UNSW AUSTRALIA

Australian Government
Australian Grape and Wine Authority

Study tour to support automated yield estimation project



FINAL REPORT to

AUSTRALIAN GRAPE AND WINE AUTHORITY

Project Number: GWT1413

Principal Investigator: **Dr Mark Whitty**

Research Organisation: **UNSW Australia**

Date: **29 September 2015**

Executive Summary

The award of this travel grant assisted Dr Mark Whitty in attending two conferences (MVA2015 and ICRA2015) to present peer-reviewed work on berry counting and bunch detection. In addition, research visits to Cornell Lake Erie Research Centre, Carnegie Mellon University and Treasury Wine Estates were undertaken. Furthermore, an inspection of the latest yield monitoring camera system developed by Steve Nuske was undertaken. These activities together resulted in increased international contacts in agriculture and viticulture, promotion of the latest work in Australia and ideas for directing existing yield estimation work.

Abstract

A number of planned activities relating to the problem of yield estimation in viticulture were undertaken with the support of AGWA funding. These included presentation of peer-reviewed work at two conferences and several research visits across the USA. The papers presented addressed the issues of bunch detection from imagery and counting berries from a single image of a bunch, with both papers showing results of between 85 and 90% accuracy. The major result from the research visits was a better understanding of the state of the art yield estimation system developed by Steve Nuske which directly informs the system development underway in an existing AGWA funded project. In addition ideas were gained for future proposals as well as directions for reducing the risks associated with the current project.

Planned activities:

1) 18-22 May 2015 Presentation of conference paper – IAPR International Conference on Machine Vision –Tokyo.

2) 1 June 2015 Meeting – Dr Steve Nuske, Carnegie Mellon University, Pittsburgh, PA.

3) 2 June 2015 Meeting – Dr Terry Bates, Cornell Lake Erie Research Centre, Portland, NY.

4) 4 – 8 June 2015 Travel to Rochester, MI to lead a team in an international robotics competition.

5) ~~17 June 2015 Meeting – Dr Nick Dokoozlian E & J Gallo, Modesto~~.

6) Dissemination of outcomes to project partners

Additional relevant activities undertaken, but not funded by this grant:

7) 30 May 2015 Presentation of conference paper – Workshop on Agricultural Robotics at ICRA2015 – International Conference on Robotics and Automation – Seattle, WA.

8) 18 June 2015 Inspection of yield estimation equipment during field tests – Dr Steve Nuske, Modesto, CA.

9) 19 June 2015 Meeting with Will Drayton, Technical Viticulture Manager, Treasury Wine Estates, Napa, CA.

Outcomes:

1) The abstract from the presented paper is: Precise yield estimation using image processing techniques has been demonstrated conceptually on a small scale. Expanding these solutions to larger scale applications requires significant computational power, which need to analyze the entirety of all captured image data. However, many images captured for yield estimation in these processes only contain small areas of useful features for analysis. This paper introduces an image processing algorithm combining color and texture information, and the use of a support vector machine, to accelerate fruit detection by isolating useful features in images. Experiments carried out on two varieties of red grapes (Shiraz and Cabernet Sauvignon) demonstrate an accuracy of 87% and recall of 90%. This method is also shown to remove the restriction on the field of view and background, which limited existing methods and is a first step towards precise and reliable yield estimation on a large scale.

   Full citation: Liu, S., Whitty, M., Cossell, S., International Conference on Machine Vision Applications (MVA 2015), Tokyo, Japan, 18 May 2015 - 22 May 2015. Proceedings editors: Ukita N.

2) Main points from discussions with Steve Nuske:
    a. Building a yield map from interpolating discrete manual samples may or may not correlate well with the final yield map from on-harvest yield monitors.
    b. Video from 1 in 10 rows is considered sufficient for estimating the overall yield number.
    c. Video from 1 in 4 rows is considered sufficient for building a yield map, any less than this and features on the map may be missed.
    d. E & J Gallo has a split watering system trial, but at enormous expense, suggesting that variable watering is not a likely outcome and other methods for regularising yield would be more valuable.
    e. The long term feasibility of building a yield map from ground based imagery was questioned. Nuske has offered a ground based proximal yield estimation service to a number of growers across the country for several years. He found that while the cost of undertaking such a service was approximately $US100 / ha, growers in general were unwilling to pay such a price for that information. Further investigation into the benefit to both growers and wineries is strongly recommended.
    f. Currently his research group is looking at counting shoots, just after budburst for the purpose of relating that to yield estimation.
    g. The cost of one camera rig was estimated at $US40k, comprised of two cameras, two flashes, a decent computer and large amount of storage.
    h. Imaging during the daytime is considered feasible (and was demonstrated), as long as the camera isn't pointing directly into the sun.

