University of Southern Queensland
Faculty of Engineering & Surveying

Turf Monitoring Technology to Aid in Benchmarking and Maintenance of Sporting Fields

A dissertation submitted by

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Abstract

A large sum of money goes into the establishment and upkeep of elite sporting fields in Australia. Unfortunately the curators of suburban ovals do not have the luxury of such budgets.

This project addresses the need for inexpensive aids to help the curators of these less elite fields to better utilize the money in their tight budgets. The aids generated also have the potential to benefit the more elite fields through better targeting of maintenance practices.

Through appropriate selection of turf cultivar and surface preparation, a surface that maximizes playability, limits injury and wears well can be created. Producing and maintaining such a uniform surface is difficult due to the variable utilization rates of different areas. To improve the effectiveness of the maintenance activities requires the field to be managed in smaller areas often related to quantity of use. Managing at this higher level requires more time being spent gathering and interpreting data, which is expensive and requires a higher curator skill level.

If the collection and interpretation of data can be mechanized, then the increased pressure applied to the curators time and skill base can be reduced. At present most analytical tools are used in research with few used commercially. This is often due to being cumbersome and difficult to use, as well as being expensive to acquire. The data produced by these instruments is often of no value to the curators as it is useless without a trained professional's interpretation.

This project, being of a research, design and construct nature, had to satisfy the fol-

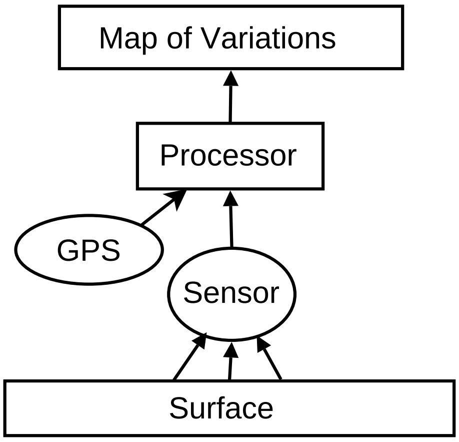

Figure 1: Flow diagram of data

lowing requirements and procedures.

The project was required to:

1. Identify quantitative measures of turf health and playability
2. Design a sensor to measure the most beneficial quantity
3. Link quantity to a position
4. Create a map of the collected data
5. Validate data collected
6. Draw conclusions as to the usefulness of the data collected

The visual analysis of a surface gives coverage and varietal information. Through replicating the human recognition processes, areas needing attention can be identified.

The path from grass to map contains a sensor (camera) and a processor (laptop) that converts the images into meaningful quantities which describe the surface condition. Combining this with a GPS unit allows turf maps to be created (refer figure 1).

The use of these maps to identify areas that require rehabilitation can save precious money and allow curators to provide better playing surfaces which make recreational activities more enjoyable for all members of the community.

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Limitations of Use

Certification of Dissertation

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

A. G. Piper

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Signature

Date

Acknowledgments

Many thanks must go to all NCEA and faculty staff that have guided me in the writing of this dissertation and helped in the development and fine tuning of equipment used in this project. In particular Mark Dunn for all of his programming, without this help, idea and goal would still be separated.

To my family and friends, thanks for all of your questions and suggestions. These comments have allowed me to get a better understanding of what I am doing and made me realise that my time has not been wasted.

A. G. Piper

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Nomenclature

Transect Method	Method of assessing surface coverage using a grid constructed of a frame and wires strung splitting the area into equal sized squares
NMEA Messages	National Marine Electronics Association standardized messages that are output from a GPS receiver.
GPGLL	NMEA String that outputs Global position in terms of Longitude Latitude and Altitude from the standard Geodatum.

Chapter 1

Introduction

With the increasing professionalism of sporting organizations and players being paid for their performance on the field, improving the standard of suburban sporting fields is of high priority. Minimizing the risk of injury to these players and other members of the public has also become a major concern with insurance premiums making it difficult for some clubs to survive.

To provide a surface that minimizes injuries and provides the required characteristics for the sporting activity can be a costly exercise. With many clubs relying on volunteer labour for maintenance they lack the required expertise to maximize the effectiveness of the limited resources they possess. While it is possible to hire an advisor this can become an expensive exercise.

Emulation of the processes used by professional curators and advisors offers the opportunity to provide information to these volunteers at a fraction of the cost. Such a system also has the opportunity helping these professionals monitor the health of a stand of turf at a higher level of detail.

This project has aimed to generate such a system that is relatively inexpensive and able to be combined into current maintenance activities with minimal hassle. The chapters following describe the research, design, development and evaluation of a vision analysis system that aims to identify the level of coverage and potentially map the distribution of species across an oval.

1.1 Overview of the Dissertation

This dissertation is organized as follows:

Chapter 2 is a literature review of relevant articles associated with the development of the system

Chapter 3 discusses the design of the camera collection system

Chapter 4 discusses the field evaluation of the camera system and

Chapter 5 concludes the dissertation and describes where further work in the area of turf management instrumentation is needed.

Chapter 2

Literature Review

2.1 Chapter Overview

A sound understanding of current maintenance practices and their remedies is vital when attempting to improve the information acquisition process. An understanding of what others have contributed to the research field and problems faced in their research allows for a more effective design process.

A literature review was conducted to investigate the following areas:

- Past areas of turf research
- Key characteristics for identifying turf species
- Causes of sporting injuries
- Elements of a sporting surface responsible for these injuries
- Maintenance practices used to reduce injuries
- Relationship between playability and likelihood of injuries

2.2 Background

With the increase in expectations of sportsmen and women, parents and insurance companies, large financial and ethical burdens have been imposed upon sporting clubs and councils. Minimizing the risk of injury has become an important issue as these bodies have become the target of torts of negligence from individuals that have hurt themselves using their facilities.

To be able to create and maintain a surface that is less likely to cause injuries requires regular maintenance and expertise from the curators. Unfortunately clubs do not always have access to these resources due to budget constraints.

This project aims to reduce these resource requirements by instrumenting various factors of playability, allowing improved targeting of funds to give the maximum response from the precious assets available.

With the large areas of turf spread across the world the issues targeted in this project are far from unique. With many government departments, university research centres and professional bodies looking at these issues, there are many sources of information available.

Literature on methods of sensing turf health, quantitative measures of the playability of a surface and background information regarding turf management are important areas of information that need to be reviewed. These areas are looked at in turn in the following sections.

2.2.1 Methods of sensing turf health

The playability of turf is largely related to its health. Through the adoption of precision turfgrass management, the health of the turf can be managed at a more intense level. When managing turf in these smaller portions, the ability to collect data quickly and non-destructively is necessitated in a broad range of climatic conditions (Fermanian, Schmidt, Narra & Anderson, 2002).

For modern curators the main tool in planning the management of the surface is through field walks. A field walk allows a visual assessment of turf health and surface playability to be made. Other senses including touch and smell allow further diagnosis to be made. Emulation of these senses, predominantly sight and touch, allows these data collection methods to be adapted and applied in greater detail.

When conducting field walks, measurements of colour, coverage and nutrition are based upon a person's visual inspection of the field, combined with years of gathered knowledge and experience. Instrumenting such thought processes is difficult, due to the complexities associated in establishing exactly what variables give rise to the person's conclusion.

Researchers at the University of Illinois (Fermanian et al.,2002) have developed a camera-based system that scans a plant's chlorophyll reflectance collecting data related to nitrogen and water stress. The system utilises three filtered charged coupled devices that capture reflectance values in the 550nm 650nm and 800nm ranges. These values correspond to Green, Red and NIR energy levels respectively. Analysis of these figures compared to sample data allows a value for various nutrient levels to be made without the need for costly tissue tests.

In research work conducted by Bastug and Buyuktas (2003) on golf course irrigation scheduling, data was collected on colour, coverage and soil moisture for a series of different irrigation scheduling techniques. The Wilson colour scale was used to determine the effects of irrigation techniques on leaf colour, while the use of the transect method gave readings on ground cover. These procedures quantify and give a more precise value compared to human observations. Mechanisation of these processes may be possible allowing such observations to be performed by people without experience in the area.

Surface temperature is the most recognised method for detecting crop water stress (US Water Conservation Laboratory, n.d.). Methods of measuring surface temperature remotely include infrared thermometers and thermal scanners. The correlation of temperature to water stress is through the assumption that as a crop transpires the water evaporated from the leaf surface cools the surrounding air and leaf itself. Such an assumption is effected by atmospheric conditions and the time of day data is collected.

This places restrictions on when data can be collected effectively. At present the use of such equipment in management is restricted by the cost associated with the purchase of such devices.

2.2.2 Measuring Playability

Different features of a surface are more important to some sports than others due to their impact on the playability of the surface. For instance, golfers are more interested with the uniformity of the surface and its interaction with their ball, whereas, rugby players require a surface that shows good traction characteristics.

