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VinoFlot RS Unification of Unmanned Aerial Systems and Remote Sensing Practices to Better Analyze Grapevine Health

James M. White
University of Denver

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Abstract

Success in agriculture is derived from nutrient-rich soil, well-tilled earth and hands-on attention. In order to meet the needs of increasing food demand, agricultural practices have endured a growing use of chemical and fertilization methods in order to produce higher yields. While the transition to an entirely chemical-free agricultural model is not achievable with regard to the quantity of crop yield, the integration of new technology and updated practices can lessen the amount of chemical and fertilizer adjuncts needed. The purpose of this plan is to offer a lightweight, customizable GIS solution to better understand crop health, in particular grapevines used in viticulture. This GIS plan introduces the VinoFlot Remote Sensing system, which will hereafter be referred to as VinoFlotRS. VinoFlotRS is a combination of unmanned aerial systems (UAS), specialty UAS hardware and software, GPS technologies and advanced image analysis software. With today's advancements and size reduction in aerial remote imaging hardware combined with the versatility of unmanned aerial systems, the ability to capture rapid and even real-time crop health data is a potentially game changing technological union. The result: providing concentrated, spatially precise aerial application to only the areas that need it – effectively lessening the amount of chemicals needed for successful yields and eliminate the artifact of unnecessary overspray. Success of this plan hinges on a combination of UAS hardware and software, lightweight imaging optics, GPS and GIS technologies, including the recognition of the limitations and concerns that surround each.

The scope of this plan will be limited to the Carlson Vineyards Winery in the Grand River Valley near Grand Junction, Colorado. The scenario assumes that Carlson Vineyards uses present day aerial application methods to combat the variety of disease and or pest issues surrounding wine grape crop yields.

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Subject Categories

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VinoFlot RS

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James M White
Masters of Geographic Information Science
Department of Geography
The University of Denver - Fall, 2014

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With today's advancements and size reduction in aerial remote imaging hardware combined with the versatility of unmanned aerial systems, the ability to capture rapid and even real-time crop health data is a potentially game changing technological union. The result: providing concentrated, spatially precise aerial application to only the areas that need it – effectively lessening the amount of chemicals needed for successful yields and eliminate the artifact of unnecessary overspray. Success of this plan hinges on a combination of UAS hardware and software, lightweight imaging optics, GPS and GIS technologies, including the recognition of the limitations and concerns that surround each.

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Disclaimer

DISCLAIMER: The results and indication of this GIS implementation plan are for educational purposes only, and has not been field tested beyond what is mentioned in this plan. Additionally, this plan lays the foundation for the development of my University of Denver Capstone project.

Acronyms & Abbreviations Index

Acronym	Full Text
FAA	Federal Aviation Administration
RS	Remote Sensing
GIS	Geographic Information System
GPS	Global Position System
PA	Precision Agriculture
PV	Precision Viticulture
SSCM	Site Specific Crop Management
UAV	Unmanned Aerial Vehicle
UAS	Unmanned Aerial System
FLIR	Forward looking Infrared
SWIR	Shortwave Infrared
NIR	Near Infrared
IR	Infrared
RGB	Red, Green, Blue
MP	Megapixel
NAS	National Airspace System

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Introduction

Precision agriculture (PA) is a rapidly growing subset-practice within the larger field of agricultural management. Also referred to as Site Specific Crop Management (SSCM), PA utilizes global positioning systems (GPS), advanced optic sensors and special hardware and software products to capture the spatial variability of land cover. Rather than treating an entire crop as a single entity, PA addresses trouble spots within the crop. This localized view of problem areas allows analysis and subsequent treatment to occur on a local level. Advantages of PA include:

- Record building and rapid comparison
- Improved decision making (through remote sensing)
- Enabling greater traceability
- Enhancing yield and quality of product
- Decreasing chemical application needs
- Reducing costs associated with broad aerial application techniques ("Precision Agriculture" - Wikipedia 2014)

Since its beginnings in the 1980's, ("Precision Agriculture" - Wikipedia 2014) PA's image capture technology has advanced and changed in parallel to the latest technological advancements. Today, PA is most often done through the use of manned aircraft – examples include: fixed wing planes and helicopters – even tractors with aerial cranes attached.

The purpose of VinoFlotRS is to further the emerging science of Precision Viticulture (PV), a subset practice under the bigger Precision Agriculture (PA) by incorporating UAS technology. PV aims provide affordable and adaptable solutions to obtain, analyze and ultimately treat grapevine crop health disorders. For the scope of this plan, the processes and procedures surrounding the application and treatment phases of the process will be acknowledged in order to build a bigger picture, but will not be addressed in detail.

Plan Participants

Client

Carlson Vineyards
461 35 Rd, Palisade, CO 81526
(970) 464-5554
Contact: Parker Carlson
Carlson Vineyards will act as a proof-of-concept test location. They are a small wine grape producer and winery in Palisade, Colorado.

Hardware Engineering Firm

Aerial Data Systems
11705 Airport Way
Suite 207
Broomfield, CO 80021
720-330-8320
Contact: Joe Falconer
Aerial Data Systems is a Colorado based manufacturer of both fixed wing and multi-rotor UAV flight platforms. In addition to custom design and build unmanned aerial systems, Aerial Data Systems provides training and support for their hardware. Utilizing an interchangeable payload module, data can be captured through sensors capable of recording: Infrared (IR) shortwave infrared (SWIR), near infrared (NIR) and red, green, blue (RGB).

