Autonomous robot with automated system for volunteer potato control

2019-04-08 – Ard Nieuwenhuizen, Bram Veldhuisen, Jan Kamp, Corné Kempenaar

Samenvatting

In dit projectplan is de aanpak uitgewerkt om te komen tot een effectieve manier van aardappelopslag bestrijding met een geautomatiseerd systeem gebaseerd op plant specifieke herkenning van deze planten met vision techniek, gecombineerd met een deep learning algoritme en actuatie van een spuitboom. Dit type toepassingen leent zich uitstekend voor het combineren met een autonoom voertuig. Echter, het is ook mogelijk in combinatie met een trekker.

Uit een marktverkenning is gebleken dat op dit moment alleen AgroIntelli (Deens high tech bedrijf, uitsluitend actief in de landbouw) ervaring heeft met de toepassing van bovenstaande technieken. Door deze kennis te vertalen naar het domein van aardappelopslag herkenning wordt verwacht dat er op korte termijn een toepassing kan worden ontwikkeld en gedemonstreerd. Het uitgangspunt is dat het te ontwikkelen systeem wordt opgebouwd op een autonoom platform dat onlangs door WUR Open Teelten voor dit doel is aangeschaft.

Ontwikkeling systeem
Bij de WUR is langjarige ervaring met aardappelopslag herkenning. WUR brengt deze kennis in in het project en werkt samen met AgroIntelli om een systeem voor dit domein geschikt te maken. Deze ondersteuning bestaat uit het beschikbaar maken van een geschikte dataset voor de opstart en demo fase, ontwerp en testen van de herkenningssoftware en het zo nodig optimaliseren van de huidige spuittechniek zoals AgroIntelli nu voorhanden heeft, dit is een spotsprayer met spuit oppervlak van 10*10cm.

Praktijk test en demonstratie
Het doel is om een op lab niveau getest systeem begin mei 2019 gereed te hebben voor een test onder praktijkomstandigheden in Valthermond. Hiertoe zal in Valthermond een testveld met suikerbieten beschikbaar gemaakt worden, waar het systeem geoptimaliseerd kan worden. Dit wordt gevolgd door een real life test op een proefveld waar een aantal stroken met opslagplanten met glyfosaat wordt bestreden. Hier worden tellingen gedaan om het succespercentage te meten van zowel gedode opslagplanten, maar ook de schade aan bietenplanten in kaart gebracht wordt. Dit alles vormt input voor een demonstratie en toelichting op de grote Onkruiddag 2019 in Valthermond (28 mei ’19).

Go-No go
De ervaringen op de demonstratiedag worden door de stuurgroep geëvalueerd. Op basis hiervan besluit de stuurgroep om al dan niet opdracht te geven voor het vervolg.

Verbetering dataset en verbreding naar uien
Het project voorziet ook in het doen van waarnemingen in een aantal suikerbieten percelen op verschillende grondsoorten en uienpercelen om te komen tot een grotere dataset voor beide gewassen. In combinatie met de kennis en ervaringen van seizoen 2019 is met deze grotere dataset in 2020 een verhoging van de bestrijdingskwaliteit van opslagplanten mogelijk in zowel suikerbieten en uien.

Microsprayer
Een optimaal werkend systeem dat gebaseerd is op bestrijding met glyfosaat vraagt een zeer nauwkeurige spuittechniek. Zelfs minimaal gespetter van glyfosaat kan leiden tot het doodgaan van een behoorlijk aantal bietenplanten. In een deelproject wordt ingezet op het ontwikkelen van een zogenoemd microsprayer spuitboom. Deze spuitboom wordt gekenmerkt door zeer nauwkeuring te richten en te doseren spuitmiddel en waarbij slechts sprake is van verwaarloosbare nevenschade aan het gewas. Het uitgangspunt is dat deze ontwikkeling wordt opgepakt door WUR in nauwe

samenwerking met een SME die zelf hierin ook investeert. In het project is wel een vergoeding opgenomen voor de kosten voor het ontwerpen van een proof of principle (1e fase - €10k). De bouwkosten van een prototype met bijbehorende eigen inzet zijn voor rekening van de SME.
Het is de bedoeling dat deze ontwikkeling van de microsprayer plaatsvindt in de periode van zomer 2019 tot vroege voorjaar 2020, zodat deze beschikbaar is voor demonstratie en test in het seizoen 2020.

