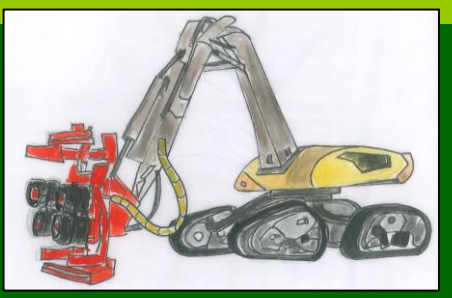
Next Generation Timber Harvesting Systems: Opportunities for remote-controlled and autonomous machinery



Prof. Rien Visser
School of Forestry, University of Canterbury
FWPA, Melbourne 4th Dec, 2017

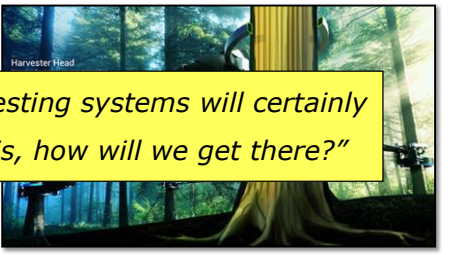
Robots in the forest?

Goal / objectives:

FWPA: review of remote control / autonomous systems for forestry

- Forestry companies interested in developments.
- Australian manufacturing opportunities for forestry equipment.
- Identify pathways for 'realistic' development.

"The future of timber harvesting systems will certainly be robotic. The question is, how will we get there?"



BARBRO-Autonomous-Harvester, Fredrik Ausinsch, Umea Sweden

Acknowledgements:

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- **Phil Taylor** – CEO, PortBlakely, Timaru
- **Bruce Talbot** – NIBIO Forestry and Forest Resources, Norway

Presentation Overview:

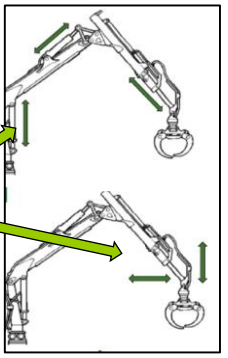
- Automation in harvesting equipment
- Definitions and development of robotics
- Existing robotics examples and ideas in harvesting
  - At different steps in harvesting
  - Near-term (1-5 yrs) + long-term (5+ yrs) opportunities
- Silviculture and Planting

Technology and Automation?

Technology - the application of scientific knowledge for practical purposes, especially in industry
- machinery and devices developed from scientific knowledge

Automation - operating a process by highly automatic means, as by electronic devices, reducing human intervention to a minimum.

Technology – e.g. boom-tip control



Directly control movement of head, not boom

- More natural for operators
  - Easier to learn and more productive
- Obstacle avoidance
  - Automatically moves over bolsters
- Opportunity to integrate with heads-up display
  - 'Point-and-shoot'

Technology - Hybrid Machines

Examples:

- El-electric forwarder
- Diesel-electric yarders
- Electric carriages

Technology - Ergonomics

"Improved operating environment for increased productivity"

- Cab design + automation

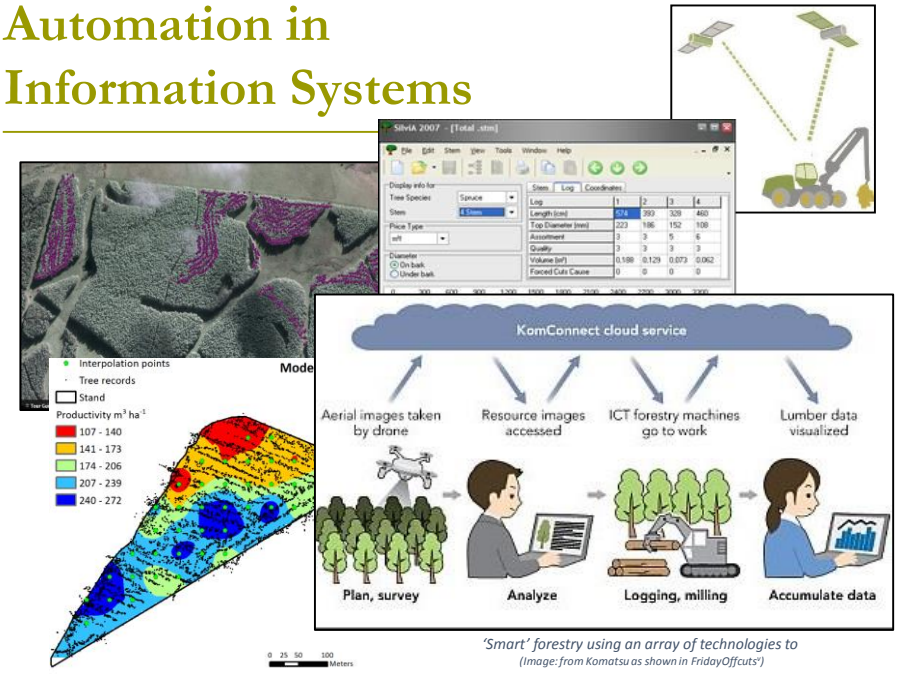
Developing technolgy: Example walking harvester

