Automatic plant counting in open fields by a machine vision system

European Field Phenotyping Workshop - Copenhagen

26-9-2014

Pieter Blok, Jochen Hemming, Wim van den Berg

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Introduction

IRS, Dutch sugar beet institute, conduct field measurements on:

- Seed quality
- Crop emergence rate

Plant counting in open fields by humans

- Labour intensive
- Susceptible to counting errors

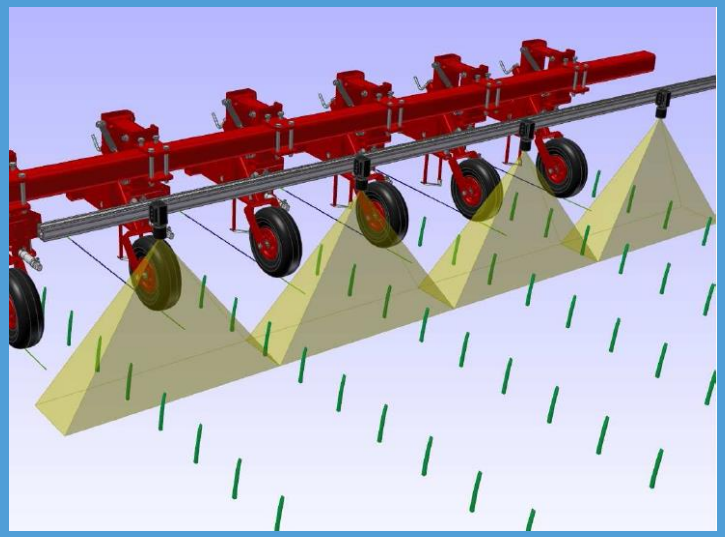
Project goal: automatic plant counting system, which is:

- Accurate
- Fast
- Labour extensive

Project approach

Machine vision system:

- Implement frame behind tractor
- Surrounded cover
- Additional illumination
- Colour-camera's (3x)
- Embedded computer
- Vision software



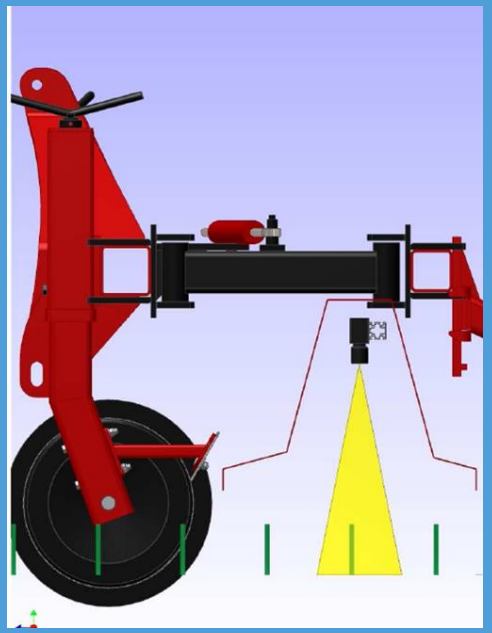
How the machine works...

