 191 205 219 57 253 205 237 1
157 245 23 167 201 213 136 94 194 208 36 30 8 184 138 217 75 196 28 58 38 126 84 159 9 220 92
52 77 119 221 111 26 238 31 237 18 227 229 230 131 189 14 146 79 42 153 192 155 7 254 212 199 1
215 113 78 106 240 250 118 235 194 200 134 136 194 134 81 92 237 79 86 116 107 191 137 135 109
228 237 173 144 116 78 157 204 219 5 244 151 71 157 223 253 227 159 148 231 67 100 219 147 2 40
25 1 246 127 82 137 4 162 76 175 148 34 118 118 179 176 74 191 199 233 128 179 102 219 130 10
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145 28 28 171 253 249 88 176 2 241 165 107 41 177 9 155 200 135 166 167 53 199 143 43 53 114 2
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2 48 169 214 114 100 179 3 81 224 46 1 72 99 177 155 76 28 119 177 15 7 99 45 35 121 65 53 9
201 25 207 176 45 207 77 146 186 207 147 43 237 119 25 103 22 167 202 205 172 198 1 167 228 1
238 143 207 133 99 110 36 147 89 171 217 199 47 45 54 64 36 34 37 133 182 133 230 133 210 28

- There is a grid of pixels 960 wide by 720 high
- For black and white, each pixel has a brightness, called its Grey Level from 0 to 255
 - ie 691,200 numbers
- For a colour image, each pixel has three numbers
 - Red 0 - 255
 - Green 0 – 255
 - Blue 0 – 255
 - ie 2,73,600 numbers

Current Inspection

- Operates with infrared images because they come out black and white
- Current inspection merely says,
 - If grey level < 100 then it's a blotch
 - If the blotch is big enough, it's naughty
 - Cannot inspect within the naughty areas
 - No mold at calyx or stem
 - No stem damage
 - Cannot inspect forensically i.e. “Here's a tiny little puncture but we know it's going to go bad later”

Current Inspection

- Infra red doesn't see into the apple, the photons reflect off the skin and tell us nothing about the flesh.
- Infra red can see a surface bruise just as monochrome and polychrome light can.
- There is information about defects that IR can't see but colour vision can.

Colour Grading

- Technically, this is easy
- The application of the technology is not pleasing at the moment
- It will improve

Bottom Line on Inspection

- People find it too hard to do anything other than IR inspection and agricultural colour classification.
- IR can only ever do a very poor job
- We require an analysis that uses all the colour information to;
 - Identify the calyx and stalk and the structures in them
 - Be capable of forensic analysis – with capability equivalent to a human.
- This has been achieved in the laboratory on kiwifruit – it is in the pipeline.

NIR Spectrometry

- Blast a lot of NIR photons at the fruit
- Some will go into the fruit and then bounce back or go through
- Look at the energies of these photons with a spectrometer, avoiding the majority which just bounced off.
- This gives an energy for each of 20 wavelengths
- This gives information on bruising, brix and other things
- One can get some information but it's not a silver bullet

Labelling

- Fruit could be at any orientation
- Applicators tend to wipe the label over the fruit
- Fruit may have a monolayer of water
- Mostly labellers put 1 label in 10 somewhere else
- And some on the calyx and stem

Robotic Fruit Handling

A SCARA robot,
USD16k or NZD40k

Very, very fast, 4
axes



Picking and Placing

- You pick it up with a vacuum cup but;
 - If you don't suck gently, you will meet a soft one and digest it.
 - If you do suck gently, you can't thrash it around
 - It takes time to establish the soft suction and check that you have it (250 mS)
- The robot can do a standard cycle in under 300mS but the fruit can't.
- When you put it down, it won't lie exactly in the tray.
- You have to bring it gently to rest, break the vacuum and lift off.
- Putting it down takes 500 mS
- Bottom line is it takes 1 ½ seconds per fruit and there is the wait time on top of that and the time to handle trays.

And, furthermore

- You can't run it blind or evil will certainly befall
- You can't run it fast because you will hurt the fruit and make it bounce
- So you get a lousy payback on the robot
- You have to singulate the bulk apples
- You have to place the apples sunny side up
- You have to place the apples with the core horizontal
- You have to manage the trays which are warped and loaded crookedly
- So you absolutely have to be a master of artificial vision and you don't really want to buy a commercial robot.

So . . .

No-one has
succeeded

or almost no-one.

Damage to fruit

$$V^2 = U^2 + 2aS$$

Where;

V = final speed

U = Initial speed

S = distance of acceleration

a = acceleration

For U = 0, S = 0.050m, a = 9.82,

$$V = 1 \text{ m/s}$$

A small quiz

If you drop a 100g kiwifruit from 50mm, the force when it hits the ground is;

- ✓ 100g
- ✓ 1000g
- ✓ 10,000g
- ✓ 17,567g

Answer

17,567g and it lasts only 1.5 mS. It takes about 300 microns to decelerate.

A bullet only takes 3 mS to go through you

(this is good, when you consider the alternative).

- Singulation
 - When the chain is moving at 600 rods per minute, this means a linear speed of about one metre per second. Engaging the fruit cleanly in a pocket is equivalent to dropping the fruit from a height of 50mm. This generates an acceleration at impact of about 150 g's. If the fruit catches the edge of a pocket, it says "Ouch"
 - Most fruit are already moving as they engage the chain, but many aren't (more than 1 in a million).