Devices such as the Stimpmeter for golf greens and the Soccer Fieldgauge (Cockerham, Watson & Keisling 1995) allow the deceleration characteristics of a surface to be measured, whilst Pennsilvania University's PENNFOOT (McNitt 2000) measures the tractive performance of a surface. The Stimpmeter and Fieldgauge measure a ball's interaction with the surface returning figures such as the time to roll a certain distance, deflection from the initial path and the rebound height reached by the ball. Such equipment allows a comparison to be made between fields and courses so as to keep them as uniform as possible and allow a standard environment to be created.

Each instrument is useful in its own situation, though near useless if applied elsewhere. Most of these instruments require setup for each point of data that is to be collected therefore are time consuming to use, compared to collecting data using a thermal scanner or camera. For a precision management approach to be implemented, measurement of such characteristics needs to be continuous so that regular measurements of suitable sized areas can be made.

2.2.3 Injuries and their contributing factors

Sporting bodies such as the Australian Football League (AFL) have been concerned with the number of injuries occurring to players involved at the elite levels of competition, due to the financial burdens associated with the payment of injured players' salaries. Many clubs have some form of injury database that records the details of injuries suffered by players. Studies into causes of injuries sustained by the players have concluded that surface conditions effect the occurrence of many injuries. Researchers such as Orchard ((2000)) have compared injuries attained by Northern and Southern teams, focusing on whether any significant differences between the two regions can be attributed to climatic and surface conditions. Ground hardness, shoe type, grass species and coverage have all been identified as being associated with the variance between lower limb injury occurrences at the two locations (Orchard 2000).

Hans Kolitzus'(2003) article deals with the risk of injury associated with synthetic turf. Though natural and synthetic turf are quite different surfaces, the performance of the surface is measured on the same components, namely the sports function, as well as the protective function. Comparisons carried out by Bramwell in the American NFL have shown that higher injury rates over a season occur on artificial turf compared to natural turf, due to the natural surface becoming softer due to climatic conditions late in the season (Orchard 2000).

2.2.4 Background on Maintenance Operations

Like any agricultural crop, turf requires regular maintenance to keep it healthy. Operations such as fertilising, aerating and mowing are all required to keep a field in good condition. In areas with low rainfall, irrigation is also required to reduce stress associated with moisture deficiencies. A background of these issues is necessary to understand how problems identified from the measurements can be rectified.

According to McNitt (2000) playing surface quality 'is dependent on soil texture, soil density, soil water content, turfgrass species, cutting height and level of wear'. This is reflected in surface hardness and surface traction as well as surface coverage and colour.

Methods used to rectify these problems depend on their contributing factors. Compaction and the presence of organic matter as well as the base soil, effect soil texture and density. Aeration, top dressing and the addition of soil amendments can improve the vapour movement through a soil, promoting better grass growth, improved drainage, larger water holding capacity and generally give a softer surface (Singer &

Munns 1999). Too loose a surface can be detrimental, giving poor traction and can lead to early fatigue (McNitt 2000).

Other maintenance activities such as mowing, re-seeding and irrigation are interrelated and need to be matched to the use of the field. For example, fields used predominantly in winter require a turf variety that tolerates trafficking in cooler conditions. Turf used inside a stadium must also be tolerant of shade. Articles relating to many sports such as tennis and AFL have scorned the quality of surfaces contained in stadiums, especially those fitted with a roof. The turf often causes controversy and cost millions of dollars relaying the surface each year (Wilson 2004).

Reducing the mowing height can improve traction, but can promote disease and reduce any cushioning effect. Mowing height must therefore be balanced to give the most traction while reducing the potential for disease. This can cause bare areas to form and further maintenance activities to be required.

Irrigating the field can also lead to disease through water logging and providing an environment that promotes bacteria development. Research data shown in Bastug and Buyuktas (2003) shows an irrigation schedule corresponding to 75% of evaporation from an A class pan to produce the best quality surface.

2.2.5 Distinguishing varieties

With so many different varieties of grass available, trying to distinguish between them at a varietal level, is extremely difficult due to the development of hybrids that combine features of many others. For example Reynolds and Flint (n.d.) in the UC Healthy Lawns Guide uses the presence of hairs on the leaf sheathes of Kikuyu grass to distinguish it from others (see Figure 2.1). The identification key on this website also uses many destructive analysis techniques, (eg root system characteristics) which violates the requirements set out for this project. Often DNA analysis is the only sure method of distinguishing between varieties.

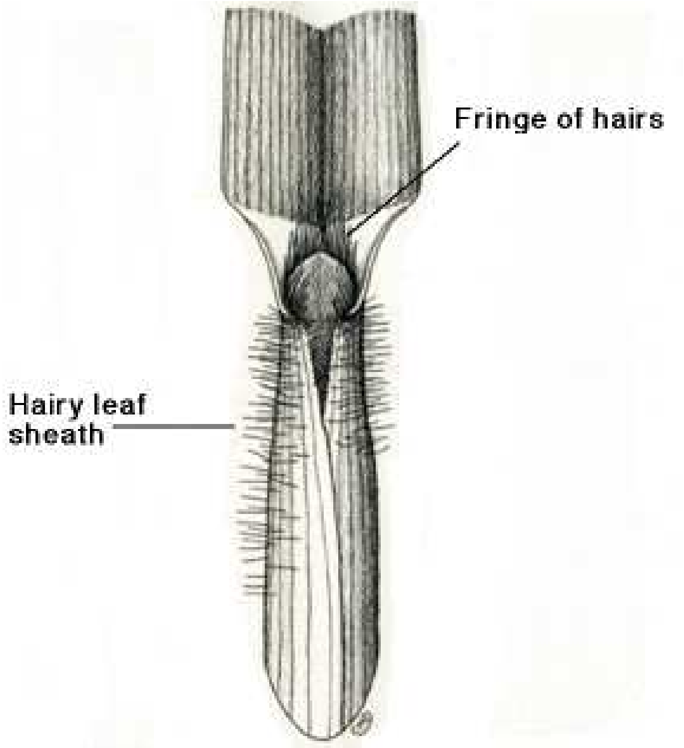


Figure 2.1: Leaf Sheath of Kikuyu Grass

2.3 Chapter Summary

The above articles have shown that to become more efficient with field maintenance activities, more information that can be used in making decisions is required. To increase the availability of such information without increasing labour requirements, the data collection method needs to be efficient and seamlessly integrated into current management practices. The equipment needs to be relatively inexpensive to allow implementation by much smaller scale clubs, as well as have the potential to be shared to minimise the capital outlay.

For this project to be successful these requirements need be satisfied, especially if the instruments produced are to be used commercially. The literature has also shown that vision is one of the most utilized senses in current field management. For this reason emulation of the visual processes currently used in assessing turf health has been targeted in this project.

Chapter 3

Design of Camera collection system

3.1 Chapter Overview

The design process is a conglomeration of achievements and setbacks. This chapter outlines these achievements and issues in datal order for the visual collection system, from when the idea of using a webcam was first proposed, through to the current system.

Broadly the design process has focused on four main areas, the creation of a consistent collection environment, the collection of consistent frames of vision, distinguishing varieties and the integration of a GPS unit. Each of these areas is dealt with in their own sections. The chapter concludes with a description of the validation that has been performed.

The decision to investigate an instrument based on visual data was made based on literature reviewed, a trip to Brisbane late in 2003 and the potential to produce meaningful data from the sensor. Other sensors proposed included a method of measuring the undulations of the surface as well as the uniformity of irrigation events. A visual sensor was considered as having the greatest potential as it could provide a variety of information, specifically coverage data and distinguish varieties. If sufficient time was available, it was proposed to look at creating other sensors. Unfortunately time was not available.

3.2 Consistent Lighting Environment

Designing a piece of equipment that collects a consistent set of parameters to use in calculations is difficult, especially when the collection environment is subject to the variability of the earth's climate. After the initial project trip to Brisbane, a prototype was constructed capturing vision using a USB camera in broad daylight. From initial review of this data it was clearly noted that lighting intensity changed considerably from shadows caused by clouds or other large objects. Other researchers, such as those in the 2002 Illinois Turfgrass research, (Furmanian, Schmidt, Narra & Anderson 2002). use a light intensity sensor to standardize the vision collected. It was decided that creating a uniform environment would produce the best results, as the use of a light intensity sensor requires calibration and is expensive.

To create this uniform lighting environment, a shroud measuring 1 metre by 1metre was designed, to eliminate any external light from reaching the the camera's field of vision. The shroud was constructed from a series of frames made using heavy gauge steel wire to which a heavy weave material was attached. These five frames were then assembled together and attached to an aluminum arm allowing the shroud to be suspended behind a wheeled cart at a uniform height. A further curtain of material was then attached to the frame edge to ensure no light could enter between the frame and ground level.