(PlusTech, then Timberjack)

- Extensive (and expensive!) development.
- Strong collaboration between manufacturing and research

→ Amazing, but expensive & slow! Also less capable than expected on slope and for environment.

Automation in Information Systems



'Smart' forestry using an array of technologies to
(Image: from Komatsu as shown in FridayOffcuts')

Technology – new machine ideas

- 'Inchworm' harvester

Definitions

Automation - operating a process by highly automatic means, as by electronic devices, reducing human intervention to a minimum.

Robot - a machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer.

Remote Control - control of a machine from a distance by means of radio or infrared signals.

Teleoperation - Teleoperation is the technical term for the operation of a machine, system or robot from a distance.

Autonomous - having the freedom to act independently; navigated and maneuvered by a computer without a need for human intervention under a range of driving situations and conditions.

Drone - an unmanned aircraft or ship that can navigate autonomously, without human control or beyond line of sight.

Slave (machine) - machine or component controlled by another machine.

Robots…

- Just celebrated its 50th birthday!
- 'Old' Robots – allowed people to avoid doing *"dirty, dull or dangerous"* tasks.
- 'Modern' Robots? → *"economic growth, improved quality of life and empowerment of people"* (Christensen, 2016)
- For forestry, plenty of exciting possibilities BUT almost complete absence of any 'productivity' information!

Bill Gates' vision…

- "Robot in every home"
  – will revolutionize the way we live.
- "Striking parallels between the personal-computer and the personal-robot industries in their early years" –
  - fragmented state-of-existence (diversity of platforms/software)
  - the inflexible operational paradigms (monolithic solutions)
  - new hardware and software trends (modularity, open-source) that paved the way for the revolution

Robot Predictions

IDC* 'Analyse the Future' study:

- By 2019, 35% of leading organizations will explore the use of robots to automate operations.
- By 2018, 30% of all new robotic deployments will be smart collaborative robots, operate 3x faster than today's robots and are safe for work around humans.
- By 2019, governments will begin implementing robotics-specific regulations to preserve jobs and to address concerns of security, safety, and privacy.
- By 2020, 60% of robots will depend on cloud-based software to define new skills and cognitive capabilities.
- By 2020, robotics growth will accelerate the talent race, leaving 35% of robotics-related jobs vacant while the average salary increases by at least 60%.

*International Data Corporation; www.idc.com

Successful forestry implementation?

Driven by the **operational cost** and **productivity**?

→ Labour is about 30% of running costs, so autonomous machine can be less productive but still be more cost effective.

Other factors to consider (McEwan 2017):

- **Health and safety** – less risk to operators, alternative workplace and options
- **Environment performance** – Imp less soil disturbance
- **Product quality** – accuracy & optin increasing value or reducing waste

- **Social aspects!**

Robotics in other Industries?

Mining: *"dirty, dull"?* – similarity in terms of operational risks and scale, but much larger investment potential

Military: *"dangerous"?* – massive R&D and funding; overlap in terms of visual recognition

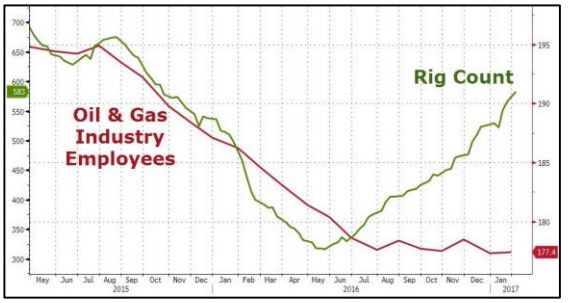
Agriculture: Greatest similarity? They have adv. of both scale and more homogenous operating environments.