3) Main points from discussion with Terry Bates
    a. A co-operative takes the majority of grapes from the Lake Erie region (32,000 acres) which means they need industry-wide crop estimation, driving current research.
    b. The co-operative pays growers on the basis of acreage and take all the fruit available, often with a long term contract for the vineyard. So there is less motivation for growers to improve their yield unless they wish to regularise and regulate it for improving quality. The co-operative had more of a problem with finding and allocating tank space.
    c. Prices are around $US220 / tonne for Concord grapes, and the aim of the region is to produce higher yields rather than higher quality, and the growing season is very short due to the cool climate.
    d. Having a cool climate and only a single variety of grapes helps with the yield estimation.
    e. Traditionally, more crop is hung than can be ripened meaning thinning is regularly performed (using harvesters) about a month after flowering. Yield monitors on harvesters are used to estimate the amount of thinning undertaken.
    f. Previous yield estimation took shoot count numbers, berries per cluster from a variety of plots in the region but poor results were obtained, with the suspicion resting on poor sampling practices.
    g. Recent work by James Taylor has investigated using NDVI + soil EC to classify a few blocks into three vigour classes, and then perform stratified sampling (16 samples total, 3 blocks) 12 days after flowering. Results were able to predict yield within 1 to 7% relative to a harvest yield monitor.
    h. The curve relating NDVI to yield at single points was found to be non-linear.
    i. Linear relationships ($R^2 = 0.59$) between flouret counts and the final yield were discovered in collaboration with Nuske, where there was already a generally uniform yield in the block.
    j. Ground based NDVI measurements have been taken, using GreenSeeker or CropCircle sensors and logged with GPS then linked to sprayers for differential spraying.

4) The team of students from UNSW Australia competed in the event with their autonomous robot, winning all the on-field challenges convincingly and taking home a raft of prize. Further details are available at https://newsroom.unsw.edu.au/news/science-tech/unsw-wins-best-autonomous-robot. Experience from the development of this robot will be applied to future projects involving autonomous systems (Unmanned Aerial Vehicles and Unmanned Ground Vehicles) in viticulture, toward the target of Digital Viticulture as promoted by Wine Australia.

5) The meeting scheduled with Dr Nick Dokoozlian at E & J Gallo was cancelled by Dr Dokoozlian one day prior due to high level company commitments.

6) Relevant results were presented to the AGWA project (DPI1401) steering group meeting on 15 July 2015. Results from the papers presented were also presented to growers and winemakers at AWRI seminars on 19, 20 and 21 August in Canberra, Orange and Mudgee. They were also presented at the Wine Tasmania Field Day on 18 September near Launceston. Further seminars and presentations to industry stakeholders are scheduled for November 2015.

7) The abstract from the presented paper is: Berry counting is an integral step towards grape vine yield estimation. As a traditional yield estimation step, counting berry by human hand is tedious and time consuming. Recent methods have approached this using specialized stereo cameras and lighting rigs which are impractical for a large scale field application. This paper presents a lightweight method for generating a representative 3D reconstruction of an individual grape bunch from a single image from one side of the bunch. The results were poor prior to the application of a sparsity factor to compensate for bunches of varying sparsity, with the final result being an absolute average accuracy of 87.6% and average error of 4.6%, with an R2 value of 0.85. These results show promise for in vivo counting of berry numbers in a non-computationally expensive manner.

   Full citation: Liu, S., Whitty, M., Cossell, S., International Conference on Robotics and Automation (IEEE), Workshop on Robotics in Agriculture, Seattle, 30 May 2015 - 30 May 2015.

8) See Appendix 1 for photos taken during the field testing. Comments are under point 2 above.

9) Main points from discussion with Will Drayton:

   a. Current manual yield estimation methods at a block level (across 45 blocks), achieve around 10% accuracy.
   b. Berry counting from frozen bunches is possible, but messy.
   c. Berry diameter measurement with homemade equipment (flatbed scanner) has been undertaken so they have a lot of interest in the mobile phone based berry diameter measurement we are investigating.
   d. Napa is a relatively cool climate area, they do approximately 10% thinning to achieve uniform yield in a block.
   e. Potential exists for us to obtain photographs of flowers and bunches on sentinel vines to assist with berry tracking and colour change tracking.

Overall outcomes

The funding provided by AGWA facilitated networking with leading international practitioners in yield estimation. This included not only up to date information about the methods used for yield estimation and their accuracy but also future plans in this area. Networking laid the foundation for further collaboration through field tests and publications.

Promotion of work done in Australia was aimed at increased the profile of Australian wine industry research and development internationally. Two peer-reviewed research papers were presented to the international community, raising awareness of current work. Current project outcomes were well received and opportunities for adapting the current work discussed. Extended versions of these publications are under preparation as journal manuscripts.

Particular assistance was gained from Steve Nuske, as the pioneer in the field of visual yield estimation, who provided both technical and operational information about the current system he has developed. This has been used to inform the development of similar systems as part of the existing AGWA funded project and future projects. In particular, future work will involve:

- Further investigation into the use of UAVs for rapid yield estimation
- Plans for stratified sampling (or equivalent) to improve the quality of yield estimation
- Intensified efforts in flower counting, berry diameter tracking and mobile app development as elements of a holistic yield estimation strategy
- Thorough cost benefit analysis surrounding yield estimation, from vine to wine, to build a stronger case for widespread adoption of technology for yield estimation in viticulture
- Avoiding generating yield maps from discretely sampled manual measurements of vines or vine segments – vine to vine variation is large at most points within a block

Appendix 1: Photos of yield estimation device developed by Steve Nuske





Camera system for capturing imagery mounted on a farm vehicle (left: side view, right: rear view).