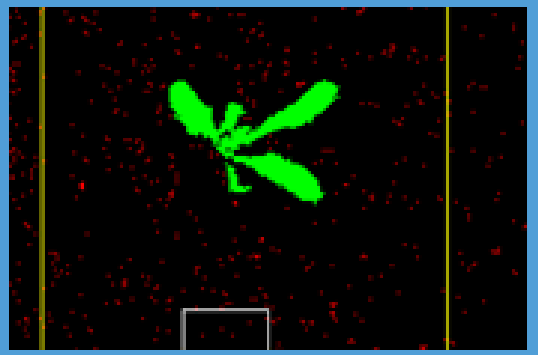
Camera's look from above
to the plants

Triggering of RGB colour images
by encoder wheel

Plant segmentation by vision software

- Colour threshold by Excessive Green
- 2 * G – R – B
- Binary image





Plant detection and count algorithm

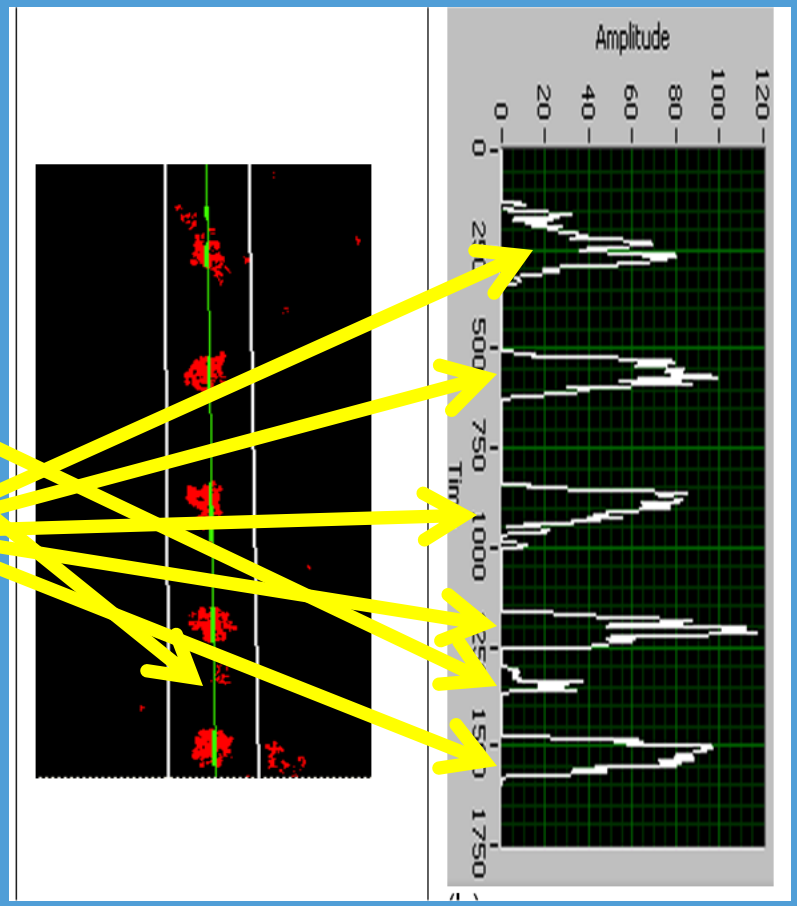
Practical problem:

- Weeds are also "plant pixels"

Still: emergence of weeds is "random"

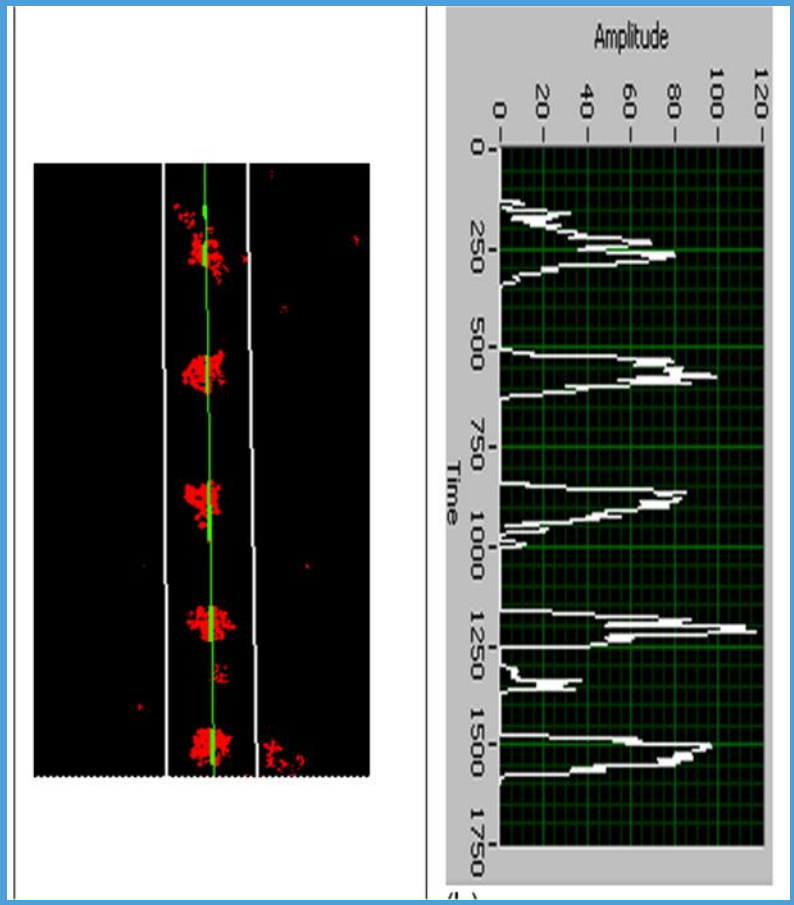
Solution: detect the regular pattern of the plants