Wisselwerking met het Smaragd project

Het project Smaragd heeft in 2018 de basis gelegd voor deze ontwikkeling door aan te tonen dat met behulp van deep learning technologie en met een relatief beperkte dataset een hoge detectiegraad van aardappelopslag planten mogelijk is. In het project Smaragd zijn de volgende activiteiten uitgevoerd.

1. er is een dataset (beelden) verzameld van aardappelopslag planten in een suikerbietenveld.
2. deze dataset is geannoteerd (van de beelden is aangegeven wat welke plant is);
3. er is een eerste systeem ontwikkeld op basis van deep learning: hiermee is aangetoond dat met de combi Dataset en deep learning systeem een hoge betrouwbaarheid geeft (ca. 95% van de planten is gedetecteerd). Tevens is aangetoond dat dit mogelijk is zonder het afdekken van het zonlicht.

Deze kennis vormt de basis voor de ontwikkelingsrichting in dit project. De dataset en bovengenoemde kennis vormt de basis voor een korte ontwikkeltijd i.s.m. AgroIntelli.

Voor 2019 is in Smaragd voorzien dat de dataset voor aardappelopslag in uien en suikerbieten wordt uitgebreid. Daarnaast zal er een inventariserende studie gedaan worden naar technische alternatieven voor bestrijding o.b.v. glyfosaat (denk aan: warmte, stroom, uitboren..). Hiermee ontstaat zicht op de meest kansrijke alternatieve methoden.
Binnen Smaragd wordt parallel aan de ontwikkeling bij AgroIntelli gewerkt aan het verbeteren van de herkenningssoftware. Deze wordt ook getest en demonstreert in Valthermond op 28 mei 2019. Hierdoor ontstaat een soort benchmark ontstaat voor de AgroIntelli oplossing. Deze vergelijking geeft zicht op de (mogelijk) benodigde verbetering van de herkenningssoftware.

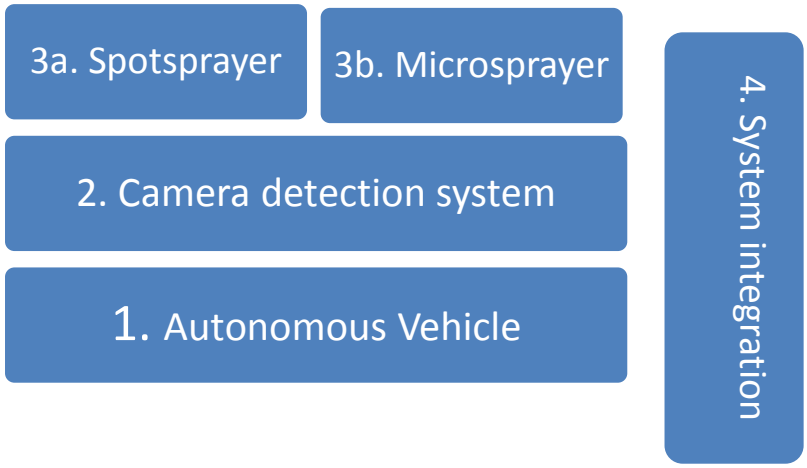
1. Background of volunteer potato control

Despite a lot of preventive measures, volunteer potatoes remain a problem in the arable crop farming. Volunteer potato control remains a labor intensive activity with multiple human labor actions in the field. On average two times per season complete fields with chicory, sugar beet, carrots or onions need to be covered to control volunteer plants with selector plant specific applications. These applications are plant specific and use glyphosate on the volunteer potato plant to control foliage and tuber in the soil.
A great demand exists to automate volunteer potato control. Within the last decade, from 2009 to 2019 several techniques for detection, navigation and control of volunteer potato plants have emerged from research and proof of concept stage. These techniques can now be brought together in a proof of concept and prototype machine. This machine can be attached to an autonomous vehicle that by itself searches for volunteer plants and destroys these. Therefore, the following business case and project is foreseen.

