February. 13, 2022
Dr. Mike Hegedus
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Putt From the Sky

RE: ENSC 405W/440 Requirements Specifications for Putt from the Sky

Dear Dr. Hegedus,

Attached to this document is Putt from the Sky's requirement specifications for our product: an automatic golf green-mapping system. This document outlines the foundational requirements we will strive to meet for mapping greens for competitive amateur and professional golfers. This system will allow users to map greens and calculate slopes automatically. We will create the system with a camera that produces a 2D surface map of the green area.

These requirement specifications outline our intended audience, and describe the various subsystems' requirements and proof-of-concept deliverables. Our company will reference this document to design, develop and test our product.

It is easy to forget that golf has not always included new technologies such as improvement irons, smart golf balls, foul-weather gear, and analysis to help golfers. Since the early days of golf, players have consistently attempted to revolutionize their sports equipment. However, despite the advanced technologies now used in golf, many professionals and top level amateurs still rely on handwritten green-mapping books. By Creating an automatic green-mapping system, we can help golfers spend less time inaccurately mapping the greens themselves and instead focus more effort on learning the nuances of each course and practicing specific shots.

Our team consists of five engineering students spanning a blend of different concentrations. We are a hard-working and dedicated team aiming to work passionately at anything we set out to do. Our primary contact is our CCO, Sam Kwon. He can be reached by email at ockwon@sfu.ca.

Requirements Specification

Putt from the Sky

ENSC 405: Company 4
Issued on February 13, 2022

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Abstract

This proposal details the outline and the requirements of our automatic golf-green mapping system. The document will begin by introducing our focus and aim for this product. It will also provide a brief background of the technologies we want to provide with Putt From the Sky. The proposal will outline the key elements of the project including a system overview, general, software, and hardware requirements. In addition, the proposal will also include the Engineering standards, Sustainability and Safety factors that the product must meet. The purpose of this document is to provide the audience a detailed understanding of the product, its focus, and its operation, while omitting the design details that will be determined and described at a later date.

Our system is composed of three main components: a data acquisition planner which will plan out our data capture plan for a green, a data acquisition device which will collect and store the raw data captured, and a processing unit that converts the raw data into a 2D topographic representation useful for our clients.

This document will conclude by indicating the planned deliverable for the proof of concept to be shown in April 2022.

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Glossary

The following table includes terms mentioned throughout the paper specific to our domain and industry.

Term	Definition
Green	A smooth grassy region with a hole in it located at the end of a golf hole
Topographic	Relating to the arrange and physical features of an area
Yardage Books/ Greens Books	A collection of notes used by golfers about the course they are currently playing. These books generally contain notes about the greens surfaces, hole layouts and relevant yardages.

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1 Introduction

Over the last 20 years the golf world has seen a substantial increase in the use of technology to help improve performance at the top level of the game. TRACKMAN® has revolutionized ball flight tracking, SHOTLINK® has generated an enormous wealth of golf shot data from the best players in the world and DECADE® has used this data to upend an outdated model of golf strategy. Despite these advances, many areas of golf continue to rely on unreliable and inaccurate practices. One area in particular are yardage books. Yardage books are a collection of notes and maps on each of the 18 holes on the golf course. These books often contain information such as distances to specific hazards, reminders for the player and maps of the green. These books are crucial to a player's success. At any competitive tournament you will see all the players referencing their own books to gather information affecting their next shot. With the exception of the professionals playing at the highest level, the green maps in yardage books are handwritten maps that usually lack detail and are not to proper scale.

Putt from the Sky is aiming to bring the advances in technology over the last 20 years to a wider audience. Our goal is to provide a digital and automated mapping solution that would allow players at all levels access to accurate and detailed maps of greens.

1.1 Background

Digital Elevation Models (DEM) were first introduced in the late 1900s and have been continuously improving over the last 40 years. Generating a DEM can be acquired through a variety of techniques and technologies, specifically photogrammetry, lidar, synthetic-aperture radar (SAR) and ground surveying to name a few[1]. Once generated a DEM can be used for many applications such as modeling water flow, rendering 3D visualizations, satellite navigation, surface analysis and many others [1]. The resolution and scale of a DEM dictates the applications it is useful for.

