



Australian
National
University



A Robotic Vision System for Rapid Inspection and Evaluation of Solar Plant Infrastructure

Final Project Report incorporating results and
lessons learnt

ANU College of
Engineering &
Computer Science

R E I M < G I N E

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COVER PHOTOGRAPH: An image taken from the aerial vehicle during data collection at Vast Solar's 1.1 MWe Jemalong pilot plant.

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List of acronyms used in this report

CSP	Concentrating solar power
DNI	Direct Normal Radiation
FRV	Fotowatio Renewable Ventures, a PV operator
NPV	Net Present Value
MWe	Megawatts of electrical capacity
O&M	Operation and maintenance
PV	Photovoltaic
RTK	Real Time Kinetic. An augmentation of GPS positioning enabling cm accuracy positioning.
TSO	Travelling Salesman Optimisation
UAV	Unmanned Aerial Vehicle

Executive Summary

Following the rapid expansion of the renewables industry sector in Australia over the last ten years, there is a growing focus in the industry on operation and maintenance (O&M) of infrastructure. A key component of effective O&M is the availability of detailed and timely data on infrastructure to enable the scheduling of maintenance and cleaning activities to economically maximise operational efficiency. For large distributed infrastructure, such as is common in renewable energy systems, efficient and economical acquisition and analysis of such data is in itself a substantive challenge.

This project investigated the feasibility of automated collection and analysis of visual data for predictive inspection and evaluation of the condition of concentrating solar power (CSP) and solar photovoltaic (PV) plants. Large-scale imaging of solar plant facilities from moving aerial, ground vehicles, and fixed view-points has the potential to reduce the time, cost, and labour spent on the monitoring of facility conditions and operating efficiency through early detection of equipment failures, accurate diagnosis of performance losses, and identification of maintenance and cleaning priorities. Aerial vehicles in particular have the potential to operate autonomously over fields of photovoltaic panels or concentrating solar power heliostat mirrors, minimizing damage and soiling caused by vehicle traffic through a solar field, and allowing direct transit from point to point leading to efficiency gains. The project evaluated aerial robotic technology for acquisition of visual data and automated processing of visual data to provide analytics on fault detection and soiling levels in solar photovoltaic and concentrating solar power plants.

Experiments demonstrating aspects of the proposed technology were undertaken at Vast Solar's 1.1 MWe Jemalong pilot plant comprising 3.5k heliostats with mirror area 12.5k m², One Sun

Solar's 12.2 MWe photovoltaic solar farm at Williamsdale NSW, and Heliostat Field 2 at CSIRO Energy in Newcastle, NSW, comprising around 400 heliostats with mirror area 1400 m².

The key findings of the project were:

- > No economic advantage was found in using automated visual inspection for detection of exterior and interior defects in PV modules and detection of corrosion in CSP heliostats. Existing methods (manual inspection and analysis of electrical output) are economic at the time scales required for scheduling of replacement and repair of such infrastructure.
- > Regular robotic monitoring of soiling levels on CSP heliostats and the ability to use such data to inform scheduling of cleaning operations yields Net Present Value (NPV) up to \$2M. The NPV is defined as the difference between the present value of cash inflows and outflows attributable directly to the robotic inspection system over the 25-year life of the plant.
- > Automated image analysis software was developed that estimates reduced reflectivity levels due to soiling to within 1% error at a panel-by-panel level from visual data. This system is sufficiently accurate to provide analytics for spatially targeted scheduling of cleaning in large scale CSP and solar PV fields.
- > Existing commercial aerial platforms, mission planning software, and present service operators are not well adapted to the specific requirements of infrastructure inspection missions. In particular, existing aerial mapping software is not appropriate for infrastructure inspection as the resolution and accuracy of the images acquired during mapping missions are insufficient for detailed defect and soiling analysis.

- > Although there is a commercial opportunity available for a company to contribute both hardware and operational software that could be on-sold to operators of PV and CSP infrastructure for inspection purposes, the market in Australia is not sufficiently large or geographically co-located to make it viable for a company to deliver such a product.

The project was successful in demonstrating the economic benefit of aerial visual monitoring of soiling levels in solar plants and developed a proof of concept vision algorithms that accurately

estimate soiling levels from high resolution images.

We recommend that the code developed, including mission planning and visual analysis software, is released under an open source licence. This will provide the opportunity for the growing eco-system of owner operator companies to adopt the outcomes of the project and use this capability to provide UAV services to solar PV and CSP plants. It would also provide the opportunity for open source developers to engage in further development of the code base and through their expertise in the code, to provide contractual advice world-wide.