2. Proposed system and objective

We propose a final system that is able to fully autonomously control volunteer potato plants. The system will consist of an autonomous robot for navigation and carriage of the automated machine. The machine will have a detection module as well as an application module that is aimed at applying glyphosate as herbicide, without harming the crop. By doing this in a controlled manner, the foliage and tuber is controlled. By monitoring the locations and applications we register where weed hotspots are, such that in following crop stands special attention can be given to these regions for repeated control. The automated machine needs to work as a standalone machine as well, such that it can be mounted on regular tractors as well, and is not solely linked to autonomous machinery.

Building blocks:



Why Building blocks
What is the strength of defining individual building blocks? We do not depend on one single integrated system. A modular system opens opportunities for different detection and application technology suppliers. Of course the trick is the integration of these two in one independent working machine, however WUR Agro Food Robotics has experience in several mechatronics integration projects with successful examples of such integration. Furthermore, towards market introductions individual blocks can be changed, optimized and or prioritized.

3. Research and development phases

The development phase is mainly focused on the automated machine for detection and control. For the detection system a camera system that can handle variable light conditions in arable farming conditions is required. Furthermore, software and a detection pipeline is required to distinguish the volunteer potato plants from crop plants, as well as to determine the location in coordinates. For the control system, application techniques need to be developed that can apply glyphosate as herbicide without drift and splash onto the weed potato plants. This application system needs to be linked to the detection system through a digital interface. The two parts of detection and application need to be linked together and require appropriate monitoring tools to gather data of number and amount of applications.

Objectives for 2019

It is too challenging to have a working microsprayer before the 2019 volunteer potato season (May-June). In order to have something to work with and demonstrate we propose to develop a spotsprayer. The spotsprayer is different from the microsprayer with respect to the accuracy. The accuracy of the spotsprayer should be a spot size of max. 100x100mm. Limited drift or splashing is accepted. It is expected that it is more likely that the spotsprayer will be used with selective herbicides, for example Goltix, rather than more effective, but none selective, herbicides like glyphosate.

For 2019 we will use the AgroIntelli spotsprayer as a basis for demonstration (and improve if necessary). Parallel to this, the development of the microsprayer solution will be started in the 3rd quarter of 2019, after the GO – NO GO decision by the steering committee.

Description of the building blocks

ad 1. Autonomous vehicle
Lead: AgroIntelli
Role WUR: Supply Robotti, including operator during test and development.

ad 2a. Camera detection system hardware
Lead: AgroIntelli
Role WUR: provide support with Dutch experiences in volunteer potato control, delivering datasets, testing algorithm. And describe the monitor- and control system.
We aim for 1.5 m sections of detection such that the detection system technology can scale with the application technology. Investments in machine width can be made on required capacity and choice for autonomous or manned machinery.

ad 2b. Detection with deep learning
Lead: AgroIntelli
Role WUR: based on Wageningen Research provided datasets AgroIntelli can further implement their deep learning pipeline for the application on volunteer potato detection. Datasets being newly collected during demo and development (this project) stay within Wageningen Research (or under conditions shared with AgroIntelli).

ad 2c. Actuator – application technology
Lead: AgroIntelli for the 2019 demo (will be based on the AgroIntelli spotsprayer solution).
Role WUR: because of building block 3b (microsprayer), a combination of on actuator and spraying boom is necessary.