3.2.1 Source of Artificial Light

With external light excluded from under the shroud, an appropriate source of artificial light was required. Initially a 12 volt florescent tube was used. Sample vision collected was of poor quality, with large quantities of motion blur noted. To produce crisper frames, the exposure time had to be reduced. This can be achieved in two ways. The period of time that the light source is on must be regulated, or the length of time that the camera is exposed to the environment is reduced. The latter is the equivalent of shutter speed on a regular film camera.

At a similar period in time Infra red was seen as a potential source of distinguishing data and the requirements for capture of this data was investigated. An array of IR LED were used as a light source and an IR filter placed over the lens of the webcam. A flasher unit was also designed, allowing computer control over when the array was switched on and the period that it remained on. Trials and further research showed that due to the way that a colour webcam collects data, the image is of a lower resolution as the sensitivity to IR is reduced. Difficulties were experienced with the flasher unit, with frames missed due to timing differences between camera and LEDs. It was also concluded that the IR array was not large enough to illuminate the area sufficiently, and hence motion blur would still be an issue.

3.3 Camera Exposure Time

After the difficulties experienced with the flashing unit for the IR array, it was decided that reducing the exposure period of the camera would yield better results. Initial trials with the florescent tube both at USQ and at ANZ stadium on 26th February produced images with poor spectral resolution and exposure could not be reduced sufficiently to eliminate blur, without producing empty frames. Due to poor fastening of the shroud to the cart, natural light was allowed to reach the sample area, and crisp images were collected at these lower exposure settings. It was concluded that a more intense source of light was required.

Two 12 Volt 50 Watt Halogen down lights, the same as those used above benches in modern kitchens, were purchased and installed underneath the shroud to provide light for the collection environment. Vision collected with the new lighting system proved to be a lot sharper, though battery life was severely reduced.

Though images had little blur, resolution was found to be too low to accurately define boundaries of leaves and other areas of interest. To improve resolution the camera was fitted to an extension to locate it closer to the sample area. This meant that the sample

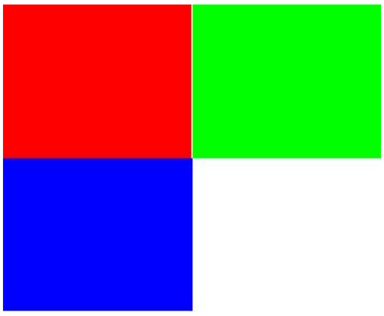


Figure 3.1: Layout of Colour Calibration Card

area became smaller, though detail was greatly increased.

The current system samples an area approximately 300mm by 300mm, 30 times per second, with a exposure of 1/3000 of a second. This means 1/100 of a second per frame. At 30 frames per second, it is possible to travel at up to .9 metres per second (3.3 kilometres per hour) before areas are not analyzed between frames. Considering it is unlikely to manage an oval on such a small scale, mowing at up to 4m/s (14.4 kilometres per hour)would not be an issue, though this is something that would be resolved if such a system was commercialized.

3.3.1 Colour Calibration

As the two halogen lights were running from a rather small 12 volt battery, the lighting intensity varied greatly effecting the uniformity of the vision that the camera collected. This made defining colour thresholds difficult.

The use of a colour calibration card (Figure 3.1) allowed a reference to a ’standard’ red, green and blue to be made. At the beginning of each collection, the card was placed underneath the camera to allow calibration to take place. In theory, the card represents the extremes of colour that the camera should experience and should be standard. Due to the variance in ink used by different printer manufacturers as well as paper absorption characteristics, producing a standard sheet requires using the same paper and printer every time.

For instance the sheet produced by the NCEA colour laser printer, compared to the bubble jet printer in the Faculty of Engineering were completely different. The analysis software struggled to distinguish between the blue and green produced by the laser, hence why the bubble jet was used.

The software recognises the different areas of colour on the card and compares their RGB values to their theoretical values. Relating the two values produces a calibration factor that are then applied to the threshold values, producing boundaries that are appropriate to the present lighting environment.

3.4 Distinguishing varieties

With a system that was producing vision that had consistent characteristics, it was decided that a trip to the Redland Bay Department of Primary Industries Research Centre would enable sample vision from a number of different species of grass to be collected. This trip occurred on 28th April.

Video was collected from the majority of the 138 plots and saved to CD's for post processing. For those varieties that were considered relatively common (Appendix C.2)a second collection was done at right angles to the first. For example Greenlees Park appears in vision collected from run one, as well as row seven. These two collections were performed to provide data to analyze and validate any system that was developed to distinguish varieties.

3.5 GPS Integration

Providing information about coverage is useless without a method of tagging it with a location so that a correlation can be made to a particular area of the field. Connecting a GPS system capable of outputting NMEA messages to the system allows a GPGLL string to be attached to the collected data. Two different GPS units have been used, both manufactured by Trimble.

Initially a unit was loaned from the Faculty of Engineering and Surveying during initial setup, while a unit of a family friend was used to produce the maps in Appendix B. Both units are capable of sub metre accuracy. This was considered sufficient for this application.

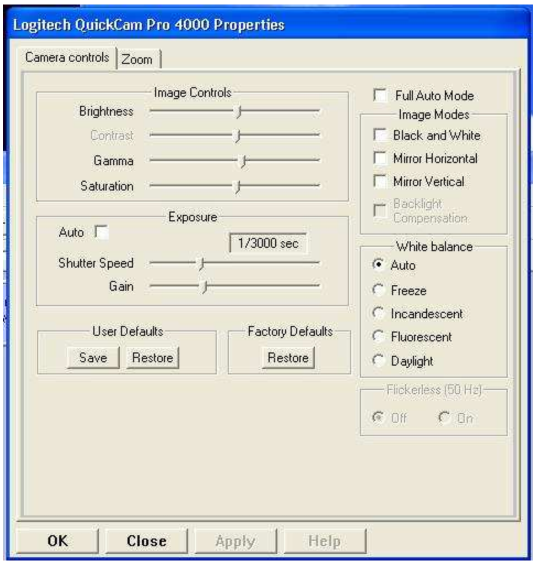
Integrating the GPS into the system was relatively hassle free, though both units were only capable of outputting a position every 1 second. With the camera recording 30 frames in this period, a linear approximation is made between the points, hence the straight lines visible on the maps. Gaps in data are due to missing GPS positions, which is often magnified by the algorithm used to create values for frames in between gathered points.

3.6 System Validation

Validation of the collection and analysis of data is an important part of this project. As the aim of this project is to replicate the observation and thought processes of an experienced curator, comparing figures generated by the equipment to those of a human is a robust way of evaluating the collection system. To strengthen the validity of the data collected, a variety of different environments need to be analyzed. Having a list of clear requirements for the system to be considered satisfactory, allows the equipment and the analysis procedures to be rated on how well they fulfill the design requirements.

3.6.1 Validation Requirements

Due to the large quantity of data that is collected and analyzed by the system, evaluation of how well the system performs is based on the observed repeatability of the system, as well as comparison of calculated values of random frames to those of a human. The field evaluation of the system had further requirements to allow for issues associated with the project being performed by a university student, and the project having a limited budget. Some other requirements were put in place due to the guidelines of the project itself.



Logitech QuickCam Pro 4000 Properties

Image Controls
Brightness
Contrast
Gamma
Saturation

Exposure
Auto ☐
1/3000 sec
Shutter Speed
Gain

☐ Full Auto Mode

Image Modes
☐ Black and White
☐ Mirror Horizontal
☐ Mirror Vertical
☐ Backlight Compensation

White balance
● Auto
○ Freeze
○ Incandescent
○ Fluorescent
○ Daylight

Flickerless (50 Hz)
● Off ○ On

Figure 3.2: Settings used for Camera during collection

The validation of the system had the following requirements:

- Be able to be carried out within reasonable distance of USQ
- Require minimal resources
- Be easy to perform without a need for training
- Produce some information that can be correlated to what can be seen visually
- Be performed within the time constraints of the project.

These guidelines have lead to the following actions being taken. They are presented in datal order, though due to the dynamic nature of the validation process, many of the actions overlap significantly.

3.6.2 Consistency of Images Collected

With the initial prototype collecting vision from a uncontrolled environment, the vision collected varied greatly from frame to frame. Further investigation of the camera collection properties (figure 3.2) showed that it was set to full auto mode, hence exposure time, brightness, contrast and gain were all varying with changes in lighting conditions, as well as ground coverage conditions.

Trials performed with auto mode turned off reduced the variation significantly, though there were still noticeable differences between full sunlight, and those experienced under shadows cast by clouds. These variations were even more defined in late afternoon where objects cast shadows over the area, especially those from the cart.

After the introduction of the shroud and artificial lighting system, consistency of the images collected improved significantly. Camera settings were kept consistent at the values detailed in figure 3.2. These settings had to be checked and reset every time that the camera was connected to the laptop.

With the use of the colour calibration card (Appendix B.1), any final variations in light intensity or camera settings appear to have been eliminated. It has been noted that under the right conditions the system will calibrate without the card, hence card should be placed under the camera before recording is started.