Fig. 1: Hand cleaning of a PV installation at CSIRO Energy in Newcastle, Australia, as part of before and after power measurements to calibrate the effect of soiling on PV power generation.

Project Overview

Project scope

Soiling/dust accumulation on heliostats and defects of PV modules are the two primary factors that strongly affect the reliability and productivity of CSP and solar PV power plants. In CSP systems, soiling directly degrades the optical efficiency of mirrors/heliostats. Reflectivity degradation can be as high as 2%/day in dry dusty environment and is typically of the order of 0.25%/day even in relatively benign environments. Regular cleaning is an established operations and maintenance activity in CSP systems. Conversely, soiling of PV plants is not considered a significant performance issue and is not quantitatively monitored in commercial PV plants. In PV plants there is more focus placed on identification of delamination, cell part isolation, and laminate discolouring, which together account for an average power loss of 10% after 15 years in the field.

A key requirement for effective and efficient operation and maintenance of CSP and PV plants is the acquisition and analysis of data that can be used to schedule maintenance and replacement to maximise operational efficiency of a plant. Although the power output of plants can be monitored, the resolution is not sufficiently detailed to identify specific faults or defects in a plant. Visual inspection of the physical hardware remains the most cost-effective methodology for identification of defects and soiling. Presently this data is almost exclusively collected manually.



Fig. 2: The aerial drone used pictured on a mirror during testing of RTK positioning capability.

Autonomous robotic systems offer considerable potential for the automated collection of visual data for renewable infrastructure. Automated image processing techniques have the potential to process visual data quickly and effectively providing simple and effective data analytics that can be used by plant managers to schedule maintenance, replacement and cleaning activities in large scale solar PV and CSP plants.

The project scope was:

To evaluate the potential for automated acquisition and analysis of visual data to enable more efficient operation and maintenance of solar PV and CSP plants.

Outcomes

Software package

The primary outcomes of the project were development of software packages for Mission Planning, Image Processing, and Image Analysis.

Mission Planning

In a UAV based inspection system for large-scale solar farms, it is necessary to hover the UAV over (or close to) solar modules and control the gimbal mounted camera that takes snapshots to acquire images with sufficient resolution and at appropriate visual perspective to provide suitably detailed images for reliable analysis. The cameras used were amongst the highest resolution cameras commercially available. The Sony a7rII colour camera with 42.4 Mpixel resolution was used as the primary vision sensor for the project and the image was acquired at a distance of 2-4m

with a high-quality lens that imaged an area only 2 times the size of the panel.

For a typical commercial solar field, with +10,000 modules, only a subset of the possible panels can be targeted in a given flight and a stochastic algorithm to sample panels was developed to provide statistical confidence in the data collected. A waypoint for each panel targeted is generated based on the survey information available from the field considered. The drone autopilot servo controls to each waypoint, at 3m above the desired panel, and at an angle of 10degrees from vertical to avoid imaging the sun or imaging the drone. A time-optimal trajectory amongst the panels was generated by using the Travelling Salesman Optimisation (TSO) problem.