Primary UAV Pilot

Joe Falconer – Private Pilot, FAA Regulation Specialist, UAV engineer

Primary Data Analyst

James White – GIS researcher with the University of Denver

Remote Sensing Consultant(s)

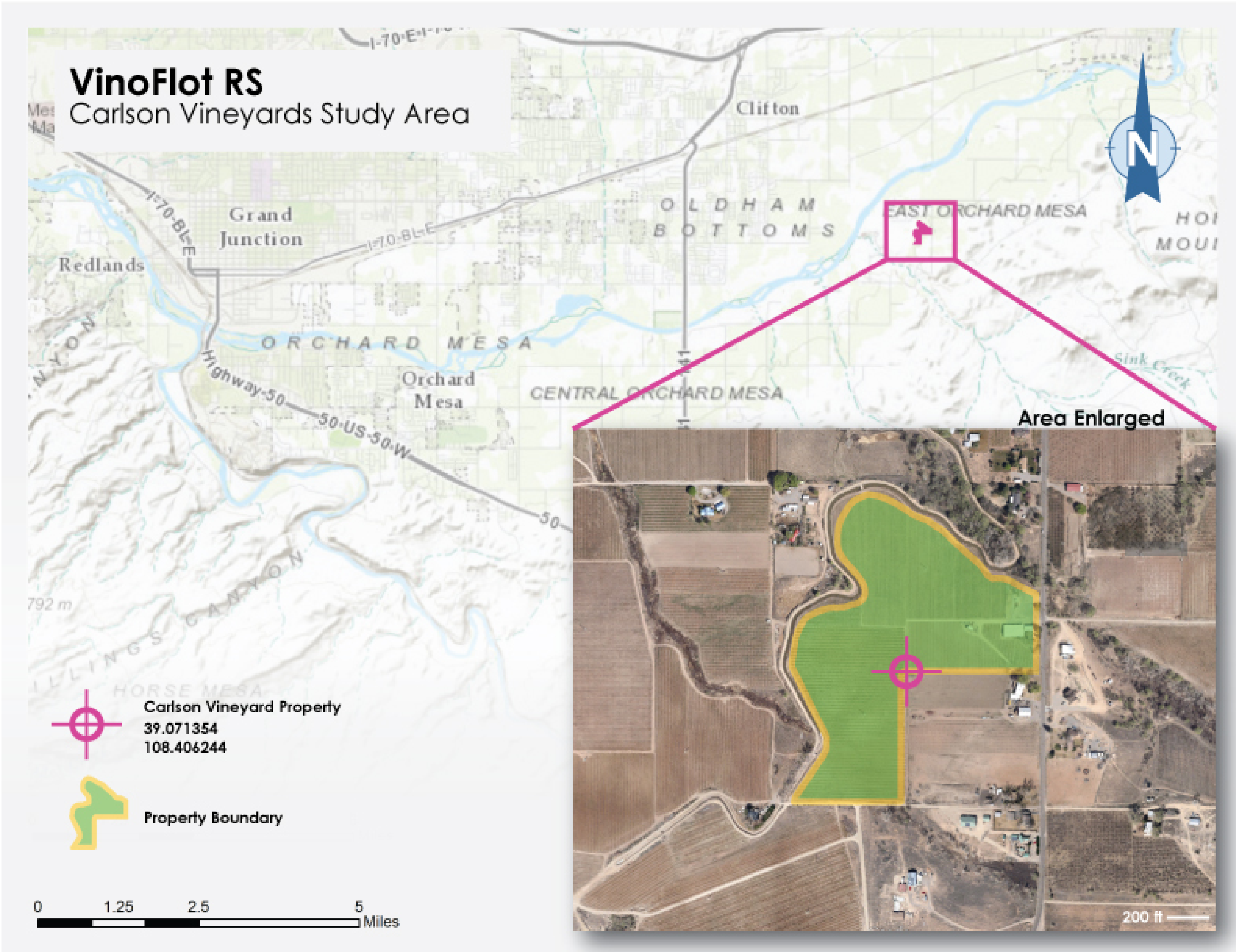
Steve Hick – Professional Cartographer, DU GIS program director, GPS Specialist

Rebbeca Powell – Professor with the University of Denver, remote sensing specialist

Aerial Application Consultant(s)

Air Care Colorado – Agricultural aerial application firm based in Lamar, Colorado. www.aircareinc.us

Area of Interest



Organization Structure

The VinoFlotRS program is a collaborative effort between academics, industry professionals and interested farmers.

The **"Client"** is the Carlson vineyard in Palisade, Colorado. Parker and Mary Carlson have owned and operated the vineyard since 1988.

The project **"Manager"** is James White, a Master Degree Candidate with the University of Denver. The details in this plan are cited to lay the foundation for his capstone research in the spring of 2015.

The **"Engineering Firm"** behind the development and implementation of the UAS technology cited in the plan are generously provided by Aerial Data Systems.

Current Environment

Currently, the typical aerial application workflow is as follows:
1) A farmer hires a crop consultant company to perform analysis on land This is done by going and looking at crops and soil on the ground, and typically only accounts for a selection of sample points.

2) A recommendation report is then given, and either the farmer or crop consultant company hires an aerial application service to "spray" the crop. In most commercial farming in the United States, little consideration is given to sectional analysis and the entire parcel is treated as a single entity. (Conyers 2014)

3) Applicator pilots are given GPS coordinate of parcel locations, which are then loaded into a flight computer and used to control the location and application of chemicals.

Needs Assessment

The implementation of updated agricultural technology has been a paramount factor in the continued growth of the industry. Yet, for the most part, the aerial technologies used to address crop health and the subsequent treatment, have largely remained unchanged, while, on-the-ground, "flightless" technologies have been adopted with open arms. With the rapid development of UAS technology, there is no question that they have enormous benefit to commercial agricultural economic growth. In fact, according to the Association of Unmanned Vehicles Systems International (AUVSI), upon the implementation of UAS within the National Air Space, these technologies have the economic potential to create 70,000 jobs and more than $13.6 billion in revenue within the 3 years following their legalization. (Keleman 2013, 14)

Application Description

Application Definition

The purpose of this plan is proving the effective integration of UAS technology in an effort to map crop health conditions within grapevine agricultural parcels. This will be done through the combination of UAV's, GPS location technology, remote sensing optics and computer analyzation software.