Detail of the camera system (left) and external laptop display (right) showing real-time imagery.

Appendix 2: MVA2015 summary slide

Automatic Grape Bunch Detection in Vineyards for Precise Yield Estimation

Scarlett Liu | Mark Whitty | Stephen Cossell

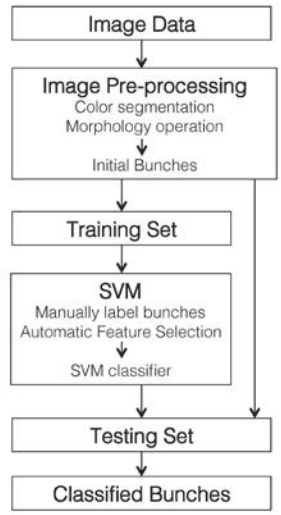
sisi.liu@unsw.edu.au, m.whitty@unsw.edu.au, macgyver@unsw.edu.au

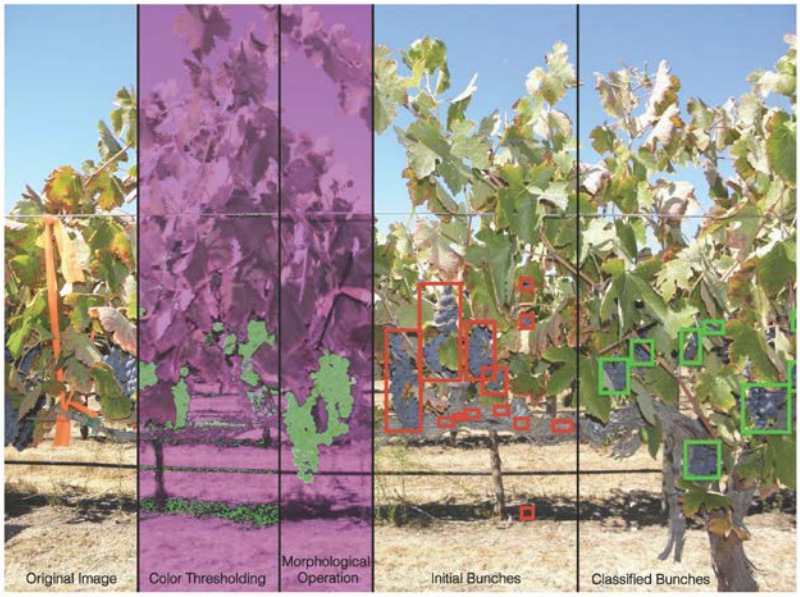
www.yieldestimation.com

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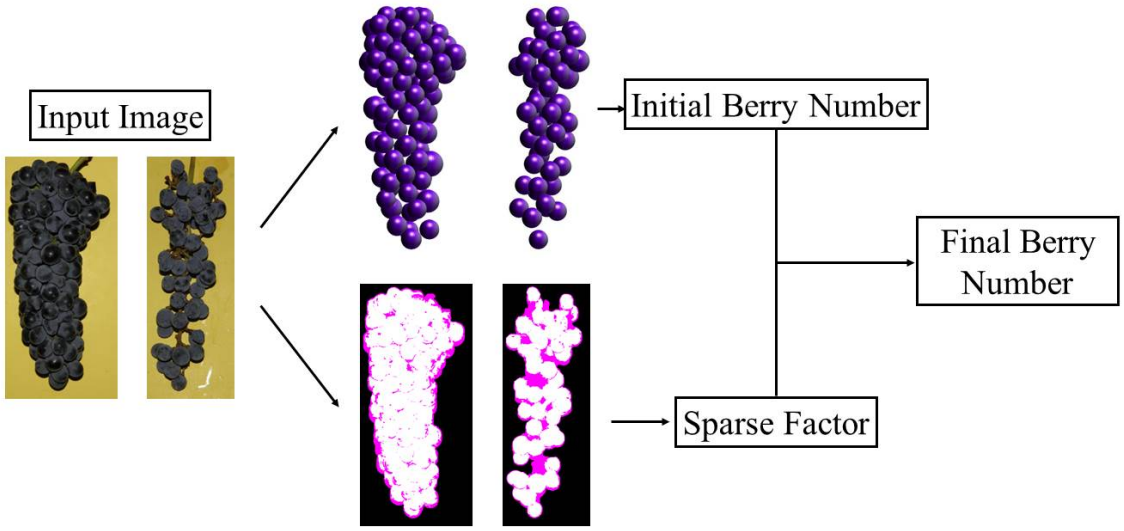
Bunch Detection Workflow





Appendix 3: ICRA2015 method slide

PROPOSED METHOD



Workflow of estimating the number of berries by a single image