- $240b market opportunity, $45b for small driverless tractors (Economist)
- 14+ years of 'field-capable' robotic machinery competitions

Urban Environment: Overlap in terms of avoidance systems and object ID

Oil Industry – recent article…

- Industry contracts - loses both equipment and employees.
- Industry rationalises and optimise use of labour resources
- In then fully supported by higher levels of automation
  - 'Iron Roughnecks' - automate the extremely repetitive task of connecting drill pipe segments
  - a once dangerous and very laborious task now requires fewer people to accomplish



The *(fake?)* News – last week…

Rise of robots could force 700 million workers into new careers by 2030

30 Nov, 2017 10:36am

Daily Telegraph UK
By: Tim Wallace

Hundreds of millions of workers worldwide will need to find new careers or a new set of skills to compete in the jobs market as robots and artificial intelligence march ahead. As many as 700 million people could be displaced from their jobs by robots by 2030, particularly if advanced economies switch to new technology rapidly, according to a study from consultancy McKinsey.

…..

If the pace is more modest – as the analysts expect – then around 375 million people, or 14 per cent of all workers, would have to move jobs and retrain. This should make workers more productive on average, driving economic growth and improving pay.

Social Aspects?

Modern machines are well designed with regard to ergonomics, BUT operators working longer hours per day to cover cost.

- different health risks to the traditional manual physical risks
- i.e. operators in thinning are required to make about 4000 control inputs per hour
- i.e. skidder operators higher levels of monotony

Higher degree of machine autonomy could readily decrease these types of occupational health and safety risks.

Jobs* – contradicting perspective?

"Each robot takes 5 jobs and reduces" and "every robot per 1000 workers reduces wages by 0.25%"

Ideals vs Reality?

Researchers = *exciting and futuristic opportunities!*

Equipment manufactures = *pragmatic & financially successful in the near-future.*

Autonomous opportunities by Harvesting Task

Felling: most exciting – but least likely! Best suited to teleoperation for niche requirements.

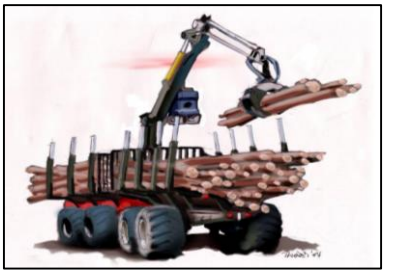
Extraction: Most realistic – technology required is mature & working environment is suitably constrained (BUT: loading and unloading!)

Processing: lends itself to higher levels of automation IF work tasks and environments become more defined

Transportation: Will align itself with transportation on public road - but more immediate opportunities for slaves

Autonomous Extraction

- Most logical + largest commercial opportunity?
- Forwarder/skidder, shuttle logs /stems from harvester to 'landing'
- GPS control + sensors



Autonomous forwarder +self-loading (Image from Ringdahl 2011)

Loading / Unloading?

- By harvester and or designated loader(s)
- Semi-autonomous - Movement + remote operator loading / unloading
  - ALSO – planning / extraction distance?

Speed of technology adoption?

McEwan (2017): survey 27 international experts - forestry equipment with a focus on equipment for harvesting fast growing Eucalyptus

- Most machines will have: smart tablet by 2020, GPS by 2020, and remote control by 2025.
- Adoption of LiDAR and or other sensors for tree selection? Still 20 years in the future!
- Autonomous skidder? Answers ranged from 5 to 20 for 50% adoption, but 90% adoption is 20 years into the future.