The use of Precision Agriculture (PA) has been a growing trend in the United States since the 1980's. (Keleman 2013, 14) However, due largely in part to restrictive FAA regulations imposed on unmanned aerial technology, the widespread implementation of UAS technology has been slow to take off. (Keleman 2013, 14; Tuttle 2013, 54; Arc User Magazine 2014, 24) If we look to the international community, particularly Japan, Australia and Europe, we see that they have been developing and using UAS technology in agriculture for over 20 years. Japan, for example, currently employs over 7000 remote aerial vehicles in rice crop agriculture practices. (Keleman 2013, 14)

Under the umbrella of research, industry leader and academics in the United States have long seen the benefits of combining lightweight, cost effective and accurate GPS and UAS technology for agricultural practice. The ability to provide a rapid aerial survey and subsequent recommendation, allows for treatment of specific problem areas. This effectively reduces costs for the farmer, reduces chemicals added to crops and watersheds, and, potentially increases crop yield.(Anderson and Gaston 2013, 138-146) As previously mentioned, the VinoFlot RS plan will be limited to the first phase of survey and analysis. The second phase being that of proving unmanned application techniques based on the results of phase 1.

GIS is an indistinguishable piece of the VinoFlotRS toolbox, when looking at the success of UAS systems in agricultural purposes. From pre-flight planning, and application processes using GPS coordinates to spatial imaging, data analysis and spatial database use, GIS technology is critical to implementation of this practice. The combination of UAV and GIS provides the primary data source— aerial image data. Along with the UAV and an optic sensor (camera), is a GPS logger that records the latitude, longitude and altitude records a spatial stamp of each image into a .gpx file. There are a number of technologies available for attaching GPS location data to individual images, in the VinoFlotRS system for example; the images will be married to the GPS log using RoboGEO software. From there, the images are converted into a GEOTIFF image format, which now contains GPS data within the metadata, and, can be processed through variety of advanced GIS imaging and visualization software.

Once images are georeferenced and processed, an analysis using remote sensing analysis software can be done to determine trouble spots. The result would be a “prescription map”, and can be further processed into GPS data for aerial application though conventional aerial methods, or through remote controlled UAV air tractor equipment capable of carrying the payload required for site specific treatment.

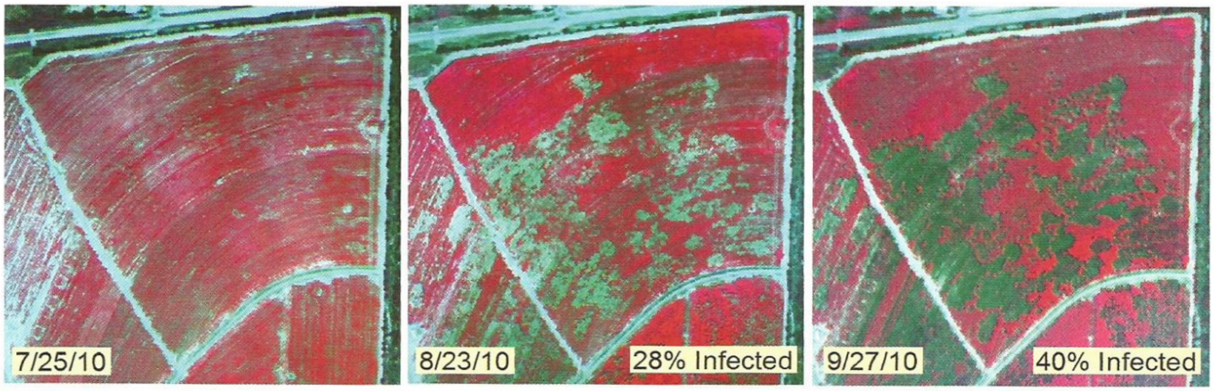


Fig .1 Color–infrared images for a root-rot infected cotton field on three dates. Health plants are colored as red while the infected plants are green.
(Yang, Hoffman, and Fritz 2013, 23)

Functional Requirements

Success of the VinoFlotRS GIS proposal requires the following:

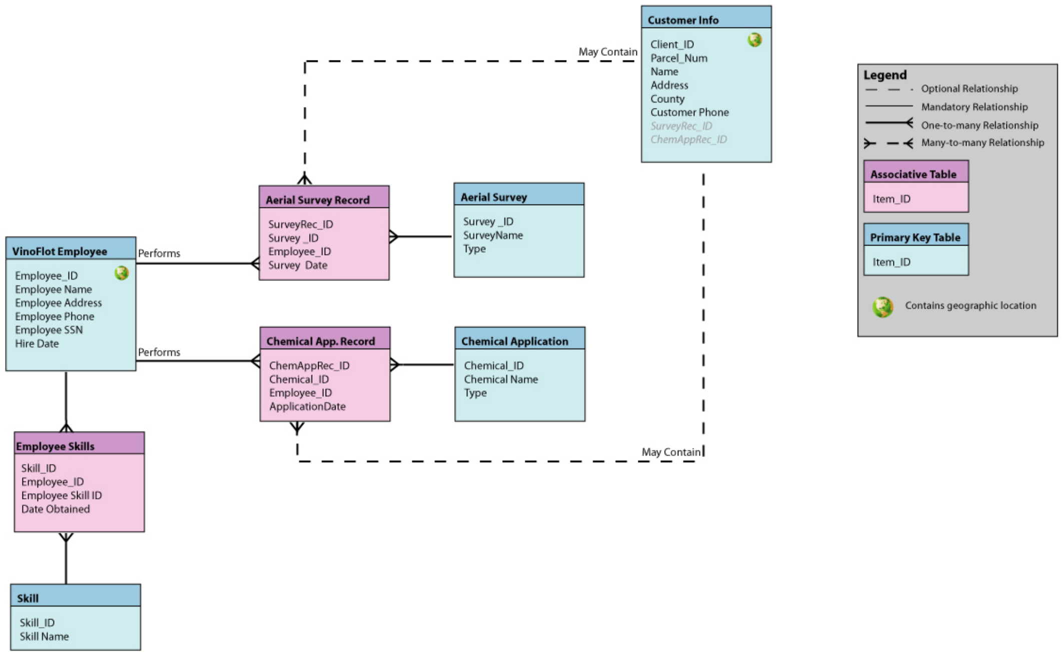
1) Site survey via GPS control points and satellite imagery
2) UAV flight to collect geo-tagged digital imagery data at a minimum of 15 CM pixel resolution
3) Image stitching/mosaic generation
4) Remote sensing evaluation (IR, NIR, SWIR) and analysis
   (See appendix for detailed definitions)