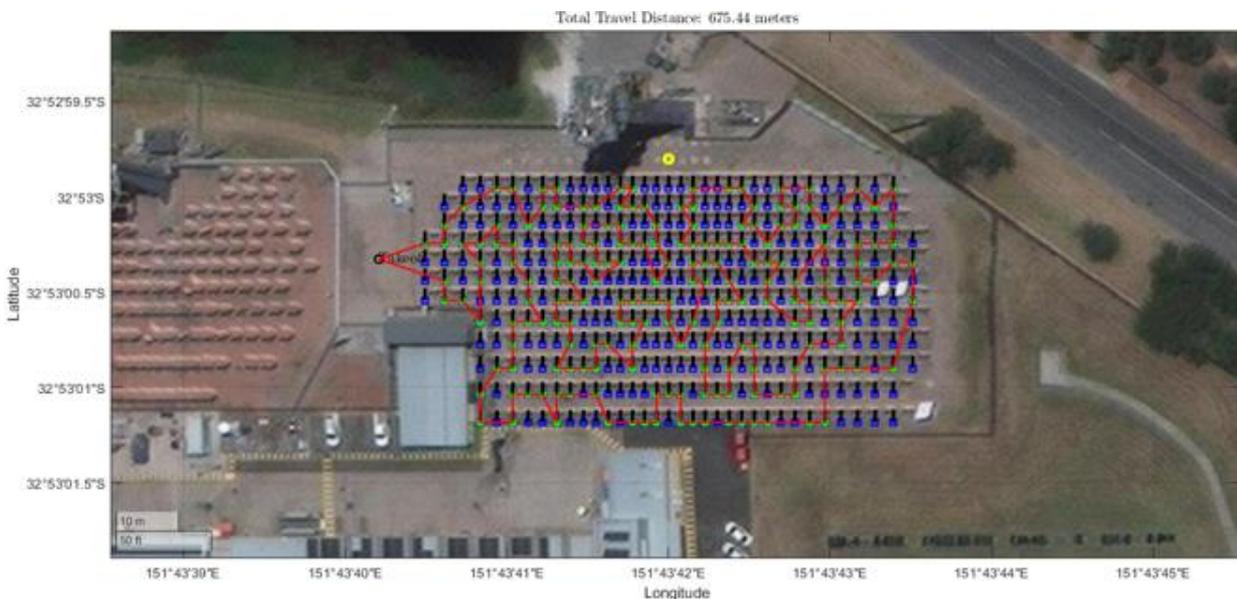


Figure 3: A typical path generated by solving the travelling salesman algorithm for an example CSP plant. Each green point is a way point generated stochastically to provide confidence of overall spatio-temporal soiling levels without requiring imaging of every heliostat. The red path is the planned trajectory, optimised for time of flight and guaranteed to return the vehicle to base within the mission duration window. The final mission planning software developed is a collection of subroutines that generate feasible mission plans for inspection flights and interfaces into the open source autopilot software ArduPilot.

Image Processing

The image processing software is a collection of software routines that reads from a directory of images acquired during an inspection mission. Each image contains a perspective view of a target panel as referenced by the mission plan log. Each image is processed to correct for camera colour characteristics and lens corrections. Then the heliostat or PV panel is segmented from the general image and a straightening operation is undertaken that

transforms the resulting image to a fronto-parallel image of the panel, as though the drone was directly in the normal direction of the panel/heliostat when the image was taken. In this way, images from different flights can be compared and directly overlaid to identify temporal changes. Moreover, the image analysis algorithms can be tuned for a single set of geometric parameters.