If all of the above settings are followed, the quality and consistency of the frames of vision collected are high. This is reflected in the two maps of the soccer oval at USQ. The two different collections running at 90 degrees to each other have produced maps (Appendix C.6 & C.5) that correlate to each other well.

The evaluation process has validated that the collection system is producing consistent data to be analyzed that is robust in nature. This provides a firm footing for calculations of coverage and identification of species.

3.6.3 Coverage Analysis

Validating that the coverage analysis algorithm is producing data that is of high quality has taken two main forms. Firstly random frames collected from the trip to the Redland Bay research centre were analyzed and compared to the values of coverage from a human. Initially it was planned to submit the data for analysis by trained individuals, though from a meeting with Craig Henderson on the 29th of January, it was concluded that to produce figures of coverage to the level that curators require could be carried out by someone with little knowledge in the area.

A software interface was created by Mark Dunn that allowed an individual frame to be split into a grid and cells be assigned as being green dormant or bare (figure B.2). This software was used to calibrate the algorithm and create the threshold values for a cell as being green dormant or bare. The algorithm looks at colour only and does not take into account any factors of shape. Shadows cast by the grass were incorporated into the calculations as initially they were being confused with bare areas. For each cell the algorithm analyzes each pixel and the cell is assigned one of the three values based on whichever holds the majority.

Larger scale trials were performed on various grassed areas around USQ. Values output from the algorithm were then compared to what was observed by the human eye. Distinguishing between green and dormant areas appeared to be relatively accurate, though picking bare areas was more difficult.

Soil colour seemed to play an important role in picking bare areas. For example black soil is often hard to distinguish from shadow and hence bare areas on a black earth are less than those on a red soil. Further work is still needed to perfect this algorithm.

3.6.4 Species Identification

After the trip to the Redland Bay research centre vision collected from the majority of the plots were post processed and values for total red, green, blue and energy were gathered for each frame of data. These frames were then multiplied by the green coverage value so as to gain values that are representative of complete coverage, to be used as standards when calculating thresholds.

Unfortunately species are not grouped on colour characteristics. Species tend to be grouped on growth habits, identifiable differences in leaf shape, presence of hairs on the leaf's surface or how the new leaf emerges. Figure 3.3 shows some of the more identifiable parts of a plant that are used to distinguish species.

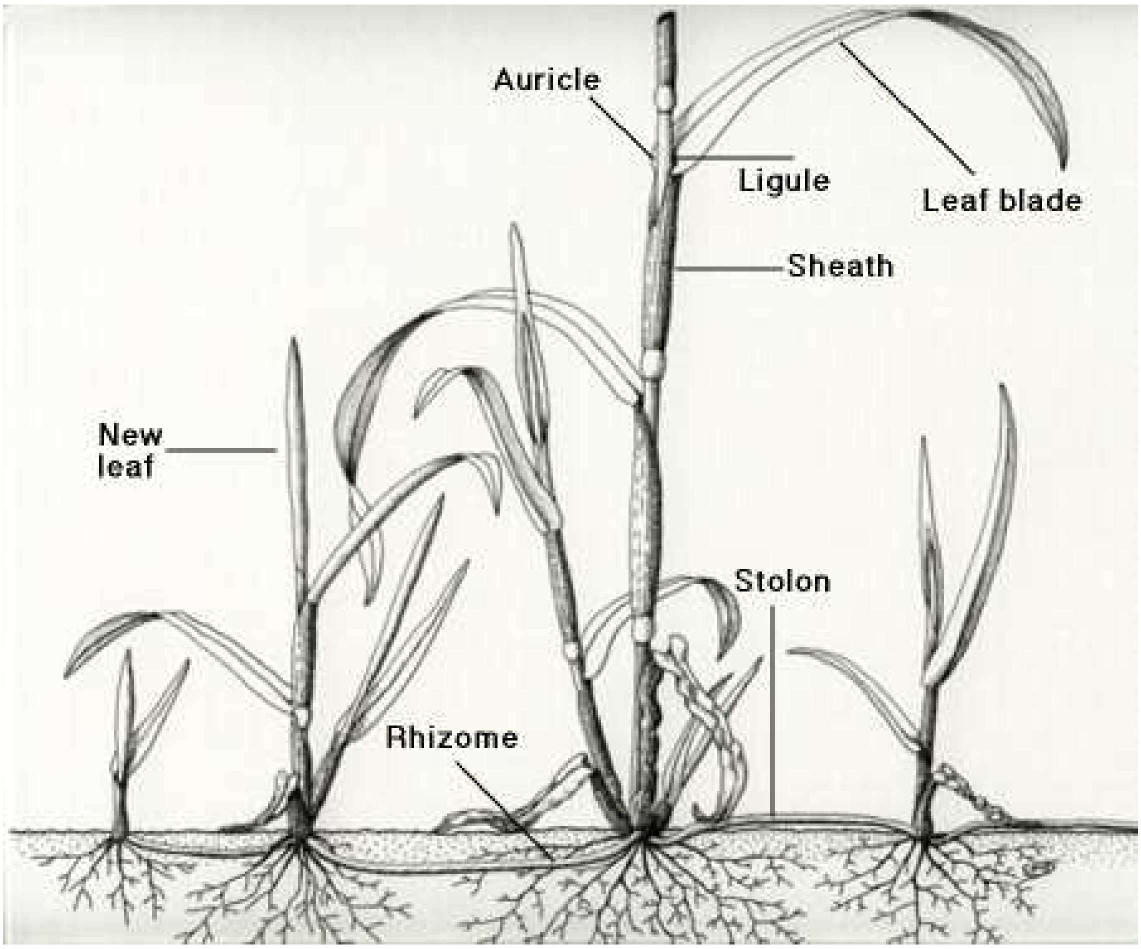


Figure 3.3: Some identifying features of grasses(Source UC Guide to Healthy Lawns)

Identification of species has so far been unsuccessful. The data collected from Redland Bay will be used in an attempt to identify species in the project using shape algorithms in the future.

3.7 Summary

As with any design task this project has had its problems as well as achievements. Issues that have been encountered, such as those associated with colour calibration have reinforced the difficulties associated with emulating human thought processes.

For instance the human eye adjusts how much light enters the retina automatically to produce the sharpest images possible. The human eye is also most sensitive to shades of green which makes the analysis of the colour of grass that much easier. Further more pattern recognition is another strength of the human brain, hence once one piece of grass has been identified, recognizing others is a case of instinct rather than a complex thought process.

Curators often have the ability to move plants and alter magnification level, something that this collection system does not. A clear requirement in the design of this system was that it be non destructive so that it had no detrimental effects on the surface characteristics of the ground being examined. This system cannot therefore analyze whether the new leaf contained within a bud is curled or not, a key identifier in the UC Healthy Lawns Guide database.

Lastly grass is a living tissue and hence has many stages in its life cycle. For example the initial shoot of a grass does not exhibit the same characteristics as a more mature plant, and seed heads are not present the whole year around. These are useful in identifying grass over a period of time, but not when an instantaneous result is required.

Chapter 4

Field Evaluation

4.1 Chapter Overview

Field evaluation and validation were performed at the same time, with the data collected used to confirm the accuracy of the algorithms, and problems experienced in the collection process noted as potential issues associated with commercial utilization. This chapter outlines what trials have been performed and issues that have been uncovered. It also reports the results from the trials and preliminary analysis as to how the information produced can be beneficial to curators in planning their maintenance activities.

4.2 Evaluation Overview

To use the system to emulate its use in a commercial situation required that sufficient data be collected to adequately identify issues that may be encountered in general use, as well as provide a representative sample of surfaces so that conclusions can be drawn from the data collected. To satisfy this, data was collected from various sources at different stages during the development.

Larger trials were undertaken at ANZ Stadium in Brisbane and the USQ soccer oval.

Smaller trials were undertaken on a grass area next to the NCEA and Faculty of Engineering. The smaller area was used for validation and trialing any modifications to the system.

Due to the limited battery life of the equipment being used, a representative sample of the the ovals were collected. At ANZ a series of runs up and down the field approximately 10 metres apart were collected.

The site near the NCEA and the faculty provided a broad range of coverage scenarios, ranging from completely bare, to dormant and patches of clover. such variety has meant that most features that we wish to identify can be found in various levels of establishment.

4.3 Evaluation Sites

4.3.1 ANZ Stadium

ANZ stadium is located in Brisbane and is used for elite competition including athletics and soccer. It has a surface that is well maintained and representative of other ovals that are used at this standard of play. The surface was uniform and grass variety distribution constant with no noticeable areas of weeds or defects. The data collected was of relatively poor quality due to the artificial light source being the fluorescent tube. Some other data was not usable as it was saved into an unreadable file.

Some extra vision was collected from one end of the field that had recently been used for a motorcross event. A large quantity of dirt was placed on the surface to build jumps and hence the grass had been starved of sunlight and undergone compaction. It was hoped that this vision would allow any detrimental effects to be identified.