Database Design

The VinoFlotRS plan, while focused on a single client, utilized a database designed for future implementation to include multiple clients and eventually multiple different agricultural needs. The following diagrams map the database and data management requirements and include:

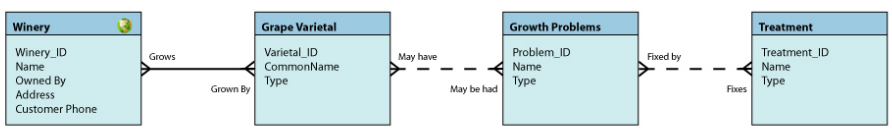
- Detailed client/crop information records
- UAV pilot that flew the mission
- The geolocation of the land parcels
- The type and quantity of chemicals that were used
- Where the image files reside on a server

Conceptual Design

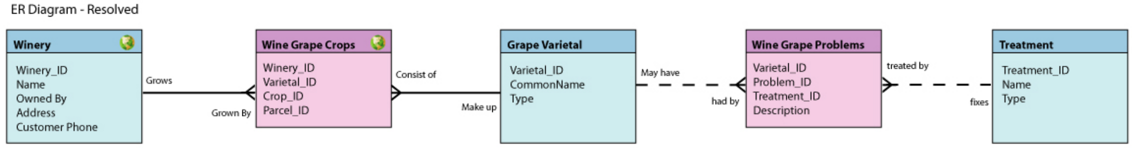


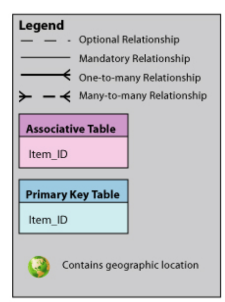
Logical Design

ER Diagram



ER Diagram - Resolved





Database Description

CustomerInfo					
Attribute:	**Description**	**Data Type**	**Width**	**Units**	**Range**
Client_ID	Unique Client #	Number	4	Integer	Auto
PARCEL_NUM	Land Parcel Number	Alpha Numeric	50	Integer	Assigned
Name	Client/Customer Name	Alpha	50		Manual
Address	Customer Address	Alpha Numeric	50		Manual
County	County	Alpha	50		Manual
Phone	Phone Number	Numeric	10		Manual
SurveyRec_ID	*Unique Record of Aerial Survey (if applicable)*	*Alpha Numeric*	*5*	*"S1234"*	*Autofill*
ChemAppRec_ID	*Unique Record of Chemical Application (if applicable)*	*Alpha Numeric*	*5*	*"A1234"*	*AutoFill*

VinoFlotEmployee					
Attribute:	**Description**	**Data Type**	**Width**	**Units**	**Range**
Employee_ID	Unique Employee #	Number	4	Integer	Auto
Last Name	Last Name	Alpha	50		Manual
First Name	First Name	Alpha	50		Manual
Address	Home Address	Alpha Numeric	50		Manual
Phone	Phone Number	Numeric	10		Manual
SSN	Social Security #	Numeric	11		Manual
Hire Date	Date of Hire	Numerical	8	yyyy-mm-dd	Manual

Chemical Application					
Attribute:	**Description**	**Type**	**Scale**	**Units**	**Range**
Chemical_ID	Unique Chemical ID #	Number	4	Integer	Auto
Name	Name of Chemical	Alpha Numeric	99		Manual
Type	Type of Treatment	Alpha Numeric	10		Pesticide, Fertilizer

Chemical Application Service Record

Attribute:	Description	Type	Scale	Units	Range
ChemAppRec_ID	Unique Chemical Application Record #	Number	5	Integer	Auto
Chemical_ID	Unique Chemical ID #	Number	4	Integer	Auto
Employee_ID	Employee who applied chemical	Number	4	Integer	Auto
Date of Service	Date of Service	Number	8	yyyy-mm-dd	Manual

Aerial Survey					
Attribute:	**Description**	**Type**	**Scale**	**Units**	**Range**
Survey_ID	Unique Problem #	Number	4	Integer	Auto
SurveyName	Name of Surveyed Problem	Alpha Numeric	99		Manual
Type	Type of Problem	Alpha Numeric	10		Pest, Disease

Aerial Survey Service Record					
Attribute:	**Description**	**Type**	**Scale**	**Units**	**Range**
ChemAppRec_ID	Unique Chemical Application Record #	Number	5		Auto
Chemical_ID	Unique Chemical ID #	Number	4		Auto
Employee_ID	Employee who applied Chemical	Number	4		Auto
Date of Service	Date of Service	Number	8	yyyy-mm-dd	Manual