Ad3a. Spotsprayer
Lead: AgroIntelli; has a basis for spotsprayer solution available
Role WUR: support improvement of the spotsprayer (if necessary), either before or during testing

Ad3b. Microsprayer
Lead: WUR
The system should be able to apply glyphosate on volunteer potato plants without drift to sugar beet plants. We foresee a system with adjusted viscosity and reduced splash on volunteer potato weed leaves. Links to herbicide manufacturers are required to adjust the properties. The complete system should have a maximum damage to the sugar beet crop of 5%. We aim for 1.5m width sections.

ad 4. System integration of detection and application technology
Lead: WUR and Dutch SME, for first demo AgroIntelli
The detection needs to be integrated with yet to be developed precision spraying application technology. We propose that the interface be described together with AgroIntelli and WUR. Based on the interface and program of requirement we can build and test the technology together with SME. We aim for 1.5 m width sections of machinery.

Transition of prototype stage to SME and farmers as end users
As count for many technical innovations, seeing is believing. Especially for this kind of technological improvements, we need to show in field experiments and demonstrations that the technology is properly capable of detecting in a wide range of circumstances as well as to apply the glyphosate under a wide range of conditions. We have a group of companies interested in the local region that wants to support the development of this technology. It is important to note that the automated machine should be able to work as a standalone module. That will enable use of the machine on manned machine as well as on unmanned machines. This will enable faster uptake of the technology in practice, thereby increasing market chances and a better ROI for the companies involved in the development. In year 1 we foresee demonstration with an autonomous vehicle and automated detection combined with spot spraying on 10x10cm spots. This will show the capabilities of the detection system. During year 1 we need to show a proof of concept improved spraying application technique like micro spraying to enable prototyping of more detailed and precise application in year 2. In year 2 we foresee a combination of detection techniques as well as prototype application techniques, and a transition to SME built machinery.

Support
During the development and implementation phase, several partners need to be involved to ensure proper daily support and investment support to the farmer and end user. This is required to enforce commercial uptake of the technology by local communities, and rise out of the prototype machinery scene. We foresee that the project team will help the commercial parties involved to ensure that proper design and implementation choices are made.

4. Project implementation (phases)

1. Preparation of 2019 demonstration
AgroIntelli will develop a working prototype with the help of WUR. The following steps:

- WUR: provides a dataset and describe IP of this dataset.
- AgroIntelli: develops the plant detection system by training the (deep learning) system and testing (lab) all elements of the pipeline. WUR will provide support where necessary.
- AgroIntelli / WUR: analyze and test the current spot spraying unit of AgroIntelli

2. Field test and demonstration

- WUR will organize a field test in Valthermond (mid May), using the WUR Robotti platform;
- AgroIntelli will support the test (optimizing the system);
- Besides testing a real glyphosate based test is done to measure the performance of the system (% of volunteer potatoes destroyed, % of sugar beet plants destroyed) as input for the big Weed demonstration day of May, the 28th.
- WUR will coordinate the demonstration and co-organize on this event.

3. Go – No go
Based on the experiences during the field test, the steering committee will decide on the progress of the project.

4. Development of a microsprayer system
WUR will carry out the following actions in the 3rd and 4th quarter:

- Describe micro spraying spray boom
- Describe interface between detection and spraying actuation
- Contact partners in SME for micro spraying
- Evaluate the concepts
- Build a microsprayer proof of concept (together with an SME)
- Test microsprayer proof of concept (2019)

in 2020:

- support the building of microsprayer prototype by a selected SME
- Test microsprayer prototype
- Integrate detection and actuation on machine
- Monitoring and control of application
- Test integrated detection and spray boom in lab
- Field test integrated detection and spray boom on tractor
- Test integration of machine with autonomous driving
- Field test by WUR from complete integrated autonomous control system
- Communication and demonstration in practice
- Knowledge transfer to Dutch SME and farmers

5. Other activities

Introduction on practical farms

In 2020 we expect to have a tested and optimized solution for the volunteer potato control that is ready to be tested on farms. We propose to test it on the 3 farms in the North East of NL, at least for several days per farm.