To date there is no publicly available information about DEMs being used for golf course topographic mapping. There are a limited number of solutions available for digitally mapping greens. The most notable of which is from StrackaLine® which was founded in 2007. Details on the method used by StracaLine are not easily available but appear to involve ground surveying to collect the topographical data.

1.2 Scope

This document outlines the high level system and functional requirements of the green mapping solution from Putt from the Sky. We have also broken down requirements by the component of the system they are a part of. Each requirement has been categorized into one of the 3 following categories: Proof-of-concept, Engineering Prototype and Production Version.

1.3 Intended Audience

This document is intended for the team members of Putt from the Sky, potential partners and the teaching team of ENSC 405W and ENSC 440, namely Dr. Mike Hegedus, Usman Ahmed, Chis Hynes and Ghazal Mirab.

1.4 Requirements Classification

The requirements in this document are classified using the following convention:

R [Section].[Subsection].[Requirement Number] - [Stage of Development]

The Section and Subsection values will come from headings in this document. The Stage of Development values will come from the following encoding table outline our 3 stages of development.

Code	Stage of Development
PC	Proof of Concept
PT	Engineering Prototype
FP	Final Production

Table 1.4.1 - Development Stage Encoding

The Proof-of-Concept requirements are those that will be met and demonstrated at the poster presentation at the end of ENSC 405W on April 12th, 2022. The Prototype requirements will be met and demonstrated at the posted presentation at the end of ENSC 440 which will be sometime in early August 2022. The Final Production requirements will be met before the device is put into production, the timeline for those requirements is still yet to be defined.

2 System Overview

The system will be used to create 2D elevation and slope grade maps of golf greens. As explained, these maps are very useful for pro and amateur golfers when they are approaching greens and putting on them. The system will provide highly accurate and detailed maps for the golfers who want to know specifics. Putt from the Sky will deliver these results with relatively low effort and high accuracy. The system will be portable to allow our data collection unit to be easily moved across the various greens collecting data at each location, which will be used to create our maps.

To capture the required data, an onsite processing unit will determine the positions and angles required for cameras or sensors to collect the necessary information. This information will be related to the green and the surrounding edges as these sections have relevance for an approaching golfer. The data will be transported back to our main processing unit where it will be sorted, filtered and parsed. This is preparation for the creation of our DEM, which will give the elevation and slope angles of each green from a course. The DEM will be converted to the 2D map that is often seen on the golf course today, but provide much more detail and accuracy than the common hand drawn maps used.. This post processing step will use a large amount of processing power and time.

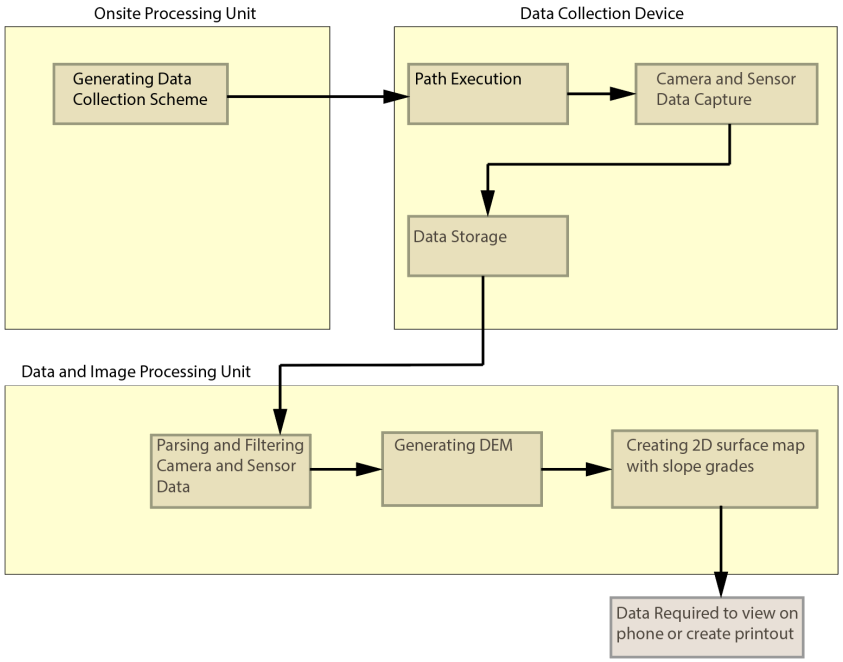

Figure 2.1.1 - System Block Diagram

3 General Requirements

In this section we will describe general requirements that summarize what our system will be capable of.