The lend of GPS equipment used by Troy Jensen from the Queensland Department of Primary Industries and Fisheries also allowed the potential to use GPS as a reference system for the data to be assessed. The GPS data output showed serious shadow effects from the grand stands, with few points recorded along the touch lines. It was resolved that the use of GPS not be ruled out, as no other economical method was available, and many of the non-elite sporting fields that the system was targeted at would not be affected by this issue.

The trip to ANZ, especially the time spent communicating with others in the research field, reinforced the major challenge with the adoption of new technology, particularly in agriculture and horticulture.

Many of the researchers and extension staff that were at ANZ were performing tests that were both time consuming, and produced data that required interpretation by a professional for to provide any worthwhile information. While the instruments may be useful in research, their commercial benefit is minimal.

Ease of use and the quality of the information produced by the system is of great importance. Few people are going to use something that is time consuming or unreliable, especially if the information produced is considered as being of little use in their maintenance practices. These two factors are highly dependent on each other.

If a system requires lengthy setup each time it is used, then it is likely that it will be used once and put in the back of the shed. Though the information that is output from the system may be highly relevant and beneficial, the system is still unlikely to be used.

Conversely if a system is near fool proof and simply requires the press of a button then the system may be used often to collect data. If the analysis software does not produce anything that is meaningful from the data, in a form that the user can understand, then the system will still be under utilized.

4.3.2 USQ Soccer Oval

At the soccer oval, only one quarter of the field was analyzed, encompassing the area bound by a line from the centre of the goal mouth, to the corner post, up the sideline to halfway, to the centre of the centre circle and back to the goal mouth(Figure C.3). Runs approximately 2 metres apart were performed at 90 degrees to each other to give two sets of data. It was hoped that these two sets of data could be compared to each other to validate that the system produces data that has a high consistency.

The quarter of the field selected, has potentially the most wear, due to its close proximity to the change rooms, and therefore subjected to more trafficking. It must be noted that the oval is currently in the off season and hence is in good condition.

Data collected from the oval showed that the reliability of either the GPS system or the collection of the NMEA strings as being low. A number of GPS points were missed in the data, leaving gaps meaning the visual data collected in these points was not used.

The cause of the GPS dropping out is not yet known, so using a different GPS source may solve this issue. Being able to output strings at a shorter interval would also help as the gaps would not be as big.

4.3.3 Grassed Area

Due to the good condition of the soccer oval, a sample from an area of poor coverage was also required. A significantly bare area of grass, as well as an area of high wear from foot traffic outside the Faculty of Engineering and Surveying building was used. This area has potential in testing if the system can be used to identify areas before they become bare.

A number of issues were encountered with the use of this area. Initially the battery used to power the light source was mounted on a small platform above the front wheel of the trolley. This made the trolley unstable and prone to tipping over. Moving the battery to an area behind the front wheel provided improved stability. This was especially important considering the ground being rough, as well as having a steep slope.

Traversing the rough areas also caused a large amount of vibration and caused lights to occasionally turn off. It was also noted that the colour calibration card must be placed underneath the camera before running the capture software. Due to the soil being red, areas of red blue green and white are all usually present in the frame. This has led to the camera 'calibrating' based upon these areas giving results that are not based on same standard colours.

4.4 Evaluation Procedure

The evaluation procedure has evolved with the system containing more and more components. A list of steps that occur during the capture of data at the time of writing is as follows:

1. Connect camera via USB to laptop
2. Connect GPS via serial cable to laptop
3. Connect power to the lights and to the GPS
4. Run Hyperterminal to check to see if GPS is outputting GPGLL NMEA strings to the serial port
5. Ensure that both lights are working under the shroud
6. Run Graphedit and check camera settings
7. Place Calibration card underneath camera
8. Run the executable MVTurf and see that system calibrates
9. Collect series of runs of data
10. Close program and disconnect batteries

The collected data is then verified, with data that has no GPS position associated with it, excluded from further analysis. A combination of Microsoft Excel and Matlab is then used to plot the data in three dimensions.

4.5 Discussion of Results

Results of field evaluation for this project were not clear cut due to its nature. The data collected can suggest some of the issues that it can be used to identify, though further

Figure 4.1: Grass Coverage in centre of goal mouth

research needs to be done for it to be confirmed. This discussion section therefore does not present results as such, but instead enlarges on areas of interest that may have potential to be of use to curators. This discussion section will look at the two main areas of research in this project, coverage and species mapping, and discuss any findings.

4.5.1 Coverage Mapping

Trials conducted at ANZ have produced few results due to the technical problems that caused little vision to be captured that was of any reasonable quality into a readable file. Though data collected was slim, the ideas and lessons learned from interaction with other professionals cannot be under-valued.

It would be good if the current collection system with the halogen lights could collect data from an oval of its elite standard. With such a uniform surface it would be interesting to see if the data collected was as uniform.

The data collected at the USQ soccer oval has shown that the area of the oval analyzed has no distinct bare areas, though variations in colour are evident. It is worth noting that areas that would be bare during a season of regular use, for example the centre of the goal mouth, are quite green both visually (figure 4.1) and in the data (figure **??**). Whereas other areas of the oval have a largely dormant substructure, these areas are predominantly new growth. This may have potential in monitoring the effectiveness of the rehabilitation of such areas. Monitoring to see if the area is changing size and whether the quantity of dormant grass is increasing would indicate whether the area requires more attention in getting re-established.

It can be seen in the maps quite clearly the difference in all of the values between the area surrounding the field and that of the playing area. It was noted that the playing area has been re seeded recently and has received some irrigation during this particularly dry period. If the colour variation is due to this irrigation, the vision collected might aid in analyzing the efficacy of the irrigation system. This has the potential to aid in assessing the need for major capital expenditure, such as filling low lying areas to stop water logging or the redesign of the irrigation system.

The maps from near the faculty building have shown clearly the location of the bare area and the area of high traffic. Areas surrounding the bare region also show as being green, which when compared to the photos also correlates well.

Being able to identify the high traffic areas that could potentially become bare allow for remedial work to be performed before the current stand of grass is lost completely. Repairing this damaged area while grass is still present is often easier and more effective than re seeding the area.

4.5.2 Species Mapping

The identification of grass species has not produced many results due to the complexities associated in distinguishing between them. After closer analysis of the vision collected from the trip to the Redland Bay research centre and further research into the key descriptors of each of the major species, it was concluded that the system required algorithms that dealt with shape and texture as well as colour. These algorithms have been investigated, but have not made it to the field evaluation stage. Validation of the values collected would also need to be carried out by a professional, capable of distinguishing the different species.

Reflecting on the trip to ANZ, the potential for distinguishing species on such a uniform surface is questionable. As the different species are combined together so well, even in small sample areas, identification would have to occur on a micro level for any accurate readings of coverage to be made. Considering that it is unlikely that these surfaces will ever be managed on such a scale, distinguishing species is pointless.

Looking at a less elite field, like the soccer field, does show there is potential for species mapping to be used in management planning. Using such a system to evaluate the effectiveness of a re-seeding activity, such as the one recently carried out, shows promise. For example, monitoring the establishment and survival rates for different parts of the field would now be possible. From this information, a decision on which mix of species is most effective can be made.

The grass area also supports the possibility of using such a system in conjunction with the management of activities, like spraying. Spot spraying, to remove clover or other weeds from the oval, would be possible with the system controlling the flow to the spray nozzle. At a more in depth agronomic level, identifying required nutrients for the optimum growth of different areas, based on the dominant species, may be possible.

4.6 Conclusion

The field evaluation of the system has reinforced the potential of the system in calculating the surface coverage of different surfaces and the need for it to be robust and simple to use. It has shown that significant bare areas, particularly those that are on red soils, are readily identified.

It has also shown that there is great potential in identifying areas of high wear using the system. For curators, this means that the system may be used to monitor these areas and time maintenance activities to maximize the response from their actions.

If appropriate algorithms can be developed to distinguish different species of grass, there is a possibility of recording the performance of different species, and therefore promote the use of specific species for certain problem areas.

Potential for the use of such a system in targeting maintenance activities has been shown and may allow weeds to be removed more effectively from a playing surface. Savings may be made in chemical costs, due to precise application, as well as performing operations at the most influential time.

Chapter 5

Conclusions and Further Work

This project has endeavoured to produce an instrument capable of collecting data that can be analyzed to provide meaningful information for curators. The vision collection system appears to be valid, with vision collected of high quality. The coverage analysis algorithm appears to be distinguishing between bare dormant and green areas with a high consistency. This needs to be extended further with the data given meaning so that maintenance activities can be scheduled from a data collection.

Identification of species requires further development to be of any benefit. Algorithms based on colour are not sufficient to distinguish between the various groups of turf available on the market. The analysis of leaf texture and shape may provide enough information to give an initial classification, though a firm identification requires closer analysis of other distinguishing features as detailed in the literature review.