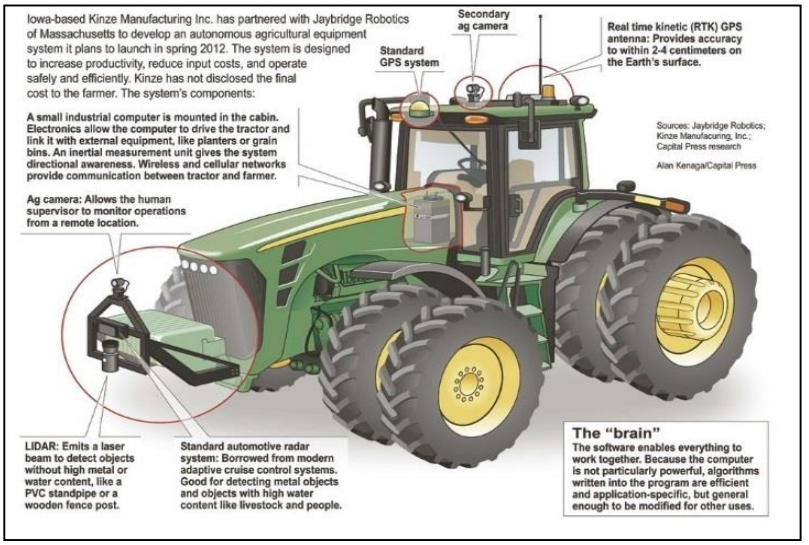
Autonomous 'Extraction' - from Agriculture

Tractor Drone

- Already advanced - for harvesting crop (e.g. grain)
- Aligns with harvester using GPS + sensors
- Returns to unloading area by GPS

Autonomous carts (tractor-pulled trailers)

Autonomous 'Extraction' – how does it work?



Levels of Automation*

**Modified from Lindroos et al. 2017*

Description	Human involvement	Example
Operator assistance	Basic simplified control functions	Computer support simplifying some actions: e.g. automatic transmission, cruise control
Partial automation	Function-specific automation	e.g. automatic self-parking, yarder carriage movement
Conditional automation	Limited self-driving automation	Autonomous vehicle movement, but under constant supervision of a person. Ability to reason outside a given set of conditions is limited
High automation	Fully automated for a defined use	A vehicle trained to drive on its own, not requiring supervision, but will request & require help
Driverless	Fully automated for all situations	A vehicle driving on its own, able to make its own decisions and learn from its surroundings

Example: Semi-autonomous yarder

Computer control / autonomous carriage movement.

→ no operator and or operator free to undertake other tasks.

Forestry - Konrad 'Pully'

Semi-autonomous, but guided by cable!

Designed for slope, shuttle between harvester and roadside / landing area

Forestry - Konrad 'Pully'

Trialling remote controlled loading…

Guidance – using laser scanner

- Forest terrain is not homogenous, need to identify 'paths' ('skid trails')

Valmet 830 forwarder tested for path detection in the forest (Image sourced from Ringdahl 2011).

Advanced guidance – using drones

- Forest terrain is not homogenous, need to identify ‘paths’ (‘skid trails’)

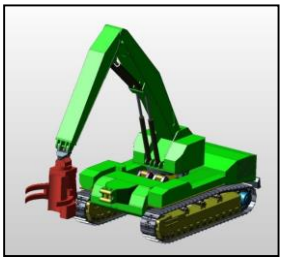
Mining industry – movement in confined space..

Purpose-build design..

purpose built autonomous farm tractor

Manufacturing opportunity = Cabless!

- Monitored and controlled via a desktop computer or portable tablet interface.
- Cab on forestry machine ≈ $100k - $150k ≈ $30/hr
- Many improved design options – e.g. simplified under-carriage design without cab (e.g. steep slope)



Remote Control

- Already available on machine such as skidders
- Some purpose built forestry 'tractors'
- Most modern machines readily retrofitted (approx. 2 hours for JD909)

Example: Remote controlled felling

- 'Besten' System – developed 1990s
- Concept: Forwarder(s) operate harvester and load directly
- → 3 machines = higher level of mechanisation?

- BUT – remote control machines are about 40% less productive without operator

Teleoperation

- Move operator to replicated environment – i.e. trailer on landing
- Future: operate from centralised facility (i.e. US Army Drone programme), or even home (taps into new workforce!).

- ***Question:*** Success under what circumstances?

Teleoperation?

