Automated Harvesting – is the Juice worth the Squeeze?
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- Low cost robotics
- Machine vision
- Bringing automation to novel areas
Automated harvesting – is the Juice Worth the Squeeze?

- Agriculture has many tasks that may be amenable to automation
- Labour is expensive, and getting more so
- Robots are becoming more and more capable, and can do tasks they couldn’t do before
- So lots of farmers want to automate tasks like harvesting
Say automation and people usually think ‘robot’…

- …but, remember robot has a much broader definition than you might think
- Robot \[n\]: a machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer
- Automation is much, much more than industrial robot arms or machine anthropomorphic behaviour

Automated harvesting is unlikely to look anything like this!

By World Wide Gifts [CC BY-SA 2.0 (http://creativecommons.org/licenses/by-sa/2.0)], via Wikimedia Commons
Automation has existed in agriculture for decades – what’s new?
Only the first 18” of apple picking is not yet automated
Why hasn’t it happened everywhere already?

- Automation is *expensive*
  - At least to begin with

- Automation is not always appropriate
  - Either because the challenge is too hard
  - Or the commercial benefit is not great enough

- So, the questions we need to answer is:
  - When is automation of harvesting relevant?
Both Commercial and Technical Feasibility
For automated harvesting – or any other automation – to be feasible it needs a combination of commercial and technical feasibility

**Commercial Feasibility**

- The more installations of the same machine, the more development cost you can afford
- Balance unit cost and development cost against the saving you get from labour

**Technical Feasibility**

- Hard to spot what makes a problem difficult for a robotic system
- After all, if robot can lift and weld a car door with sub-millimetre accuracy, picking a raspberry should be easy, right?
The scale of the opportunity is large enough

- 20 billion apples grown in US
  - All picked by hand
  - Revenue of $3.75B

- 300M Head of lettuce sold in UK
  - All hand picked (in the UK)
  - £800M Contributed to economy
Some numbers from a non-agri project

- Unit cost before automation: £10 000
- Unit cost after automation: £60 000
- Development cost: £10 000 000
- Labour cost saving: £20 000 per unit per year

- The saving has to be worth the unit cost AND the development cost
  - Typical payback is only after many years – 5 is good

- Off the shelf solutions don’t exist, there will be development cost
  - This project ONLY made sense because they are deploying across thousands of sites
A successful harvesting robot requires a lot of different things to come together

**Machine vision**
- Capable of detecting non-uniform object
- Cluttered backgrounds

**Low power, low cost design**
- Replaced labour is not huge
- Suitable for use in agricultural environment

**Choice of task to automate**
- Can change the environment to make it easier
- What’s good for humans is not necessarily suitable for robots
Choosing the right task to automate
It can be quite tricky to understand the difference between an easy task to automate and one that’s nearly impossible

- Walking is hard
- Lifting a car is easy

- Picking a tiny microprocessor chip off a conveyor belt fast is easy
- Picking an apple of a tree slowly is hard (but feasible)

- Getting 90% of the way is easy
- Getting the next 5% can be hard…
- … and the next 4% even harder
Example capabilities in Agritech

**Fruit handling robot – demonstrator**

- Robots are poor at dealing with uncertainty e.g. different size objects in different locations
- This is a clear unmet need with platform implications
- By combining novel machine vision technologies (size, shape and colour shade) with tailored grasping mechanisms, we can allow a robot to differentiate between two similar objects positioned at random and select one as quick as a human can
- This compares favourably with robots featured in Amazon’s Picking Challenge which are very slow in comparison: 16 items selected in 20 minutes

This demonstrates one small part of the puzzle
Machine Vision
Machine vision is important in automating more difficult tasks

- Even humans struggle…
- Roughly 2/3rds of brain used for visual processing

- What colour is the dress?

- Population answers:
  - 57% - blue and black
  - 30% - white and gold
  - 13% - [other]
Image processing problems – what exists?

- Frameworks provide generic image filtering, transformations, low-level algorithms
Image processing problems – what exists?

- What is missing is the hard bit:
  - Choosing and combining the right algorithms
  - Knowing where to make trade-offs, choosing alternative strategies, etc…

Machine vision software frameworks
Deep convolutional neural networks

- Exciting new technique in image recognition
  - Imagenet 96.5% accurate vs 94.9% for humans!

- Requires large amounts of data to avoid over-fitting…
- … but can use pre-trained networks and transfer learning

- Results were mixed:
  - Not particularly well suited to the problem of identifying the location of the fruit
  - Transfer learning is powerful and cheap, if you have enough data
  - Hard to obtain enough data
Real world challenges
Crop/plant identification and analysis tool (1/2)

- Analysing fields of a particular broad acre crop to understand plant spacing and relative maturity.
  - Aim is to massively increase the amount of data available at present on “real time” crop metrics
  - Data can be used to provide guidance for crop protection and treatment practices – may result in the use of less input(s) for the same yield levels

- Technical solution involved:
  - Designing and implementing algorithms to detect plants accurately and gather size information.
  - Designing complementary hardware, particularly optical aspects of the system to make sure that high quality data is captured in the field.
Crop/plant identification and analysis tool (2/2)

- Technical challenges included:
  - Detecting “green-ness” of plants in varying lighting and background conditions.
  - Handling occlusions, overlaps and obscuration of plants using algorithms designed to make the most of a noisy data set.
  - Algorithm had to be suitably flexible to deal with real life variations in quality of data due to bumpy cart ride, operator errors and limitations of available computing hardware.
Conclusions
So automation in agriculture IS worth investing in BUT…

- The business case must make sense
  - Typically this means many installations are required

- You have to start with the problem and work out which technology is the best solution
  - Don’t start with a robot and try to apply it to everything
  - It’s now about engineering as much as science

- You have to pick the right task
  - Not all are suitable
  - Be prepared to change the environment to make it easier for robots