Skills					
Attribute:	**Description**	**Type**	**Scale**	**Units**	**Range**
Skill_ID	Unique Skill #	Number	4	Integer	Auto
Skill Name	Name of Skill	Alpha Numeric	50		Manual

Employee Skills					
Attribute:	**Description**	**Type**	**Scale**	**Units**	**Range**
EmployeeSkill_ID	Unique Employee Skill #	Number	6	Integer	Auto
Employee_ID	Unique Employee #	Number	6	Integer	Auto
Skill_ID	Unique Skill #	Number	10	Integer	Auto

Data Acquisition / Conversion Strategy

The data required for analysis is acquired through optical sensors and cameras mounted beneath the UAV. They will be captured as an image data file -- JPEG, TIFF or RAW Data. In the case of multispectral image capture, and depending on the spectral bands needed, there can be multiple image files recorded for a single frame. Two kinds of optic sensors are useful in acquiring ground data for analysis in the VinoFlotRS plan.

First is a digital camera, which is capable of recording very high resolution composite red, green, blue (RGB) images through either charged-couple device (CCD) or complementary metal-oxide semiconductor (CMOS) sensors. For the purposes of this plan, these sensors are capable of capturing the “greenness” of specific crops. When calibrated properly, pixel evaluations can be made to help determine the variation of plan vigor within individual crops. (Lamb, Hall, and Louis 2001, 89-94)

Second, are multispectral optic sensors, which are capable of recording data outside the visual (RGB) range of the electromagnetic spectrum (ES). For most agricultural purposes, the wavelengths within the infrared range of the ES spectrum are most useful. However, advanced sensors have the capacity to record the reflectance of ground based objects in various spatial, radiometric, spectral and temporal resolutions.(Hall and others 2002, 36-47) By capturing aerial data as multispectral images, the ability to extract and analyze specific wavelengths of data in quantifiable methods, can aid in understanding a vast number of issues concerning specific plant and soil health. The complete science behind multispectral image analysis is beyond the scope of this plan and will only be discussed as a broad topic. Fig 2 portrays the visual representation of the electromagnetic spectrum, and distinguishes where visible RGB reflectance falls within the greater electromagnetic spectrum. Fig 3 shows what the resulting images look like when multispectral imaging is used.

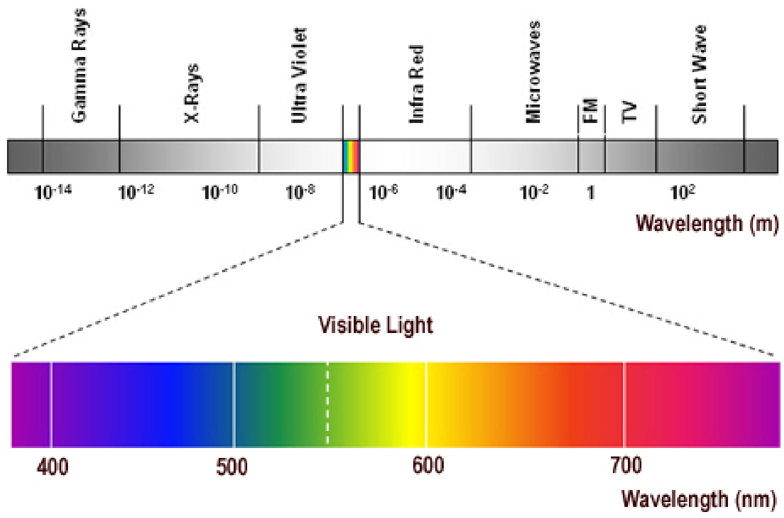


Fig. 2. – Visual representation of electromagnetic spectrum
Image courtesy of pro-lite.co.uk.com