This project has reinforced that the collection of data in such a project requires a uniform environment. The use of a shroud and an artificial light source proved effective in producing images that were highly consistent. The lights used must produce enough energy to allow a broad spectrum of colours to be captured. The shroud must be sturdy enough to withstand vibration associated with transport, and sturdy enough to traverse undulating ground.

5.1 Further Work

The research conducted in this project is far from comprehensive regarding the use of instruments in the maintenance of sporting fields. With so few tools available to curators, any tool that is designed can be beneficial in monitoring and maintaining fields. The key area is the conversion of the data collected into information that is meaningful.

The system that has been designed and evaluated has large potential to be expanded further. Little has been done analyzing what the maps produced can provide and hence data collected is of little value in its present form.

The use of alternative algorithms may be able to define the different species of grass that are present on an oval. The current system can not make any firm conclusions, though the data collected from Redland Bay could be used in further research.

Using Infra Red instead of natural light may allow more distinctions to be made between different grasses. The use of IR may also remove some of the issues associated with ground colour.

This project has focused on visual characteristics to describe a sporting surface. Further investigation into other sensors to measure irrigation efficiency and surface undulations would also hold great potential, especially if a firm correlation can be drawn regarding playability or the likelihood of injury and the data collected by the sensor.

5.2 Summary

Undertaking this final year project has been enlightening and enjoyable. Though no mind blowing results have come from it, the work that has been performed has shown that there is potential for these instruments to be developed. If such units can be created the potential savings from their use are enormous. It is hoped that the research I have performed in this area will contribute to sport being safer and enjoyable for all members of the community.

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Appendix A

Project Specification

Appendix B

Colour Calibration Card and Screen Shots

B.1 Introduction to this Appendix

This appendix contains the colour calibration card used to standardize the values of red green and blue being collected by the camera. This appendix also contains screen shots of the various program used in the collection and analysis of the data used in this project.

B.2 Colour Calibration Card

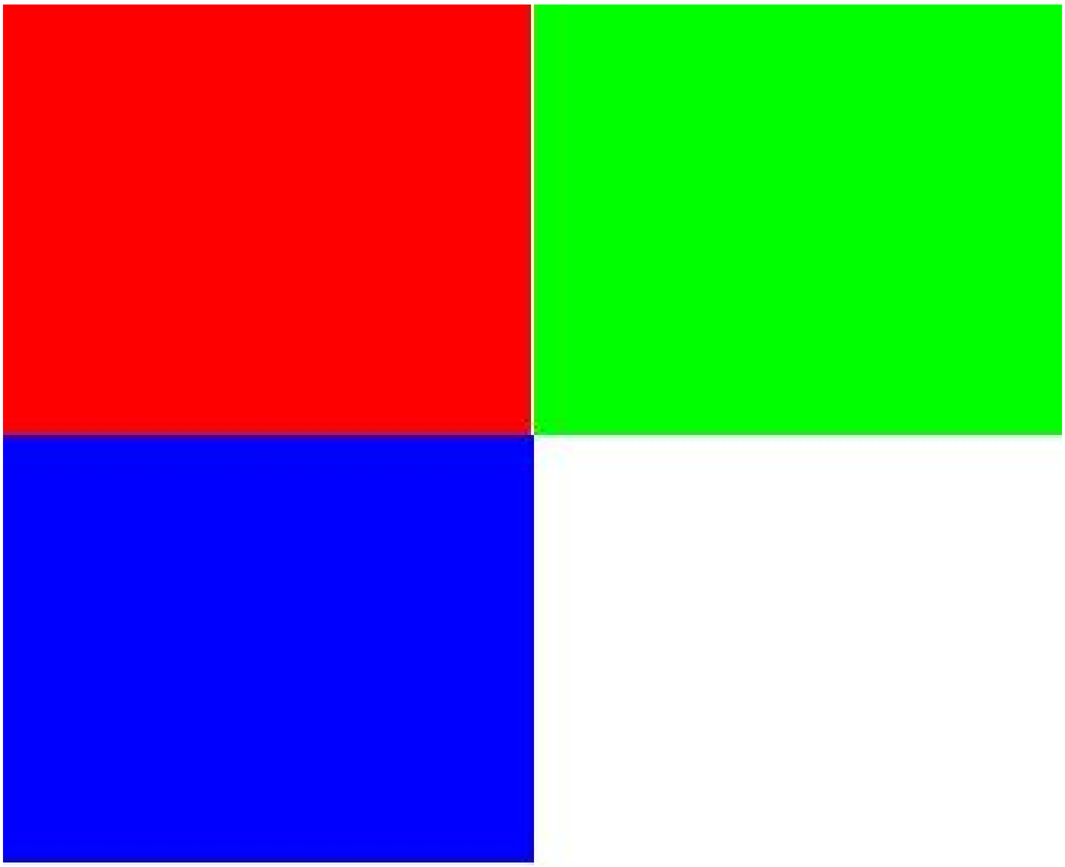
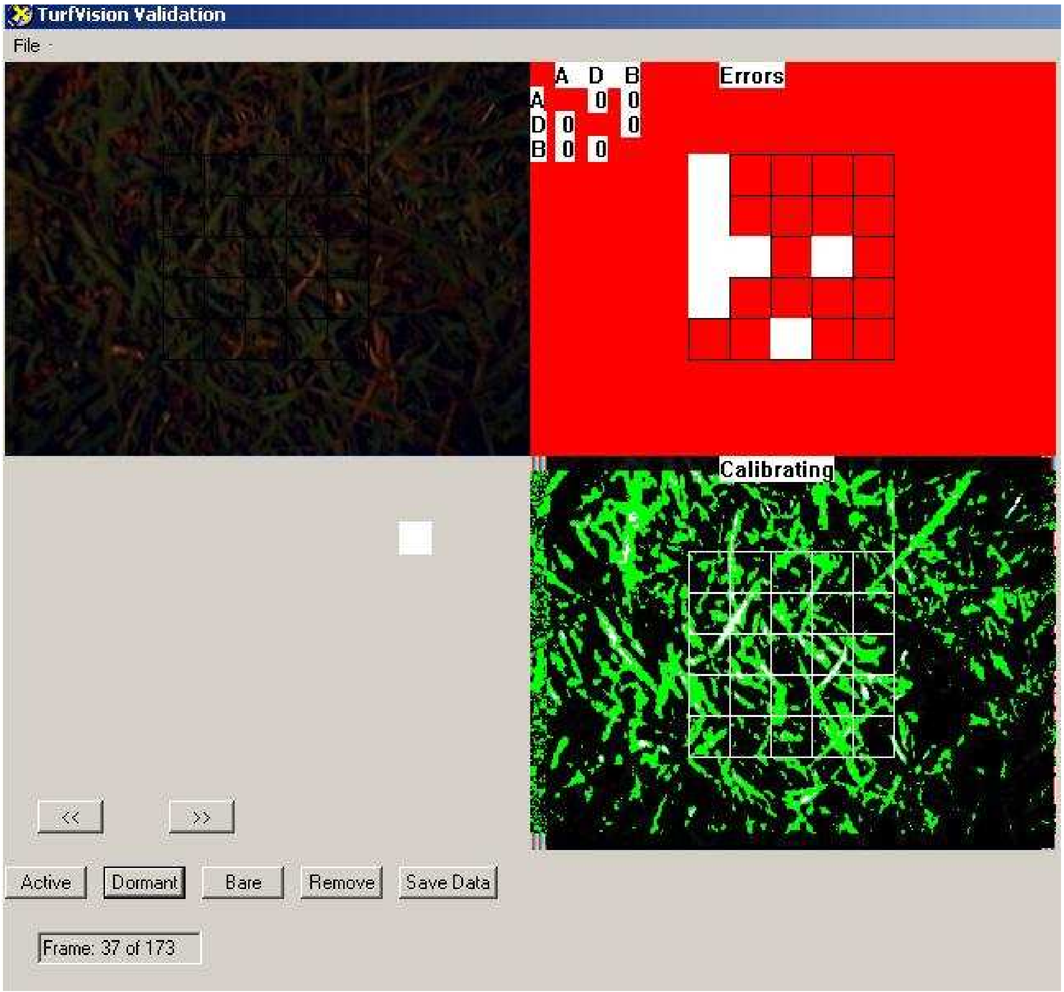


Figure B.1: Colour Calibration Card

B.3 Coverage validation software



	A	D	B
A		0	0
D	0		0
B	0	0	

Frame: 37 of 173

Figure B.2: Coverage validation software

Appendix C

Maps Photos and Tables

C.1 Overview

This chapter incorporates various maps that have been output by the system during field evaluation, photos showing where these maps have come from and tables detailing the layout of the turf plots at the Redland Bay research centre. Many of the figures do appear at other places in this dissertation, though are reproduced here for clarity.