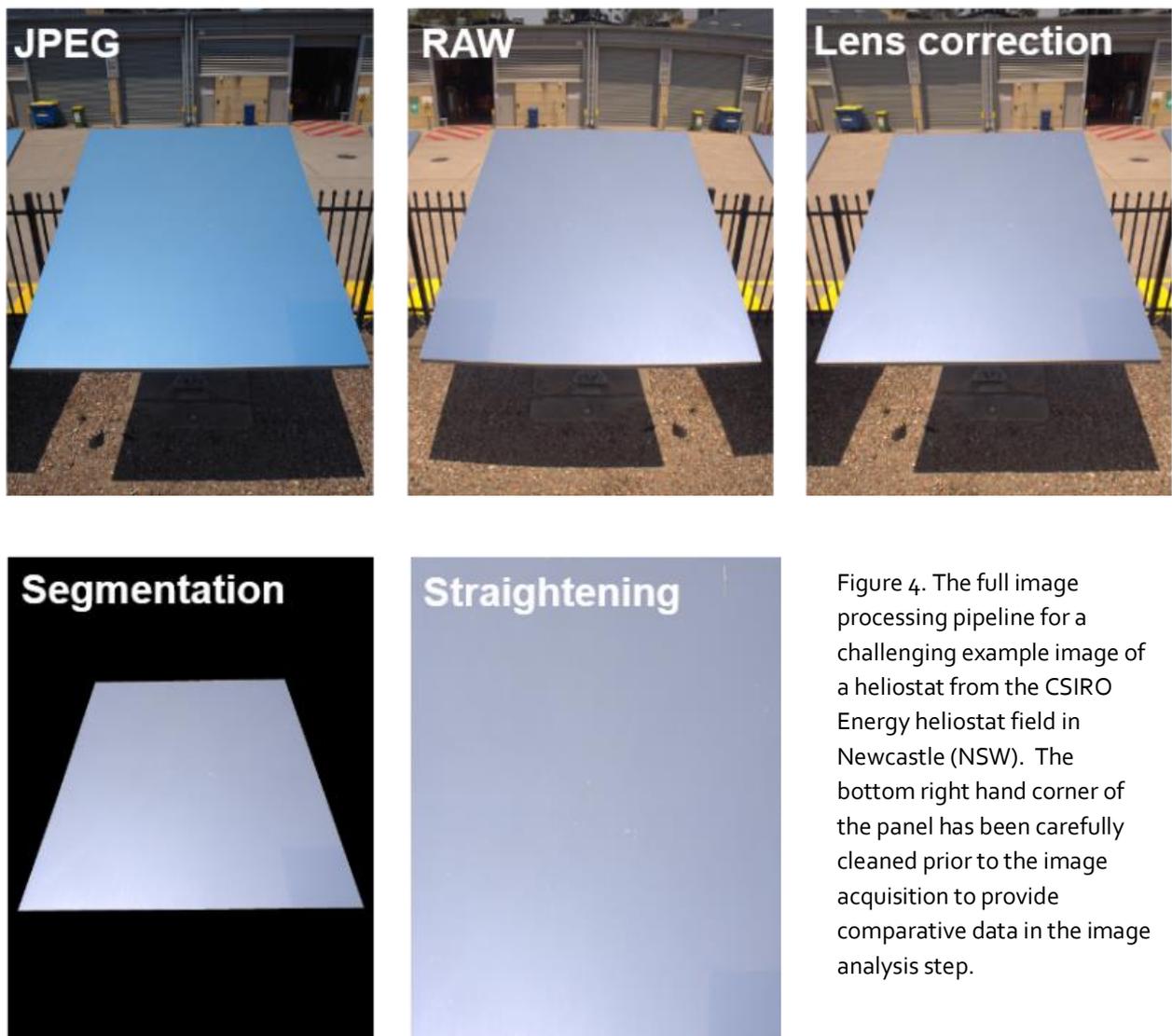


Figure 4. The full image processing pipeline for a challenging example image of a heliostat from the CSIRO Energy heliostat field in Newcastle (NSW). The bottom right hand corner of the panel has been carefully cleaned prior to the image acquisition to provide comparative data in the image analysis step.

Image Analysis

The image analysis module of the software processes the fronto-parallel images from the previous module to extract information on soiling and defects. The first stage identifies a sky model for each image. In Figure 5 the output from the image processing is shown in image a). The actual intensity of the image is visualised using a colour mapping in image b). There is clearly a localised soiling of the mirror (bird scat) in the top left of the mirror and a visible clean patch in the bottom right (each panel was had a small square area cleaned to provide comparative data). There is also a clear high intensity region in the lower central section of the image that is due to the changing light intensity of the sky imaged by the mirror. The sky variation is modelled and removed to generate a normalised image as shown in image c).

The normalised image is fitted to a 3 mode spectral classification associated with clean sky reflection, moderate soiling (associated with dust), and hard soiling (bird scat and mirror damage). The relative intensities of the criteria are shown in Figure 4. The hard reflectance classification clearly identifies the bird scat soiling on the mirror. The ratio of clean reflectance classification to moderate soiling reflectance can be correlated to provide a good estimate (within 1% accuracy) of the actual mirror reflectance as measured with a reflectometer. For this mirror the level of soiling was high, yielding an overall reflectance of 86.2%. The reflectance in the cleaned patch in the bottom right of the mirror is clearly differentiated from the remainder of the mirror and had a reflectance of 94%.

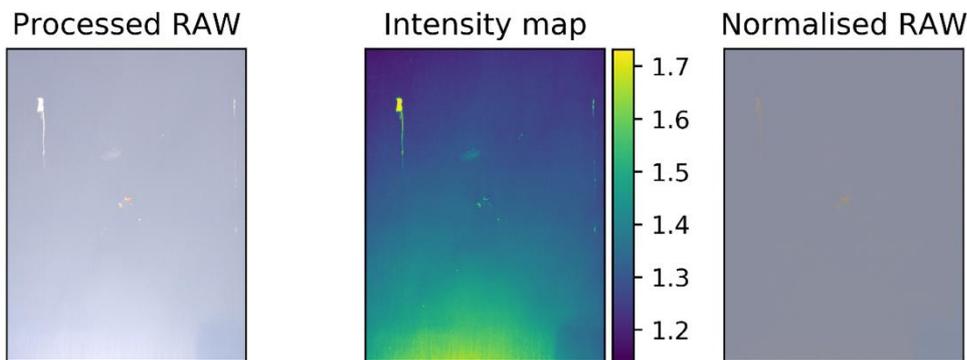


Figure 5. The sky model normalisation for panel N32 in the CSIRO Energy Heliostat Field 2 in Newcastle (NSW).