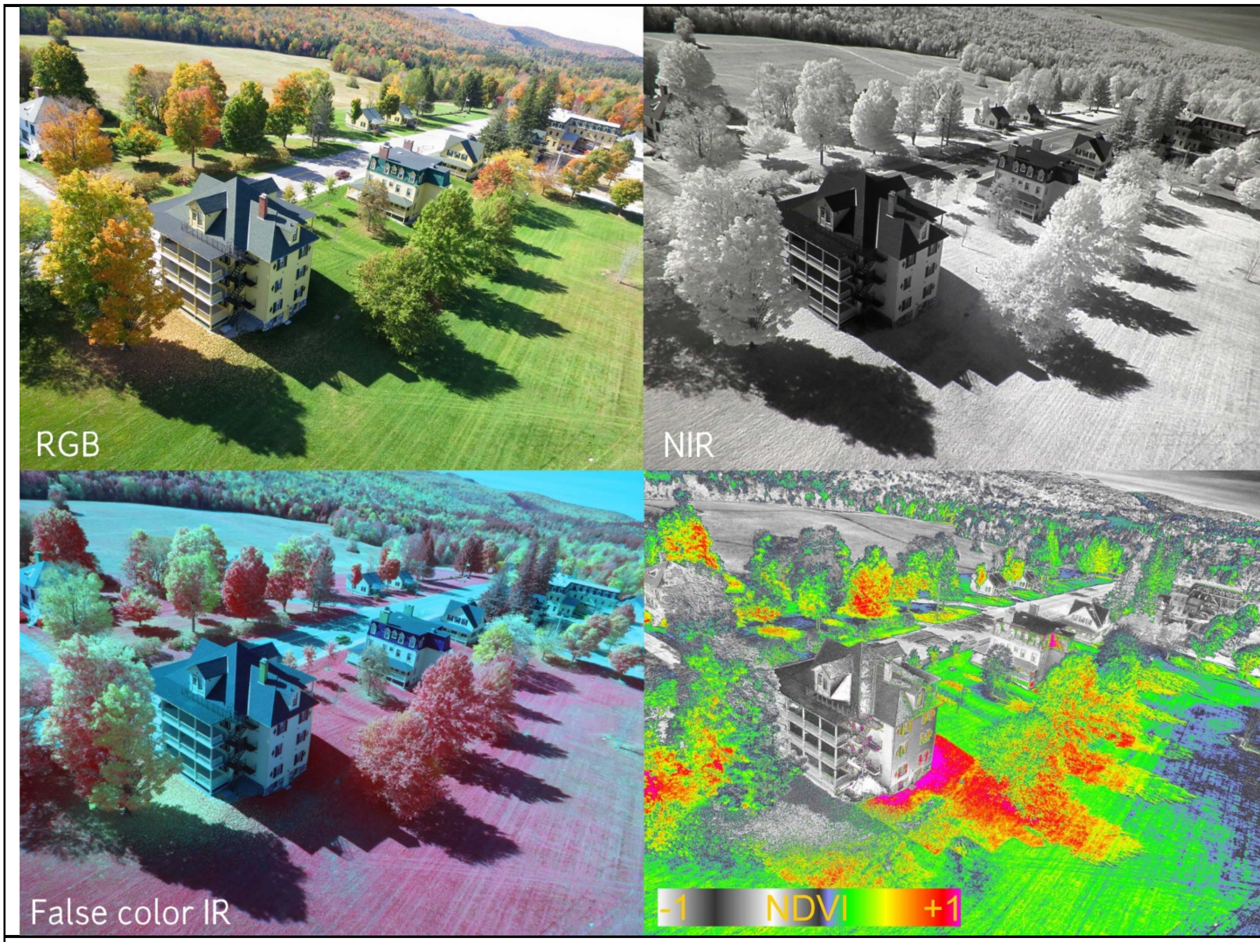


Fig.3. Four Variations of images captured via multispectral imaging.
(Fastie 2014)

Successful and efficient use of aerial photography requires the image sensor to record ground data at a specific size as determined by the use of the image. Do we need a pixel resolution that can identify aphids, single grapes or grape leaves? This size is determined by specific needs of the mission. For the VinoFlotRS pilot project, overall crop health conditions are the goal and can be determined by the vigor and extent of the vine canopy. (Lamb, Hall, and Louis 2001, 89-94) In this case, a pixel resolution of about 6 inches or 15 centimeter is adequate for analysis. (This size is determined by the approximate size of grapevine leaf)

In order to determine the scale of the aerial photo, expressed as its representative fraction (RF) by the height of the moving platform (UAV/Optic Sensor) and by the focal length of the camera, we can calculate our flight needs with the following equation: **RF = f/H*, where H* = H - h**, with H = height (elevation with reference to sea level) of the camera and h is the height of a reference point on the surface, so that H - h is the distance between the UAV and the top of the vine canopy. This calculation assumes flat ground surface; in rugged terrain, scale in effect varies with the elevations. (Lillesand, Kiefer, and Chipman 2008, 756)

Technical Requirements

Software Requirements

Pix4D – Specialty software used to automatically “stitch” multiple overlapping aerial images into a continuous high resolution file.

Multispectral Image Analysis Software – Currently, a number of remote sensing analysis software packages are being evaluated to determine which is best suited for evaluation. Considerations here will be evaluated based on ease of use, integration with current software and cost. The following software is being evaluated:

- Orfeo Toolbox
- GRASS GIS
- TNT MIPS
- MultiSpec Remote Sensing
  (see appendix for detailed summaries of these programs)

Flight planning and pre-analysis Software – DJI Ground Control is the preferred flight planning software. It is easy to use, usable on PC and Mobile devices, and works with a number of common GIS file formats. It allows creation or import of control points for automated flight planning. Out of the box, it utilizes Google Maps as images for planning purposes. Since these maps and aerial photos are not always up to date, the possibility to load user generated base maps is possible.

Hardware Requirements

UAV

This proposal will utilize a purpose built multi-rotor UAV, in a hexacopter (6 rotor) configuration paired with a 3 axis gimbal, onboard GPS logger and antenna, and capability of downward facing optic payload of 4 lbs. or less. Engineered and built by Aerial Data Systems, this UAV configuration is custom built utilizing an optimized configuration of both proprietary and off the shelf components.

Optical Capture Requirements

Standard RGB + Near Infrared

The current optic configuration utilizes a Sony NEX7 camera capable of 24megapixel RGB data capture. This unit also has the option for near IR sensing when paired with a lens filter. In Agriculture, NIR wavelengths are used to determine ground cover variances and soil chemistry. They are widely used in the quantification of many types of agricultural evaluations due in part to their reliability and low cost. (Raghavachari 2001; Workman, Jerry.,Weyer, Lois., 2008)

Advanced Multispectral Optics

Additional multispectral optical sensor technology will be evaluated based on weight, cost, and need to capture spectral data in different wavelengths.

Computing Requirements

The following is a description of the minimum hardware requirements as determined by the software processing needs:

- Windows 7 Professional
- Intel Core i5
- LCD Display, 256GB Solid State Drive,
- 16 GB RAM
- 4GB Graphics Card

At the time of writing, an off-site desktop is the preferred solution for processing and analysis due to the large volume of photos used in the orthomosaic process. However, future needs may dictate a mobile (laptop) solution if rapid data turnaround is required.

Network Requirements

Current

All processing and file exchange will occur on the local machine level via hard drive, memory card and direct transfer. Internet / WiFi are not a requirement and no data will be pulled from a central media storage drive. The Sony NEX camera captures image data on a small Secure Digital (SD) memory card. This is one of the current standards for in camera photographic data recordings. They are reliable, durable and interchangeable within many camera manufacturers. The SD card format is universally accepted in portable and built-in image card readers for computers. Once the UAV had landed, the SD card is physically removed and the data is transferred to a hard drive.