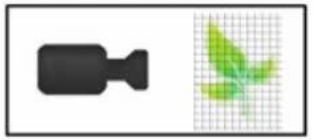
Method: Fast-Fourier Transform (Bontsema *et al*. 1991)



Vision software

- Plant distance as input for the FFT (regularity detection)
- Plant row detection and automatic side-shift of implement
- Colour threshold adaptations
  - Green
  - Multiple colour range
- Plant size





NumPlantsTotalM

0	0	0	0	0	0

Low

7

High

200

5

0,0

km/u

Opslaan

ResetTot

Volgende

Optellen

Veldje

Steketee

08:15
17/09

Validation in open field

33 subplots:

- Sugar beet
- 6 rows
- Length: 12m

Comparison:

- Human counts
  → “True Counts”
- Machine counts
- Total: 198 counts

Human count vs. machine count

- H_0 hypothesis: no difference between human count and machine vision count
- ANOVA F-test ($P<0.05$) to discriminate the two counting methods
- Just above the significance level
- H_0 hypothesis was not rejected

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Analysis of variance
====================

Variate: Counting

Source of variation      d.f.       s.s.       m.s.     v.r.  F pr.

Locatie.Rij1_6.*Units* stratum
Method of counting          1     1.9798     1.9798     3.54  0.061
Residual                  197   110.0202     0.5585

Total                     395 18247.4141


Tables of means
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Variate: Counting