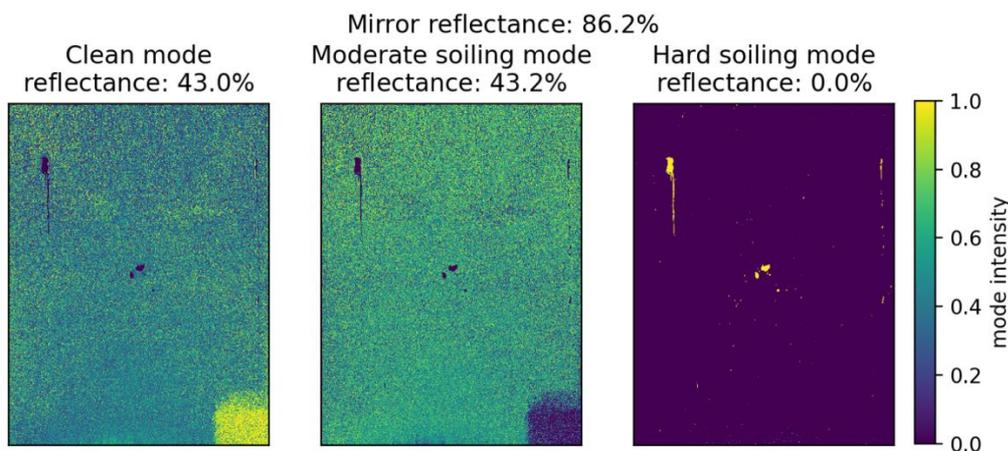


Figure 6. The reflectance classification for module N32 of the CSIRO Energy Heliostat Field 2 in Newcastle (NSW)

Cost Benefit Analysis

A cost benefit analysis for automated acquisition and processing of visual data for defect and soiling analysis of solar PV and CSP plants was undertaken. The economic cases are quite different for the two technologies.

Solar PV

For solar PV there is a large variation in the available data that reduces confidence in our conclusions. Furthermore, the economic case is highly sensitive to the relative environment, both in terms of wages for a given country and the method (level of automation) of cleaning, as well as to local environmental and weather conditions, and installation size. The following observations were made:

- > The cost benefit of automated defect identification in solar PV fields showed that existing methods are economical. Defects and faults (not including soiling) in solar PV fields tend to be long term problems. The existing maintenance and repair schedules depend on visual inspection, monitoring of the power generated typically string by string within the plant, and more recently annual or biannual aerial surveys using infra-red cameras. These methods are effective at identifying drops in power generation and in tracking down faulty panels. Infrared imaging of solar PV is effective at identifying faults and can be undertaken from a high vantage point since it does not require high resolution images (unlike soiling analysis). Existing photogrammetric survey methods can be employed using infrared cameras and there are existing software packages and UAV operators that offer this service.
- > The opportunity for robotic monitoring of soiling on PV plants appears to be most evident where semi-automated cleaning systems (such as truck mounted systems) are

used. This is a small but growing market, with such systems now in use in Australia. For a regular soiling rate of 0.2%/day typical of a fringe-of-grid location, bimonthly cleaning would improve annual output by around 3%. The alternative - oversizing the plant for an equivalent gain - costs around \$6/m², setting a budget for cleaning that is achievable by semi-automated systems available today. In reality, for many rural PV plant locations in Australia, dust and rain events are far from regular. Operators are required to make decisions about dispatching a cleaning crew to different parts of the field, labour costs are high, and in these locations, robotic soiling inspection may be a useful tool.

- > Robotic inspection from drones for the purposes of targeted cleaning of localised inhomogenous soiling (such as bird droppings) is likely to be cost beneficial for large plants where local soiling is an issue, but is dependent upon the prevalence and severity/size of localised soiling and on the regularity of normal manual cleaning, or the availability of automated cleaning technology.



Fig. 7: An image taken during RTK testing. The way point was set directly over the test mirror and the camera oriented to image the drone. In real data collection, the drone would be offset and the camera would image the sky in the mirror.

CSP plants

If a solar field is soiled in a non-homogeneous way then there is significant value to be gained by cleaning in a prioritised way. By optimising the cleaning threshold based on the relative potential contribution of each heliostat (mirrors closer to the tower have higher annual optical efficiency), and cost of electricity changes throughout the year, the cleaning routines can be optimised to reduce their cost (i.e. by cleaning no more than is cost-effective to do so).

- > Regular cleaning is always justified in CSP plants due to the impact of soiling on the performance of a mirror. Scheduling of cleaning is an existing procedure in CSP plants and improving efficiency of the scheduling will yield financial benefits.
- > The present project has demonstrated that an automated system could be developed that would have sufficient accuracy and efficiency

to provide regular data for targeted scheduling of cleaning processes. Benefits in terms of Net Present Value (NPV) are estimated to be in the range \$1.5-2.4 million for a 115 MWe plant with 10 hrs storage, which is a commercial scale plant similar in size to Crescent Dunes. The NPV is defined as the difference between the present value of cash inflows and outflows attributable directly to the robotic inspection system over the 25-year life of the plant.