Volunteer potato detection in onions

- collect a data set in onions fields and annotate this dataset.
- develop a deep learning algorithm for this crop, including testing and implementation

5. Project organization

AgroIntelli:
To be determined; project leads and engineers

Wageningen University and Research
Core group:
Jan Kamp – Project coordinator (dissemination, demonstration)
Ard Nieuwenhuizen – Application technology and system integration
Bram Veldhuisen – implementation at farmers practice, instructions for use
Support group:
Pieter Blok – Deep learning for detection and actuation
Koen van Boheemen – Knowledge development on navigation and robot control
Corné Kempenaar – Dissemination through e.g. fieldlab NPPL
Johan Booij – instructions for use and contacts with local SME
Gert Kootstra – Robotics actuators and deep learning
Thijs Ruigrok – Deep learning and mobile field robotics

Dutch SME: To be determined; contacts are made and available for:
- Mechanical construction
- Spraying technology

- System integration and control electronics for linking sprayer to detection system
- Monitoring and integration through IoT technologies
- Support and investment management as well as robot introduction on arable farms

6. Project Planning

2019 Q1

- Building block Hardware - AgroIntelli
- Building block Navigation - AgroIntelli
- Building block Detection – AgroIntelli has the lead, uses our experience to build the algorithm
- Building block Actuation – AgroIntelli with support of WUR (using SME's – existing nozzles / solutions)
- Building block Monitoring and Control – AgroIntelli / WUR (links to geo platforms and usage parameters

2019 Q2

- Test and Demonstration of autonomous platform with automated detection system and spot sprayer 10x10cm
- data collection volunteer potatoes and onions

2019 Q3

- Development proof of concept microsprayer application system

2019 Q4

- Lab test microsprayer application system and start of development prototype

2020 Q1

- Development of microsprayer application by SME (with support of WUR)
- Field test of prototype
- implementation of detection pipeline for volunteer potatoes in onions.

2020 Q2

- Farm test and evaluation
- test in onions

2020 after Q2

- Disseminate and support technology transfer to other interested SME (budget is task-setting)

7. Budget and financing

Budget summary

(All cost are excl. VAT)

Own investments by external partners are left out of the budget.

2019	Agro	OT 1	OT2	FTE	Total person.	Material cost
- Development of AgroIntelli detection-actuation system	38	8	83	8		
- Organize Weed field day (28-5-19)	0	20	20	0		
- Projectcoordination / - meetings	12	90	12	0		
hrs	**50**	**118**	**115**	**8**		
hourly rate	126	180	126	126		
Subtotal	6300	21240	14490	1008	**43.038**	**55.646**
- total Personell+material						**98.684**
Go- No Go						
- Development of microsprayer boom (1st phase)	88	0	24	0		
- Projectcoordination / - meetings	8	32	8	0		
Subtotal (hrs)	96	32	32	0		
hourly rate	126	180	126	126		
Subtotal	12096	5760	4032	0	**21.888**	**5.500**
- total Personell+material						27.388
Total 2019						**126.072**
2020						
- Building and testing microsprayer boom	200	20	124	0		
- Introduction on practical farms	0	0	40	0		
- Development of system for onion crop	24	0	44	0		
- Projectcoordination / - meetings	12	60	12	0		
Total 2020	**236**	**80**	**220**	**0**		
hourly rate	**129**	**184**	**129**	**129**		
Subtotal (personell)	30444	14720	28380	0	**73.544**	**16.800**
Total 2020						**90.344**
Total 2019 and 2020	**382**	**230**	**367**	**8**		**216.416**