C.2 USQ Soccer Oval

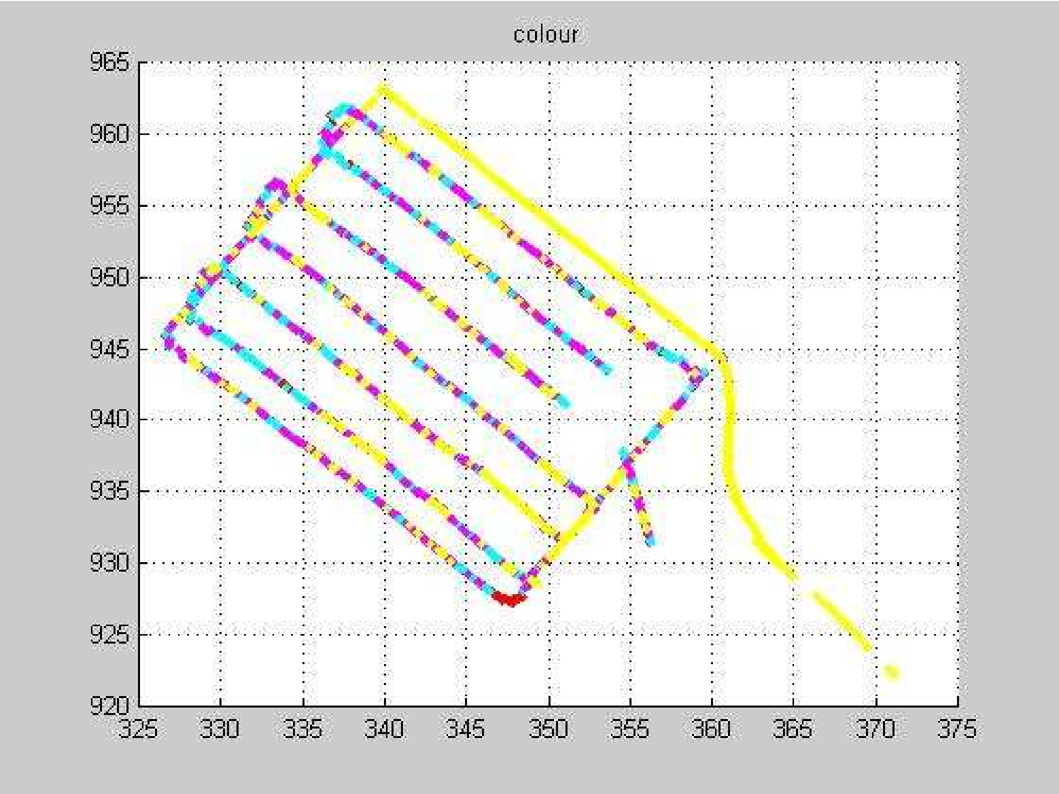


Figure C.1: Map of Soccer Field using colour equation

C.3 Grass area near NCEA

C.4 Redland Bay Research Centre

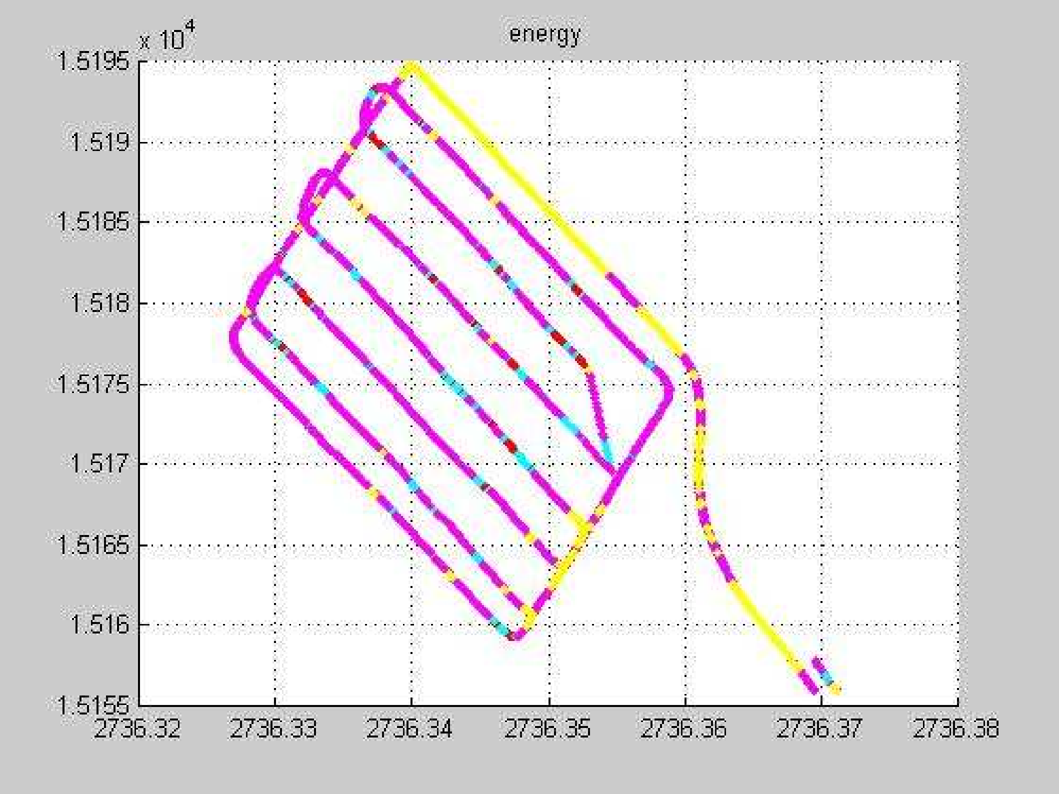


Figure C.2: Map of Soccer Field energy values

Figure C.3: Area of Soccer Field analyzed

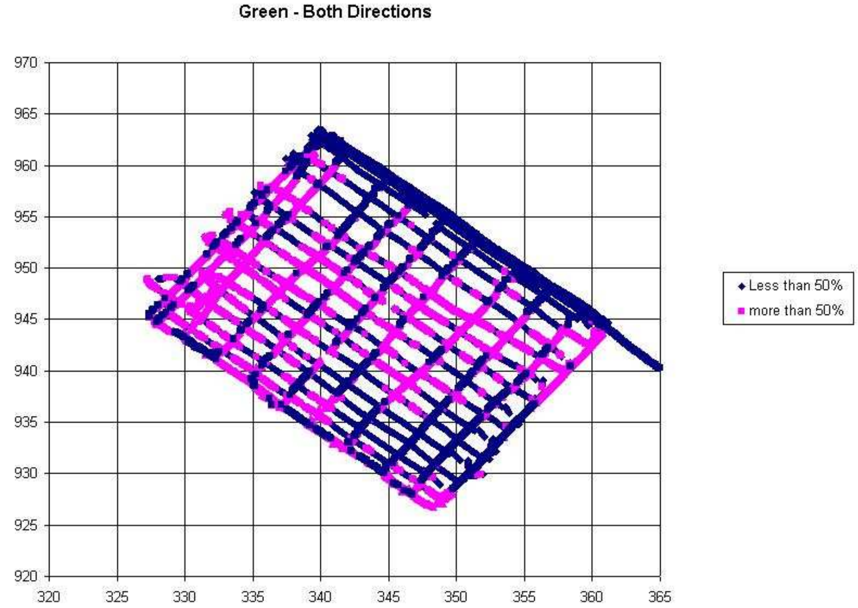


Figure C.4: Map of values produced using green algorithm

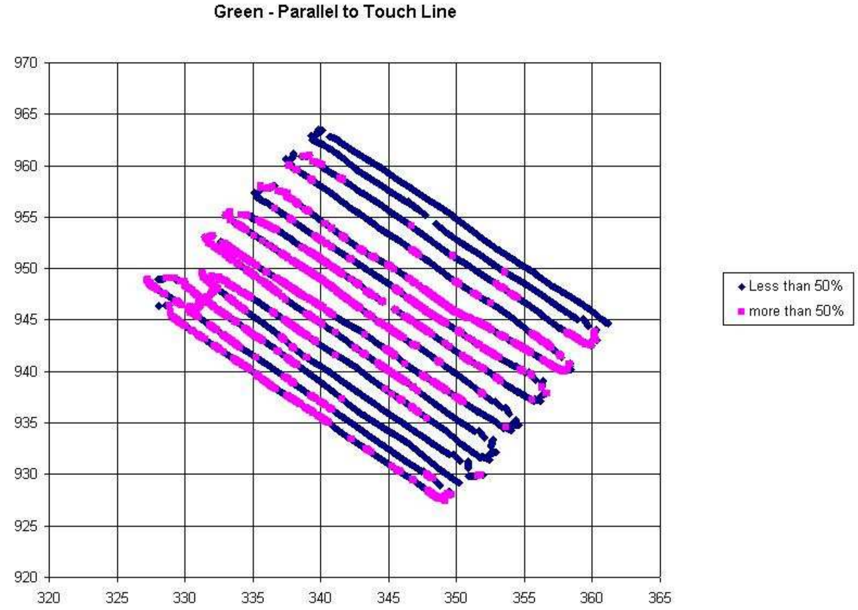


Figure C.5: Map of values produced using green algorithm Parallel to touch line

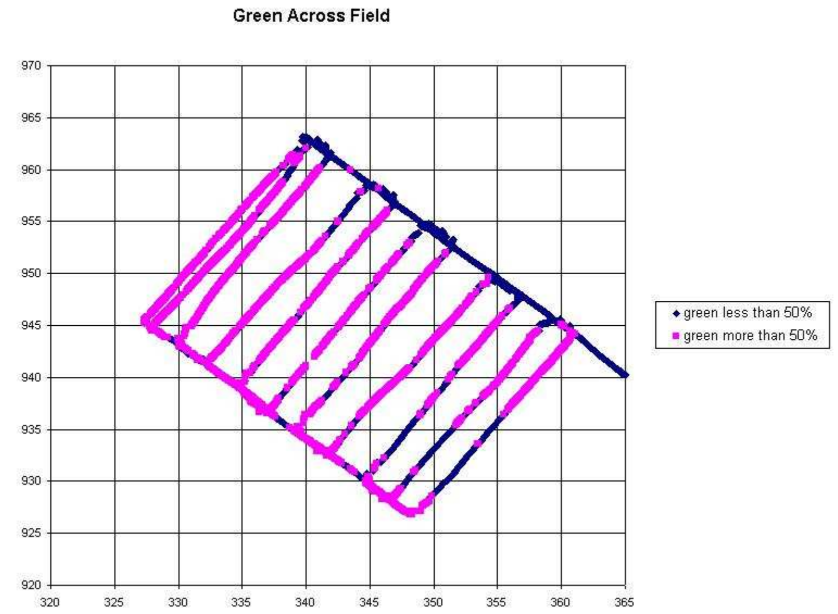


Figure C.6: Map of values produced using green algorithm Perpendicular to Touch line

Figure C.7: The Area Analyzed near Z block USQ Showing the Clear Bare Area and the Collection Apparatus

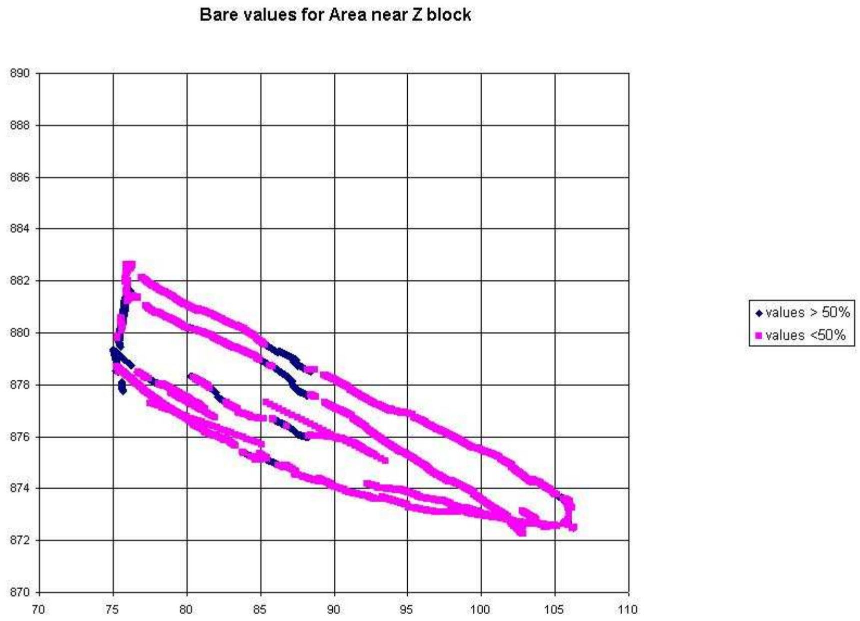


Figure C.8: The Map of the area shown above with bare area clearly visible

Table C.1: Plot Layout at Redland Bay Research Centre

BUCDAC Bison	BUCDAC BT-25	PASNOT Argentine	PASNOT Competidor	PASNIC Blue Dawn	PASNOT ACT 2
STESEC B137	BUCDAC UCHL-1	PASNOT Riba	PASNOT CPI 38824	PASNOT ACT-1	PASNOT Pensacola
STESEC BT12	STESEC Sir Walter	STESEC ST - 85	STESEC ST - 91	PENCLA Commmon Kikuyu	PENCLA Whittet
STESEC Sir James	STESEC Shademaster	STESEC Svelvet	STESEC Palmetto	PENCLA Breakwell	PENCLA Noonan
STESEC St-15	STESEC ST-26	AXOAFF Narrowleaf Carpet	AXOCOM Broadleaf Carpet	AXOCOM Whitsunday White	PENCLA WAI Plant A
DACAUS Sweet Smother	PSESPI *Pseudor. Spinescens*	EREOPH Common Centipede	EREOPH Centek	EREOPH TifBlair	POAHYB Reveille
SPOVIR *Spor. Virginicus(WA)*	SPOVIR *Spor. Viginicus (CQ)*	ZOYJAP Traveler	ZOYJAP Darwin K78	ZOYJAP Sunrise	ZOYJAP Jamur
SPOVIR Ozlawn	ZOYJAP Palisades	ZOYJAP Zenith	ZOYJAP Companion	ZOYJAP Cathay	ZOYJAP T 1 Meyer
ZOYMAT Zorro	ZOYMAT Cavalier	ZOYJAP Empire	ZOYJAP Empress	ZOYJAP ZT-11	ZOYJAP Z-3