- > Lifetime savings from improving cleaning efficiency based on high quality spatially resolved soiling data is estimated to be approximately 14x the cost of the initial investment in automated data acquisition system hardware



Figure 8. Image of photovoltaic panels at One Sun Solar's 12.2 MWe photovoltaic solar farm at Williamsdale NSW taken during data collection. Individual panels are identified and segmented as indicated with overlaid red rectangle demonstrating the first stage of the image processing pipeline.

Transferability

We believe that there is a commercial opportunity available for a company to contribute both hardware and operational software that could be on-sold to operators of PV and CSP infrastructure for inspection purposes based on the technology developed in this project. However, the relative savings even in single CSP plant is only in the region of \$1.5-2M and the total market in Australia is small. Even internationally, there are only approximately 50 CSP plants making the total international market capital for automated inspection less than \$100M, although this will grow quickly. It is infeasible to try and commercialise such technology through a spinoff company based on physical provision of automated inspection services.

The recommendation for commercial translation of the outcomes is to open source the unmanned systems operations software and visual analysis software developed by the project. This will provide the opportunity for the growing ecosystem of owner operator companies to pick up on the outcomes and provide UAV services to solar PV and CSP plants in addition to their existing business of surveying and aerial photography. It would also provide the opportunity for open source developers to engage in further development of the code base and through their expertise in the code, to provide contractual advice world-wide.

Conclusion and next steps

In conclusion, the project was successful in addressing its objectives. A suite of software packages were developed that provide mission planning for solar inspection missions for UAV systems, and can process the resulting high resolution images of solar PV panels and heliostat mirrors to identify soiling levels and predict power efficiency. A cost benefit analysis shows that there is potential Net Present Value (NPV) of \$1.5-2M or more for typical CSP plants in using automated visual monitoring of soiling levels to inform cleaning schedules. The cost benefit of

soiling estimation for solar PV fields is marginal and the benefit for fault detection is negligible.

The most appropriate next step is the open sourcing of the full software package developed in the project. This will have the maximal benefit for Australian renewables industry by providing the software to the Australian and international community in a timely manner.

Lessons Learnt

Lessons Learnt Report: Access to Unmanned Aerial Systems Providers

Project Name: A Robotic Vision System for Rapid Inspection and Evaluation of Solar Plant Infrastructure

Knowledge Category:	Logistical
Knowledge Type:	Operation and maintenance
Technology Type:	Solar Thermal
State/Territory:	ACT

Key learning

The commercial provision of unmanned aerial systems services in Australia is presently serviced by a growing number of owner operators. Sometimes these services are associated with established survey companies, however, mostly these services are provided by ex-hobby enthusiasts working part time. The level of professionalism within the sector is not high and the complexity of the aerial hardware can lead to significant issues in service delivery, particularly for non-standard inspection tasks where the software interfaces are not well developed.

Implications for future projects

Time and effort needs to be allocated to the development of the mission planning and operational software for the specific types of inspection missions targeted.

Knowledge gap

Mission planning and flight control software targeted to the specific requirements of the missions is required. Commercially available medium sized quadrotors of the correct dimensions for the tasks considered are not easily available and a good quality 'hobby' drone kit is required. This focuses the software development on the open source autopilot platforms on which such hobby systems rely.

Background

Objectives or project requirements

The objective considered for this lesson learnt was to demonstrate automated acquisition of visual images of solar PV panels and CSP heliostats using autonomous aerial vehicles.

Process undertaken

We initially partnered with an aerial services company in the project proposal. This company went broke in the first six months of the project. We then partnered with a surveying company that provided aerial services. This company ceased aerial services after an additional six months of the project due to a change in staffing levels. We then partnered with an owner provider who remained active throughout the project. However, the company was limited to single quadrotor vehicles of a suitable capacity and flight times were limited due to limited batteries and charging times. Faults and crashes in the hardware cost the project significant lost experiment time and compromised data acquisition.

Lessons Learnt Report:

Availability of Computer Vision Engineers

Project Name: A Robotic Vision System for Rapid Inspection and Evaluation of Solar Plant Infrastructure

Knowledge Category:	Other (Please Specify): Human Resources
Knowledge Type:	Operation and maintenance
Technology Type:	Solar Thermal
State/Territory:	ACT

Key learning

Finding suitably experienced staff to develop computer vision algorithms for a specific application in the present academic environment is highly challenging.

Implications for future projects

Projects should consider recruiting staff from renewables energy background and training them in computer vision technology.