Future
In anticipation of a growing client and market base, the ability for high speed, centralized cloud storage should be considered. Additionally, as the program develops, multiple processing machines should be engaged to act as a render “farm” which would require a stable and high speed local area network.

Pilot Project

The work done with Carlson Vineyards will act as a pilot project to better develop all the varied components of VinoFlotRS. The objective is to provide a prescription map of affected vegetation and compare the traditional aerial agriculture application methods to the proposed site specific model outlined in this plan. This will be achieved by flying a UAV mounted with an NIR sensor to capture hundreds of overlapping images of the Carson vineyard which will then be orthorectified/orthomosaiced and analyzed through a remote sensing software tool. The exact date(s) of this mission are not yet determined, but will likely occur during the initial few weeks after vine leaf emergence begins in the early summer of 2015. It should be noted that this plan only covers an initial flight to obtain data suitable for determining trouble spots within a parcel. After a prescription map is produced, subsequent flights and data processing should be flown before and after aerial application in an effort to highlight the rapid revisit capabilities of UAS systems versus traditional satellite monitoring.

Personnel Definitions & Requirements

The personnel required to operate the VinoFlotRS are as follows:

UAV Pilot
The UAV pilot will be trained in basic FAA and NAS airspace regulations, flight planning, basic GPS knowledge and remote control robotics handling.

Software Interface Technician
This individual will have a concrete knowledge of GIS & GPS principals. Excellent software comprehension and trouble shooting skills are required. Comprehension of remote sensing principals and spectral vegetation signatures are required. Ability to manage complex workflows, involving numerous software and hardware procedures

is integral.

Database and System Administrator

This person will have an understanding of the above roles for the sake of managing the project data. They need not be experts or hold certification in any of the specialties. This person will need to understand database management practices, data input methodology and file transfer and image conversion techniques. This individual will assist in presentation and report creation.

Training Requirements & Certifications

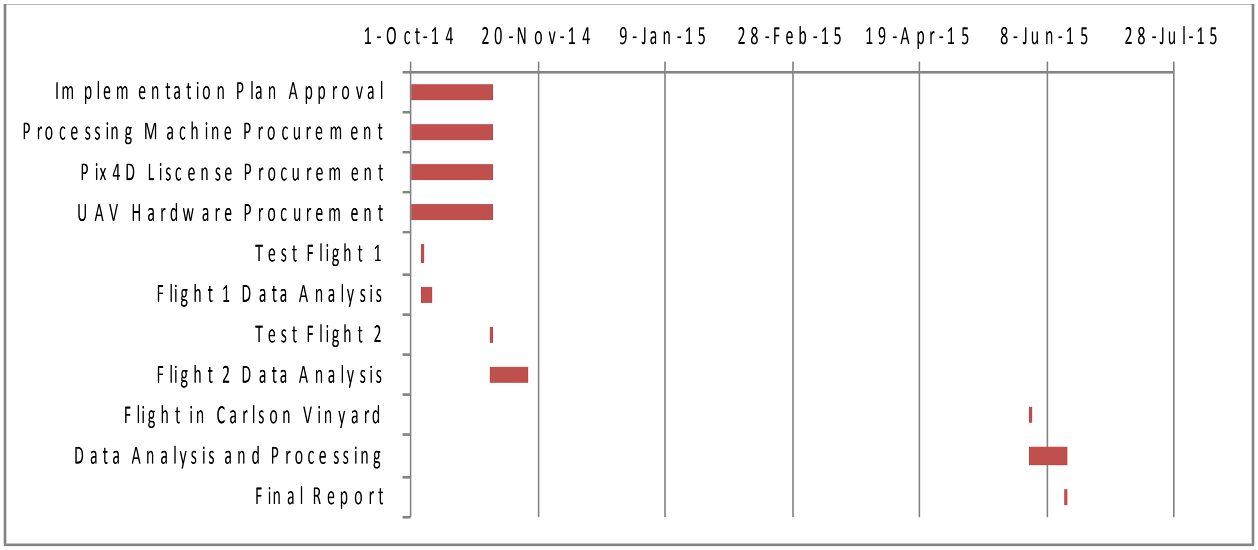
The UAV Pilot will be required to hold an FAA approved UAV pilot's certification. This will give a comprehensive understanding of aerodynamics, weather, flight patterns, in-field repairs and FAA rules and regulations in regards to the National Airspace (NAS).

Training Program

Aerial Data Systems in conjunction with the University of Denver GIS department, currently offer an array of certifications to prepare pilots for the functions associated with UAV flight within the National Airspace. A comprehensive UAV Pilot Certification includes:

- GIS Fundamentals
- UAV Core Training
- Hands-On Training
- FAA private Pilots written exam
- Multirotor flight training

Schedule



The schedule of this project is set to change due to environmental, technical, NAS and other unforeseen events.

Funding Needs & Resources

The major components that will require funding are:

Item	Description	Source	Cost
Computer	Processor: 4th Generation Intel® Core™ i7-4790 processor (8M Cache, up to 4.0 GHz) Operating System: Windows 7 Professional English 64bit (includes Windows 8.1 Pro 64bit License and Media) Memory[1]: 12GB[2] Dual Channel DDR3 SDRAM at 1600MHz Hard Drive: 1TB 7200 RPM SATA Hard Drive 6.0 Gb/s Video Card: NVIDIA® GeForce® GTX 745 4GB DDR3	www.dell.com	$ 1100.00 *(May qualify for academic pricing and discounts)*
MS Office 365	Includes MS Access database software	www.Microsoft.com	$150.00 *(1 year license as lease)*

