Grower Summary

HNS PO 194

GROWBOT: A Grower-Reprogrammable Robot for Ornamental Plant Production Tasks

Final Report 2019

Project title:	GROWBOT: A Grower-Reprogrammable Robot for Ornamental Plant Production Tasks
Project number:	HNS/PO 194
Project leader:	Aran Sena, King's College London
Report:	Final Report, September 2019
Previous report:	Annual Report, September 2018
Key staff:	Academic Supervisor (1 st): Dr. Matthew J. Howard Academic Supervisor (2 nd): Dr. Elizabeth Sklar AHDB Research Manager: Dr. Jim Dimmock
Location of project:	King's College London
Industry Representative:	Bruce Harnett (Kernock Park Plants), Jamie Dewhurst (J&A Growers)
Date project commenced:	October 2016

DISCLAIMER

While the Agriculture and Horticulture Development Board seeks to ensure that the information contained within this document is accurate at the time of printing, no warranty is given in respect thereof and, to the maximum extent permitted by law the Agriculture and Horticulture Development Board accepts no liability for loss, damage or injury howsoever caused (including that caused by negligence) or suffered directly or indirectly in relation to information and opinions contained in or omitted from this document.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

Aran Sena

PhD Student

King's College London

Signature .... Date ....

Dr. Matthew Howard

Senior Lecturer

King's College London

Signature .... Date ....

Report authorised by:

Dr. Jim Dimmock

Resource Management Scientist

AHDB

Signature .... Date ....

Dr. Georgina Key

Resource Management Scientist

AHDB

Signature .... Date ....

Grower Summary

- This is the final report for AHDB PhD studentship HNS/PO 194 – *"GROWBOT: A Grower-Reprogrammable Robot for Ornamental Plant Production Tasks"*.
- The research outputs from this project have been published in top robotics venues, IEEE International Conference on Robotics and Automation (ICRA), IEEE International Conference on Robotics and Intelligent Systems (IROS), and International Journal of Robotics Research (IJRR). Presenting at these conferences and publishing in a top-tier journal has helped give exposure to the GROWBOT project, and will hopefully spur others, globally, to take up the research agenda of expanding the use of collaborative robots for increasingly dextrous tasks with more general users.
- In addition to research outputs, a number of public engagement activities have been undertaken. Schools workshops, community magazine articles, public speaking events, and engagement with the wider horticultural research community across Europe have been valuable activities for spreading the GROWBOT message of highly adaptive robotic systems offering automation of long-standing problem tasks, not for replacement of human works but for improving throughput capabilities of SME's and improving working conditions for the employees.

Headline

Horticulture faces significant challenges which conventional automation technology has struggled to address due to capability, economic, and expertise limitations. GROWBOT research has focused on robotic systems that learn directly from growers rather than being explicitly programmed, and has shown that this is a promising approach toward widespread horticultural automation.

Background

The original project brief specified by the AHDB summarised the objectives for this project as (emphasis added):

> *[GROWBOT] will investigate ways in which* ***non-expert users*** *(i.e., those without technical expertise in robot programming and control), but that are nevertheless skilled in plant processing, can use robots in their work, to relieve them of the more* ***repetitive, labour-intensive tasks*** *encountered.*
>
> *Focus will be given to improving* ***efficiency*** *and competitiveness in small/medium scale businesses, typically processing* ***relatively small batches*** *of a wide variety of plants, as*

> *opposed to the traditional large facilities specialised in processing large volumes of single-varieties. For this reason, the project will investigate ways of automating tasks that are usually* ***difficult to achieve at small scale****, such as taking and inserting cuttings, grading and collating plant specimens.*

As can be seen from this brief, the core focus was to develop the technology required to better support small/medium scale businesses producing products in relatively small batch sizes. Being small/medium business as well as producing relatively small batched products presents a significant barrier to automation using conventional systems due to lacking an economy of scale to offset the capital costs of setting up the automation.

In addition to batch size limitations, the fragile and variable nature of horticultural products leads to further constraints on automation options, as many systems will lack the capability to manipulate the organic matter directly and reliably without damaging it.

These limitations lead to a strong dependence on manual labour for production processes which, given larger batch sizes and more robust products, might otherwise be automated, e.g. packaging.

Labour security is an issue for the horticulture industry as it is becoming increasingly difficult for to source the casual labour force required for these manual processes. This is a problem that is both affected by short-term ongoing political developments around freedom of movement for people, but also a longer-term downward trend of people entering the industry and people travelling for the casual labour roles offered in horticulture.

Given these labour challenges, and the difficulty of deploying conventional automation into horticultural businesses which depend on flexible, small-batch production processes, it is clear that new approaches to horticultural production are required.

Modern robotic systems offer a potential solution. Combining general-purpose robot arms which are designed using a safety-first approach for use around non-experts, with intelligent learning systems that allow the robot to adaptively automate a wide variety of tasks could enable the automation of the low-batch, repetitive, labour-intensive tasks found in horticulture.