Knowledge gap

Staff from a renewables background do not have knowledge of the latest computer algorithms. Within this cohort, however, there are academics and engineers with a strong background in spectral qualities of light and optics as well as statistical analysis techniques. From here understanding the imaging and sampling systems of cameras is straightforward and the development of statistical algorithms is accessible. Geometric vision algorithms and learning based algorithms would be more challenging but would be accessible in time.

Background

Objectives or project requirements

Develop image processing algorithms to estimate soiling levels on panels.

Process undertaken

The project employed three different research fellows drawn from the computer vision community before finally employing Charles-Alexis Asselineau from a renewables background.

It was Charles-Alexis that led the development of the final algorithms that estimated soiling levels to the required accuracy. Although all three of the earlier research fellows made contributions to the project, their short tenure and focus on more pure computer vision problems meant that the overall progress in the project was slow.

Lessons Learnt Report: Engagement with Solar Photovoltaic Companies

Project Name: A Robotic Vision System for Rapid Inspection and Evaluation of Solar Plant Infrastructure

Knowledge Category:	Logistical
Knowledge Type:	Operation and maintenance
Technology Type:	Solar PV
State/Territory:	ACT

Key learning

Getting substantive engagement with solar photovoltaic industry companies was difficult.

Implications for future projects

Vision based infrastructure inspection projects for photovoltaic plants are unlikely to be well supported.

Knowledge gap

Photovoltaic plants operation and management does concern itself with identification and rectification of faults. However, along with the availability of power monitoring, existing high-level infrared survey technology provides a good data acquisition methodology for these plants and detailed low level vision data is unlikely to add much value.

Background

Objectives or project requirements

The project proposal was equally concerned with photovoltaic and solar thermal renewables energy technology. The early focus of the project was in detection and identification of solar panel defects. However, based on a number of experimental studies it became clear that such defects were most visible in the infrared spectrum rather than the visible light spectrum. Although this is still a computer vision algorithm, failure or defects of panels are clearly visible to a human from high level infrared survey data. The time scale of repair and replacement of such infrastructure is such that human inspection of regular biyearly/quarterly high level survey data from a photovoltaic plant will provide a viable O&M strategy that addresses panel defects such as delamination, delamination, cell part isolation, and laminate discolouring.

Process undertaken

The project partnered with Vast Solar (a CSP operator) and FRV (Fotowatio Renewable Ventures, a PV operator). There was a change of personnel in FRV and the new management were not in favour of supporting the project. The project identified a local operator One Sun Solar and used the Williamsdale solar field for experimental activities. However, One Sun Solar were never a full partner of the project and experimental work was undertaken under a Visitor/Non-Disclosure Agreement.

Lessons Learnt Report: Limited economic advantage in automated visual inspection of defects in photovoltaic (PV) modules for soiling detection.

Project Name: A Robotic Vision System for Rapid Inspection and Evaluation of Solar Plant Infrastructure

Knowledge Category:	Logistical
Knowledge Type:	Operation and maintenance
Technology Type:	Solar PV
State/Territory:	ACT

Key learning

The cost benefit of automated defect identification in solar PV fields showed that existing methods are economical. Infrared imaging of solar PV is effective at identifying a wide range of faults. Infrared aerial surveys of solar fields are already in active use. The resolution of image data required is fairly low and existing photometric aerial survey software packages produce good quality results. The associated data analysis is simple and does not require automated systems.

Implications for future projects

The opportunity for robotic monitoring of soiling on PV plants appears to be most evident where semi-automated cleaning systems (such as truck mounted systems) are used. This is a small but growing market, with such systems now in use in Australia. In such plants, operators are required to make decisions about dispatching a cleaning crew to different parts of the field and the case for automated evaluation of soiling is stronger.

Robotic inspection from drones for the purposes of targeted cleaning of localised inhomogenous soiling (such as bird droppings) is likely to be cost beneficial for large plants where local soiling is an issue, but is dependent on the availability of automated cleaning technology.

Knowledge gap

Defects and faults (not including soiling) in solar PV fields tend to be long term problems. The existing maintenance and repair schedules use visual inspection, monitoring of the power generated typically string by string within the plant, and more recently annual or biannual aerial surveys using infra-red cameras. Since faults occur over long periods, then infrequent monitoring is economically viable.

Background

Objectives or project requirements

Soiling of PV plants is not considered a significant performance issue and is not quantitatively monitored in commercial PV plants. In PV plants there is more focus placed on identification of delamination, cell part isolation, and laminate discolouring, which together account for an average power loss of 10% after 15 years in the field

Process undertaken

Machine learning algorithms were investigated for detection of delamination, cell part isolation, and laminate discolouring using high resolution RGB images. It was determined that using infrared imaging to estimate local efficiency of a panel was more effective than RGB image processing, even exploiting state-of-the-art machine learning solutions. The team verified that solar PV companies are already using infrared aerial survey data in monitoring solar PV fields.