ZOYMAT Royal	DIGDID Tropika	ZOYJAP El Toro	ZOYJAP De Anza	ZOYJAP Victoria	ZOYJAP ZT-94
DIGDID DB-1	DIGDID Qld Blue Couch	BOTPER Dawson	BOTPER Emerald Downs	BOTPER Keppel	PANLAX Shadegrow
DIGDID S-1	DIGDID Aussiblue	CYNDAC NuMex Sahara	CYNDAC Speedy Couch	CYNDAC DN009	CYNDAC Sultan
PASVAG Sea Isle 1	PASVAG Saltene	CYNDAC Jackpot	CYNDAC La Paloma	CYNDAC Southern Star	CYNDAC Pyramid
PASVAG Velvetene	PASVAG SI98	CYNDAC Mirage	CYNDAC SR 9554	CYNDAC Mohawk	CYNDAC Sun Devil II
CYNDAC Sun Devil	CYNDAC Sun Star	CYNDAC Savannah	CYNDAC Shangri-La	CYNDAC Royal Cape 11	CYNDAC JT1
CYNDAC Majestic	CYNDAC Sonesta	CYNDAC Bosker	CYNHYB TifSport	CYNDAC Sydney	CYNDAC Primavera
CYNDAC Blackjack	CYNDAC Hatfield	CYNDAC Legend	CYNDAC Windsor Green	CYNDAC Wintergreen	CYNDAC Greenlees Park
CYNDAC Spare	CYNHYB WS001	CYNDAC National Park	CYNDAC Oz-E-Green	CYNDAC SS-2	CYNDAC FLoraTeX
ZOYHYB Emerald	CYNDAC CT-2	CYNDAC Princess	CYNDAC Yukon	CYNDAC Riviera	ZOYMAC *Zoy.macrantha(NSW)*
ZOYMAT G1	CYNDAC Mountain Green	CYNDAC Lplateau	CYNDAC Conquest	CYNDAC Riley's Super Sport	CYNDAC Spare
ZOYMAC Zoy. macratha(SA/T)	CYNHYB TifSport	CYNHYB Santa Ana	CYNHYB Tifway	CYNHYB WS200	ZOYTEN *Zoy. Tenuifolia*
ZOYTEN *Zoysia tenuifolia*	ZOYMAT Facet	CYNHYB Tifgreen	CYNHYB TifDwarf	CYNHYB Tifdwarf(Jindalee)	CYNHYB Novatek
CYNTRA *Cyn. Transvaalensis*	PASVAG Sea Isle 2000	CYNHYB Champion Dwarf	CYNHYB FloraDwarf	CYNHYB MS-Supreme	CYNHYB TifEagle
6	5	4	3	2	1

Table C.2: More Common Turf Varieties at Redland Bay Research Centre

		PASNOT Argentine			
					PASNOT Pensacola
				PENCLA Commmon Kikuyu	PENCLA Whittet
		AXOAFF Narrowleaf Carpet	AXOCOM Broadleaf Carpet		
	DIGDID Qld Blue Couch				
	DIGDID Aussiblue			CYNDAC DN009	
			CYNDAC TifSport		
				CYNDAC Wintergreen	CYNDAC Greenlees Park
	CYNDAC CT-2	CYNDAC Princess			
		CYNDAC plateau	CYNDAC Conquest		
	CYNHYB TifSport	CYNHYB Santa Ana			
6	5	4	3	2	1