Dual Screen 24" LCD Monitor Package	2 x 24" Dell Ultra Sharp LCD Monitors	www.dell.com	$ 869.00 *(May qualify for academic pricing and discounts)*
UAV Hardware	Hexacopter with GPS, Controller, Gimble	Aerial Data Systems	$30,000 *(It is likely that flight time can be leased with ADS and this cost would be considerably lower)*
Sony NEX 7	24 MP Camera with Interchangeable lens and filter options	www.amazon.com	$1240.00 *(It is likely this component would be included with the UAV resulting in lower cost)*
UAV Pilot Training Program	UAVs In Business + GIS	www.ads.com	$ 3000.00 *(It is likely this component would be included with the UAV lower costs)*
1 Year Pix4D Software License	Orthomosaic visualization software	www.pix4d.com	$ 3,300.00 *(May qualify for academic pricing and discounts)*
Ground Transportation, Lodging and Meals for UAV Pilot and GIS Software Engineer	2 nights in Palisade/Grand Junction Area with gasoline, food and lodging * Based on gasoline at $3.50/gallon for 250 miles at 24 MPG (Roughly $45 each way), double room rates in June at approximately $100.00/night, food per diem at $40.00 pp/day		$450.00
		Low Total	$2,719
		High Total	$40,109

Funding will be requested from the Department of the Environment and Natural Resources with the University of Denver. If pre-approval is given to this plan, a detailed budget proposal with partnership agreements and academic pricing will be developed for submittal. Part of the success of the pilot program will return value to the GIS department for furthering the education of UAV's in GIS, which is a rapidly emerging practice within the GIS profession.

Summary

One of the biggest concerns with this plan orbit the FAA's restrictive position on UAV's for commercial purposes. Under the 2012 FAA Modernization and Reform act,

Congress has included language requiring the FAA to expedite the safe integration of UAS into the national airspace by September 30, 2015. (Franson 2013) Much debate still surrounds the use of "drones", largely in part to the negative association embodied with their use in the military and unauthorized surveillance flights. Additionally, on the side of the debate regarding hobbyist use of UAVs, the regulations are vague or unknown. Earlier this year, the National Park Service was forced to restrict all UAS operations within the Park system after multiple hobbyists crashed their "drones" into landmark features within the Park.
Continued proof of safe flight, adherence to rules and regulations within the National Air Space, and proof of value are all factors if the September 2015 deadline is going to be met. With continued support, academic research and hardware development, commercial UAV flight seems less likely a matter of "if" but rather "when."

The literature surrounding the science of remote sensing -- and its enormous benefits in agriculture cannot be argued. The need for further development and refinement of UAS technology in agriculture is critical, especially with regards to "high value crops... in complex terrain or small fields where conventional aircraft may not be suitable or too expensive." According to University of California Professor, Ken Giles. (Franson 2013)The engineering success of reliable, cost effective UAV's is taking flight and we are noting the success of these combined technologies within the international community.

Aerial Data Systems in conjunction with University of Denver's GIS students continue to refine and prove the ideas presented within this plan. The groundwork for VinoFlotRS' successful implementation has been laid, and I propose this plan be reviewed by a group of industry professionals and practitioners for accuracy and viability.

Next Steps and Recommendations

Implementation of the VinoFlotRS technology hinges on the continued success and problem solving in regards to:

- Cost / benefit compared to current technologies
- Advanced sensors & payload capabilities on-board the UAV
- Safe UAV operation and how to minimize this risk
- Reliable and repeatable operation
- Approval for commercial use in the NAS

Appendix

Software Definitions

Software	Summary
Orfeo Toolbox	The Orfeo toolbox (OTB) was developed by the French space agency (CNES) in 2006. The toolbox is originally targeted at high resolution satellite images acquired by the Orfeo constellation: Pleiades satellites and Cosmo-Skymed but also handles a wide variety of sensors.
GRASS GIS	A free, open-source geographical information system (GIS) capable of handling raster, topological vector, image processing, and graphic data. GRASS is available on multiple platforms, including Mac OS X, Microsoft Windows and Linux.
TNT MIPS	TNTmips is a geospatial analysis system providing a fully featured GIS, RDBMS, and automated image processing system with CAD, TIN, surface modeling, map layout and innovative data publishing tools. It is available in a full featured software package or as free version, with limited project size. TNTmips is used worldwide for educational, self-learning, and small projects (e.g., archaeological sites, neighborhood planning, and precision farming).
MultiSpec Remote Sensing (© Purdue Research Foundation)	MultiSpec is a processing system for interactively analyzing Earth observational multispectral image data such as that produced by the Landsat series of Earth satellites and hyperspectral image data from current and future airborne and space borne systems such as AVIRIS. The primary objective of MultiSpec is as an aid to export the results of our research into devising good methods for analyzing such hyperspectral image data.
RoboGeo	RoboGeo is a geocoding software program which synchronizes a Global Positioning System track log with a collection of time-coded pictures.

Remote Sensing and Multispectral Terminology Definitions

Acronym	Name	Definition / Description / Value
IR	Infrared	Invisible radiant energy encompassing wavelengths of the electromagnetic spectrum just beyond the extent of the visual spectrum. They are most often used in thermal imaging and can been observed between 700 nm – 1 mm
NIR	Near Infrared	A subdivision within the IR range. The specific shape of the spectral signature observed can help determine not only difference in cellular structure of plant canopy, but also moisture content and other plant health conditions within the same species. NIR wavelengths are observed between 0.75–1.4 µm
SWIR	Short Wave Infrared	A subdivision within the IR range, SWIR

		typically is used in looking at moisture and water content. It can be useful to determine plant health during times of drought and also soil moisture content. SWIR wavelengths are also extremely sensitive toward thermal radiation, and can help detect areas of high heat when sunlight interference is absent. SWIR wavelengths are observed between 1.4-3 µm

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