- **Dropping the fruit at the Drop**
 - Padding works well and the fruit can drop 200mm and then decelerate over 3mm ($a = 67 \text{ g's}$ ie 6,700 g for a 100g fruit – but it's spread over a reasonable area)
 - At high rod numbers, the last fruit is generally not out of the way and you have one fruit falling onto another. The fruit might follow each other 100 milliseconds apart. But the first fruit will have not have moved out of the way, though it will have decelerated = Mega-ouch, a twofer.
- **Rule of thumb - in the American argot**
 - As you make the conveyor go lippetylop in order to get more whoopass, you get alotta twofers.

Packing out

- Lotta unskilled, rough and indifferent labour, particularly on 3rd shift and we pity them.
- There aren't any commercial systems which do this
- What? None?

– Well, hardly any.

Two new things

1. A novel fruit handling scheme – to fix the whole problem
2. An automated packing cell – as a bandaid

And now for a new look for the
packhouse . . .

A Novel Concept

- Go slow, stupid. Don't do ten fruit per second, do one fruit per second.
- All fruit operations are then slow and much easier and much more gentle.
- Take the time to do a better job of inspection/grading.
- Orient the fruit before you apply the label.
- Retain the fruit in its puck until it is lifted by robot into a tray. (fear the drop)
- Have the time to handle each fruit – NIR, orienting before labelling, soft spot measurement or whatever.
- Design for the same number of fruit packed per hour per square metre as existing systems

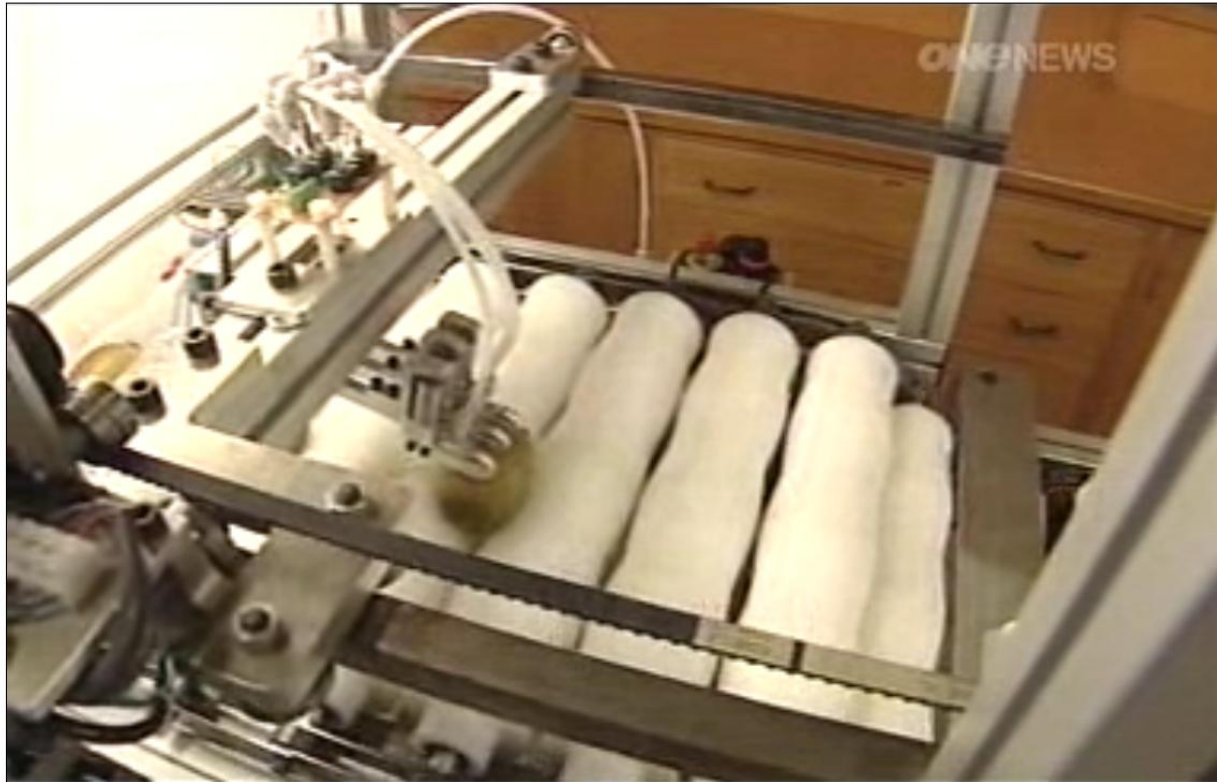
Fruit in one of four grooves



Fruit moving to pack



Soft spot measurement



Robotic packing and tray management



Bottom Line

- If you pack slowly, the fruit has a better time and it saves a lot of money.
- You have to automate in order to be able to afford to pack slowly.

And now for a packing station . . .
-this fits on a standard drop conveyor

State of the Art

- One machine in service, at 3600 fruit per hour, seven machines built and waiting to be deployed.
- Packs apples sunny side up into trays, core horizontal, pointing pretty much in the same direction.
- No capital cost – pack house pays per standard tray packed and the system performance improves over time.
- Eventually there will be enough for everyone but in the short term there will be a bit of supply shock.