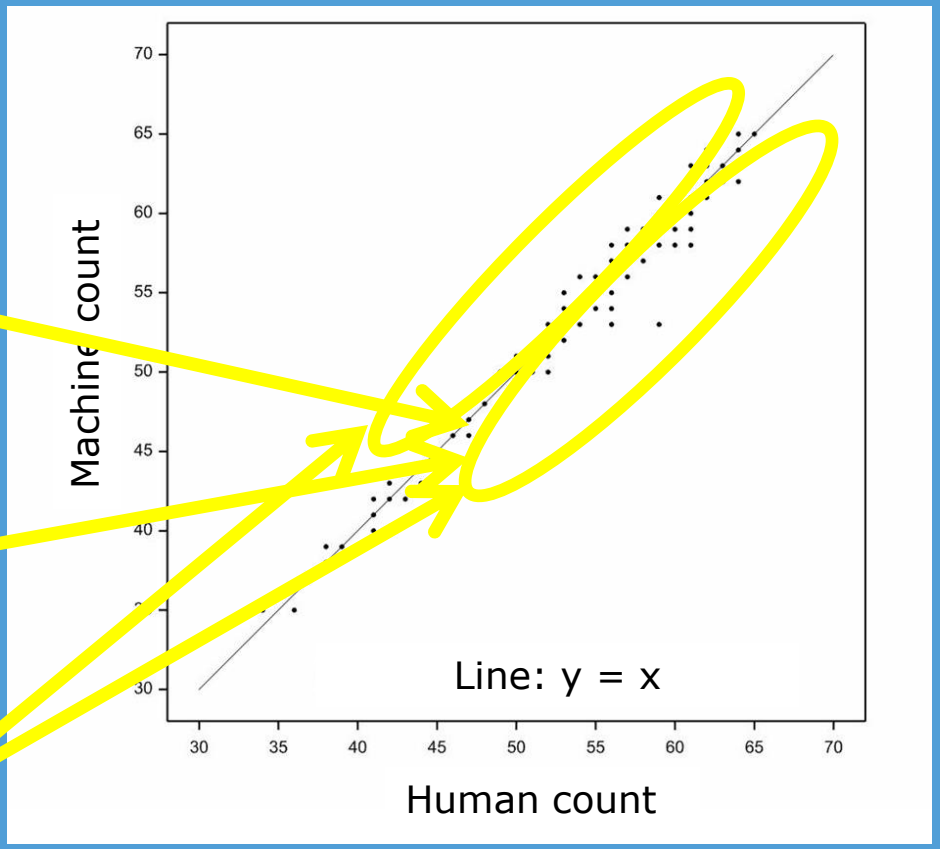
Grand mean  55.808

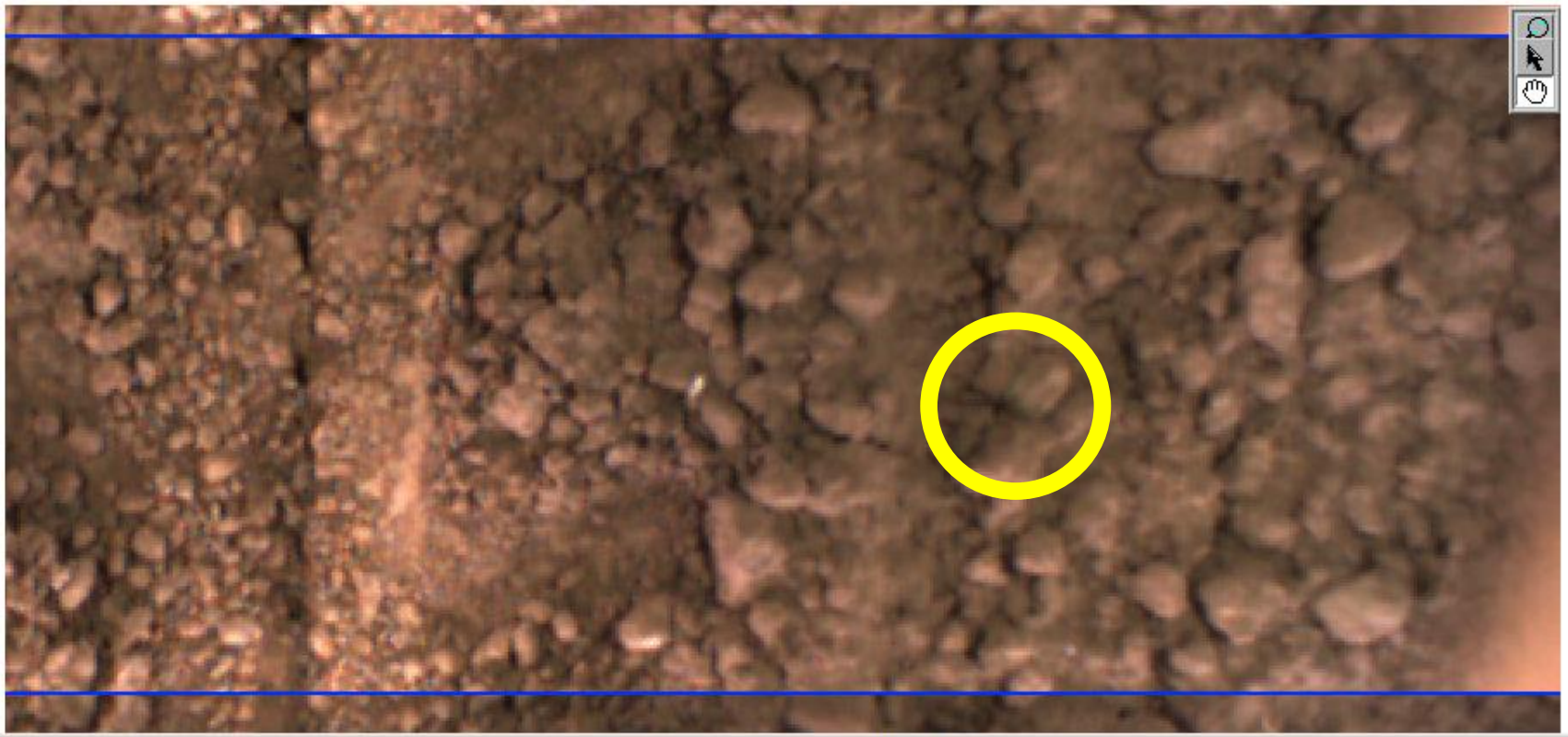
 Method of counting    Machine     Human
                        55.737    55.879
```

Some differences explained...

The current machine setup is unable to detect:

- Damaged plants by animals
- Occluded plants by clods and bigger plants
- Irregular crop emergence (FFT)





NumPlantsTotalM

14	14	12	15	16	11

Low

7

0 50 100 150 200 255

High

205

5

0,0

km/u

0 1 2 3 4 5

Opslaan

ResetTot

Volgende

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Veldje

Steketee

09:23
11/09

Some improvements to make the machine better

- Plant segmentation based on specific shape and (leaf) colour:
  - Opportunity for more plant phenotyping tasks!
  - Plant coverage calculation is possible!
- Light configuration
- “Learning by doing” : Kalman filter

Nevertheless:

- The system is accurate, but can still be improved (P=0.061)
- Working speed = 4.5 km/h
- Continuous counting (even at night)
- Uniform counting: not prone to “human counting errors”:
  - loss of concentration
  - different counting techniques in case of multiple human counters
- This system replaces 3 human counters

Thank you for your attention!

Questions?

Remarks?

Suggestions to make the machine better?

Contact:
pieter.blok@wur.nl

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