Annex 1: Detailed budget information

Omschrijving	Agro	OT 1	OT 2	FTE		Material cost
2019						
- Development of AgroIntelli detection-actuation system						
Document and supply current datasets for deep learning algorithm						
Describe sprayboom with current nozzles for 100x100mm spraying						
Describe Monitoring and control of application						
Design and develop camera detection system hardware						
Deep learning algorithms development (in sugarbeet)						
Development Autonomous platform (in sugar beet)						
Build spot sprayer						
Test autonomous driving platform						2.400
Experimental field for summer 2019						2.000
Testing during summer 2019 (incl tellingen proefbedrijf)						3.000
Collecting new datasets in sugar beet and onion crop (incl annotatie)						4.800
Subtotal (hrs)	38	8	83	8		
hourly rate	126	180	126	126		
Subtotal	4788	1440	10458	1008	**17.694**	**12.200**
- Material cost (thrid party)						
Adaption spraying unit						14.450
Materials / building of detection unit						17.696
Travel and demonstration cost						6.300
						38.446
- Organize Weed field day (28-5-19)						
Organization field day (28-5-19) - (subtotal) hrs		20	20			**5.000**
hourly rate	126	180	126	126		
Subtotal	0	3600	2520	0	**6.120**	**5.000**
- Projectcoordination / - meetings						
Inventory of potential partners in system development (Autumn 2018)						
Project meeting overleg najaar 2018/2019						
Project management 2019						
Subtotal (hrs)	12	90	12	0		
hourly rate	**126**	**180**	**126**	**126**		
Subtotal	1512	16200	1512	0	**19.224**	
Subtotaal (till Go-No go)	50	118	115	8	**98.684**	
GO - NO GO						
- Development of microsprayer boom (1st phase)						
2019						
Describe microspraying sprayboom						
Describe interface between detection and spraying actuation						
Contact partners in SME for microspraying						
Evaluation of concepts						
Build microsprayer proof of concept						5.500
Test microsprayer proof of concept (2019)						
Subtotal (hrs)	88	0	24	0	900	
hourly rate	126	180	126	126		
Subtotal	11088	0	3024	0	**14.112**	**5.500**
- Projectcoordination / - meetings						
Project meeting overleg najaar 2018/2019						
Project management 2019						
Subtotal (hrs)	**8**	**32**	**8**	**0**		
hourly rate	**126**	**180**	**126**	**126**		
Subtotal	1008	5760	1008	0	**7.776**	
hrs	**146**	**150**	**147**	**8**		
hourly rate	**126**	**180**	**126**	**126**		
Subtotal (personell)	18396	27000	18522	1008	**64.926**	**61.146**
- Material cost						
Total cost 2019						**126.072**

2020						
- Building and testing microsprayer boom						
Build microsprayer prototype						
Test microsprayer prototype (2020)						
Integrate detection and actuation on machine						
Monitoring and control of application						
Test integrated detection and sprayboom in lab						
Field test integrated detection and sprayboom on tractor						
Test integration of machine with autonomous driving						6.000
Field test by WUR from complete integrated autonomous control system						
Communication and demonstration in practise						
Knowledge transfer to Dutch SME and farmers						
Subtotal	**200**	**20**	**124**	**0**		
hourly rate	**129**	**184**	**129**	**129**		
Subtotal (personell)	25800	3680	15996	0	**45.476**	**6.000**
- Introduction on practical farms						
Introduction of system to arable farming practice at 3 farms			**40**			
hourly rate	129	184	129	129		
Subtotal (personell)	0	0	5160	0	**5.160**	**9.000**
- Development of system for onion crop						
Deep learning algorithms development (in onion)						
Test volunteer potato control in onion crop						1.800
Subtotal	**24**	**0**	**44**	**0**		
hourly rate	129	184	129	129		
Subtotal (personell)	3096	0	5676	0	**8.772**	**1.800**
- Projectcoordination / - meetings						
Project meetings 2020						
Projectmgt						
Subtotal	**12**	**60**	**12**	**0**		
hourly rate	129	184	129	129		
Subtotal (personell)	1548	11040	1548	0	**14.136**	
Total 2020	236	80	220	0		
hourly rate	**129**	**184**	**129**	**129**		
Subtotal (personell)	30444	14720	28380	0	**73.544**	
- Material cost						**16.800**
Total cost 2020						**90.344**
						216.416
2021						
Guide SME and farmers by introduction of autonomous solution	20		20			
Testing of SME built machinery			40			
Projectoverleg		pm				
Projectmgt		pm				
Total 2021	**20**	**0**	**60**	**0**		