Summary

Robots that learn to perform tasks by observing demonstrations provided by people, i.e. *Learning from Demonstration* (LfD), are capable of performing tasks which would be difficult to explicitly program by hand, even by experts. An issue of using learning systems directly with end-users (i.e. the growers on farms), rather than deploying them with the help of experts, is that the performance of the system strongly depends on the quality of data provided by the

person doing the teaching, and so detailed knowledge on *how* the robot learns is often still critical for effective robot learning to take place.

In order to provide examples to the robot which are informative, it is useful for the person doing the teaching to have some idea of what the robot requires for learning to take place. Does showing it how to perform a task once mean it will learn all possible variations? If not one example, how many examples should we provide? Are some examples more informative than others? The answer to these questions generally depends on the type of learning method deployed with the robot, and the nature of the task being automated. It may not even be possible for the robot to learn the desired task given the selected learning method.

A deeper understanding of the interaction between teacher and learner is thus required to make these systems usable for non-experts. It is preferable to enable non-experts use these systems, as they are far more numerous than robotics systems experts, it is far less costly than employing specialised skilled experts, and non-experts may still offer domain expertise for the process they would like automated (e.g. growers wanting to automate their grading processes could bring detailed knowledge of where best to grab a plant to avoid damaging it). Enabling robot learning systems to work with non-experts would thus provide a large pool of users capable of deploying the systems effectively, in a cost-effective way for businesses, and allow them to use their domain expertise to identify use-cases for robot deployment.

Given the potential benefit of non-expert users of robot learning systems, and the increasing availability of commercial off-the shelf (COTS) robot hardware, GROWBOT has thus sought to improve the efficiency of how people teach robot learners, and make the robot learners more effective at using the data provided by the person. As this is completely new approach to horticultural automation, new research and engineering methods are required, and so the research outputs from GROWBOT are not a one-shot solution to the issues faced by industry, but ground-breaking steps toward satisfying the needs of industry.

This research has thus developed (i) a framework which allows researchers and engineers better design robotic learning systems which interact and are programmed by non-expert users, and (ii) an improved learning algorithm which is designed to be more robust to teaching errors made by people teaching robot systems. Both outputs are supported through extensive experimentation, both under laboratory conditions as well as testing directly with end-users on grower sites.

In order to deploy robots on grower’s sites effectively in the near future, it is proposed that this approach of designing robot learner systems for manual task automation with a focus on increasing non-expert understanding of the robot learning process and deploying learning algorithms which minimize the impact of poor teaching behaviour is a critical step toward success.

Financial Benefits

Direct analysis of financial benefits from robotic automation on grower sites was not an objective for the GROWBOT project; however, a rough estimation has been provided in previous reports. This estimation has been based on, and refined through, discussions with growers and information gathered from government reports.

Taking a naïve view we can compare the £40,000 fixed cost of the robot against the recurring £14,217 cost of the human labourer, this represents a ~2.8 year break-even/payback period. National Insurance contributions, pension entitlements, holiday hours, sick leave, etc. lead to an annual cost closer to £16,000 per year, shortening the breakeven/payback period. Payback periods can be even lower again, as there are many factors beyond the cost price which affect payback, e.g. a robot can work consistently for long hours, and can work with higher precision. Of course, these benefits can only be realised if the robot system is *capable* of automating the target process. A challenge faced in the horticulture industry is that many of the involved processes which are not already handled by conventional automation equipment such as conveyors and palletization robots are not feasibly automated by conventional systems without *significant* engineering effort and cost, thus eliminating any economic benefit over maintaining a casual workforce.

The financial benefits offered by robotic automation are not exclusively gained through labour *replacement* as might conventionally be believed. Gains may also be made by making more *effective* use of people. People will continue to be far more capable and cost-effective at dynamic dexterous manipulation across a wide array of tasks than robots for the foreseeable future, so if robot systems can be improved to handle the simpler and repetitive tasks that currently drain workers' time, the workers can then focus on activities which provide a greater value-add to the product or production process. Indeed, based on multiple grower site visits, it was often observed that there were many processes being manually done that *existing* collaborative robot systems could help with, but either a lack of awareness or risk-aversion had prevented the companies exploring a collaborative robot option.

Finally, in addition to the potential financial benefits, there is the remaining issue that labour is becoming more difficult to secure for growers. This is not an exclusive issue to the UK, with similar difficulties experienced in the Netherlands, Germany, Australia, and the US.

Action Points

Horticulture is a diverse industry, with each business facing unique challenges. To help accelerate development of robotic automation, work with researchers in whatever capacity you can to help them gather real-world, industry-relevant information.

While automation of directly handling plant material is currently not achievable with end-user programmable systems (at least not easily, or reliably), there are many basic processes that have been observed during grower visits which would benefit from automation with collaborative robots (e.g. during packaging processes, palletisation, etc.). Engage with researchers and collaborative robot distributors to better understand how these robots are deployed in practice.