Examples for success:

- Unacceptable risk to operator
- Too onerous to reach work site
- Shortage of operators
- Machine with low utilisation

Existing Forestry Examples:

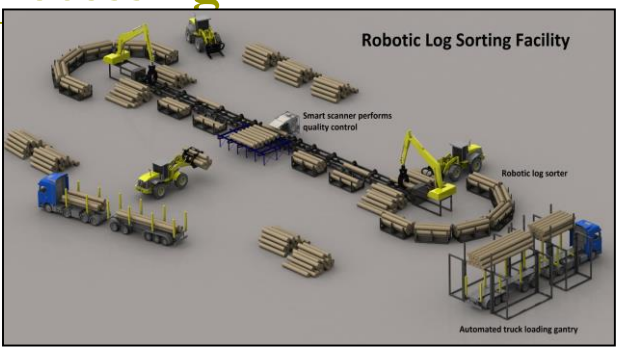
- Tailhold machine
- Winch-assist machines
- Dangerous work environments

Remote Controlled Feller-Buncher

Commercial retrofit solution on military site:

Landing / Processing

- Focus of new NZ FGR programme…



- Autonomous unloading
- Automated processing
- Robotic sorting
- Autonomous fleeting
- Automated truck loading

Self-driving refuse truck

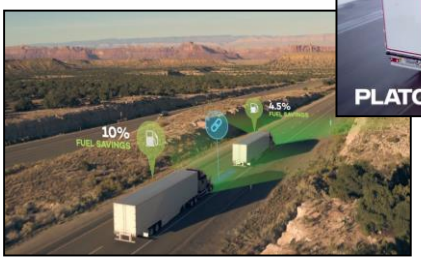
+ safety

Transportation

- Off-highway – great potential / storage yards
- On-highway – public interest and safety issues

Logging truck opportunities – **platooning**

- Driver can rest (semi-autonomous)
- Fewer drivers (slave trucks)
- Fuel savings

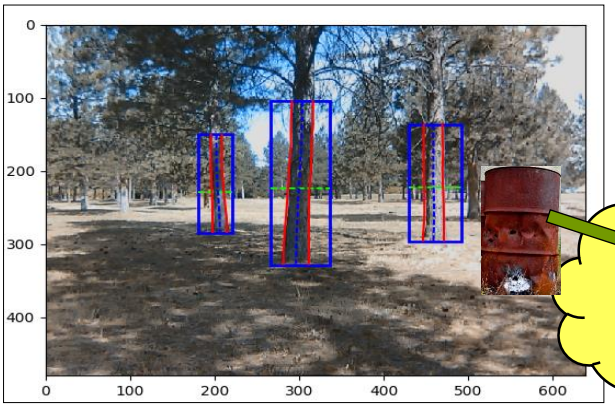


How autonomous trucks work…

+ safety

Future: Autonomous felling

- Hardware is there – technology exists
- Software is not – "cant see the trees"



Output from the OSU / USFS tree identification vision system

Future: Autonomous loading

- Hardware is there – technology exists
- Software is almost – felled trees have defined shape

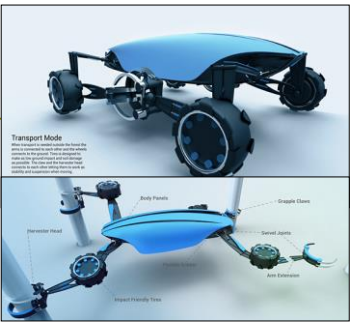
Output from the NIBIO, Norway

Felling – 'slaves'

- Concept: 1 operated harvester + slave machines cutting multiple rows

Felling – future ideas?

- BARBRO – drives into forest, but then grabs and fells trees
- Swinging – prototype

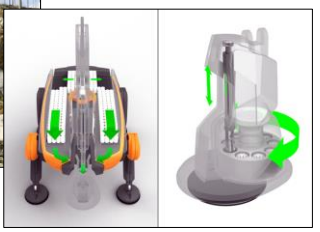


BARBRO Autonomous Harvester

Tree-to-tree 'swinging' forest harvester (Parker et al., 2015)

Silviculture - Planting

- Planting machines and or using aerial drones



Anna-Karin Bergkvist

Silviculture – pruning / tending

- Pruning machine – 'tree monkey' – already available 20+ years.
- From horticulture – vine pruning + citrus fruit picking!

Summary

- Many exciting developments and robotic technology will become 'common'.
- Hardware reliable and available, software (esp 'vision') is still very restrictive for forestry applications.
- 'New' opportunities for machine manufacturers:
  1. Autonomous extraction systems + purpose built
  2. Remote control + purpose build