Lessons Learnt Report: Regular monitoring of soiling levels on CSP heliostats is economic.

Project Name: A Robotic Vision System for Rapid Inspection and Evaluation of Solar Plant Infrastructure

Knowledge Category:	Logistical
Knowledge Type:	Operation and maintenance
Technology Type:	Solar Thermal
State/Territory:	ACT

Key learning

If a solar field is soiled in a non-homogeneous manner then there is significant value to be gained by cleaning in a prioritised way. Lifetime savings from improving cleaning efficiency based on high quality spatially resolved soiling data is estimated to be approximately 14x the cost of the initial investment in automated data acquisition system hardware. Benefits in terms of Net Present Value are estimated to be in the range \$1.5-2.4 million for a commercial scale plant.

Implications for future projects

This project has developed proof of concept software for the full tool chain required to provide automated inspection of CSP heliostats for soiling inspection. Implementation of such a system requires a whole system engineering consideration of the operational requirements; implementation of a contractor or operator team to operate the drone, installation and purchase of drone hardware and landing fields, schedules for operation, refinement of the mission planning

software along with operational procedures, refinement of the image processing software, and implementation of procedures for scheduling of cleaning based on data produced.

Knowledge gap

Existing aerial survey software and aerial survey systems are targeted at photometric aerial survey outcomes. Such survey systems fuse multiple photographs taken over an area into a single large scale map. Metric information on the terrain is derived from image matching and triangulation.

Detailed inspection of infrastructure is a very different problem involving close-up images of specific parts of the infrastructure and inspection of these images to show faults or damage. The vehicle must be manoeuvred to a specific relation in relation to the infrastructure to obtain the desired image and focus is critical. No existing software is available for this task in solar plants.

Background

Objectives or project requirements

Optimising cleaning based on levels of soiling of individual heliostats allows evaluation of the relative potential contribution of each heliostat and cost of electricity changes throughout the year. Availability of spatially detailed soiling data allows cleaning routines to be optimised to increase cost effectiveness of plant operation.

Process undertaken

The present project has developed software tools for each of the stages in the tool chain required for implementation of an automated system. The image processing software developed is capable of determining loss of reflectivity of a mirror due to soiling to an accuracy of 1%.

Lessons Learnt Report: Open source code release for technology transfer of automated soiling inspection.

Project Name: A Robotic Vision System for Rapid Inspection and Evaluation of Solar Plant Infrastructure

Knowledge Category:	Logistical
Knowledge Type:	Operation and maintenance
Technology Type:	Solar Thermal
State/Territory:	ACT

Key learning

Operation of autonomous drone technology requires significant infrastructure and knowledge that is far removed from the standard skill base of a solar energy company. There is a growing ecosystem of small firms that contract out aerial photography, aerial survey, and aerial security services to clients. Due to the quickly changing nature of the technology these firms are closely connected to the open source software community, where much of the system development is undertaken. Releasing open source code into this community will lead to aerial robotics firms tendering to CSP industry operators to provide soiling monitoring services to the industry.

Implications for future projects

The provision of aerial inspection services requires a targeted team or external contractor that manage the infrastructure and requirements of the aerial systems operation. The target of future projects should be to provide technology and software for these teams/contractors to provide the highest value services to the plant operator.

Knowledge gap

The relative savings from automated soiling in a single CSP plant is only in the region of \$1.5-2M NPV. Australia has a single plant and the international market has only approximately 50 CSP plants. This market is too small and too distributed internationally for a company to profit from direct physical provision of automated inspection services. A firm can easily benefit from adding soiling detection as an additional service (amongst many) that they provide, if they have access to suitable software.

Background

Objectives or project requirements

A key requirement for effective and efficient operation and maintenance of CSP and PV plants is the acquisition and analysis of data that can be used to schedule maintenance and replacement to maximise operational efficiency of a plant. Visual inspection of physical hardware remains the most cost-effective existing methodology for identification of soiling. Autonomous aerial robotic systems offer considerable potential for the automated collection soiling data.

Process undertaken

A wide range of potential applications of aerial survey technology was considered by the project. The potential value to the industry partners was evaluated throughout the project leading to a re-evaluation of priorities during the project. The project discontinued research into identification and categorisation of delamination, cell part isolation, and laminate discolouring, in PV fields, noting that existing infrared survey techniques are effective in identifying these faults. The resulting focus on soiling levels on PV panels and CSP mirrors has led to development of a suite of software packages that are in a form that can be released as open source code.