3.1 System Requirements

Requirement ID	Description
R 3.1.1 - PT	The system should be able to operate between the temperatures of 5.0°C and 35°C
R 3.1.2 - PT	The system should be able to operate with a wind of up to 20km/h
R 3.1.3 - PT	The system must include a data collection device, an onsite processing unit, a main processing unit and a user interface
R 3.1.4 - PT	The data collection system must be portable, less than 25 pounds and easy to move across a golf course
R 3.1.5 - FP	The processing unit will have sufficient battery life to process scans for 18 greens
R 3.1.6 - PT	The data collection device must be capable of controlling data collection parameters that impact the quantity and quality of the data
R 3.1.7 - PC	The data collection device and onsite processing unit will have sufficient battery life to complete a scan of 1 greens
R 3.1.7 - PT	The data collection device and onsite processing unit will have sufficient battery life to complete scans of 9 greens
R 3.1.7 - FP	The data collection device and onsite processing unit will have sufficient battery life to complete scans of 18 greens
R 3.1.8 - PC	The data collection device should be capable of storing all the data collected from 1 scan of a green
R 3.1.8 - PT	The data collection device should be capable of storing all the data collected from 9 scans of a green
R 3.1.8 - FP	The data collection device should be capable of storing all the data collected from 18 green scans
R 3.1.9 - FP	The user interface will allow a new surveyor to be trained to use the system in under 1 hour

Table 3.1.1 - System Requirements

3.2 Functional Requirements

Requirement ID	Description
R 3.2.1 - PC	A customized data collection plan can be created for any golf green
R 3.2.2 - PT	The processing unit can use the data collected to create a 2D map of the golf green which indicates the elevation changes and slope grades
R 3.2.3 - PT	The system must be capable of completing the data collection process of planning, execution, and processing one green within 15 minutes

Table 3.2.1 - Functional Requirements

4 Software Requirements

This section will outline the overall structure of the green mapping system from a software perspective. The software requirements are divided into two sections. First, general requirements that will determine what the software will do, then the processing requirements will define the computational capabilities.

4.1 General Requirements

Requirement ID	Description
R 4.1.1 - PT	The user should be able to plan and edit a data collection plan to be able to map differing green configurations
R 4.1.2 - PT	The user should be able to develop and edit the image and/or sensor acquisition plan to specify the amount of data collected
R 4.1.3 - PC	The user should be able to import the acquired data to the processing unit
R 4.1.4 - FP	The user should be able to modify the acquired data to exclude obvious data collection errors of the surface
R 4.1.6 - PC	The software will create a 2D topographic representation as output for the end user
R 4.1.7 - PC	The 2D topographic model produced by the system should have an accuracy of one slope point per 50 cm^2
R 4.1.7 - PT	The 2D topographic model produced by the system should have an accuracy of one slope point per 15 cm^2
R 4.1.7 - FP	The 2D topographic model produced by the system should have an accuracy of one slope point per 5 cm^2

Table 4.1.1 - Software General Requirements

4.2 Processing Requirements

Requirement ID	Description
R 4.2.1 - PC	The software will be able to run on x86 and ARM processors
R 4.2.2 - PC	The software will store the surface model generated

Table 4.2.1 - Software Processing Requirements

5 Hardware Requirements

This section will outline the various hardware requirements necessary to achieve the desired goal of Putt from the Sky. Our system consists of a data acquisition planner, data acquisition device and data processing unit. To operate our system we know we will need to be able to power our devices with batteries and provide a physical solution using a microcontroller to capture the necessary data. The details of how to accomplish this are yet to be determined but the following requirements outline what will be accomplished.

5.1 General Requirements

Requirement ID	Description
R 5.1.1 - PT	The device should have circuit protection from water splash and dust
R 5.1.2 - PC	The device should be controlled autonomously
R 5.1.3 - PT	The device frame should be made with strong and durable material enough to withstand a 1m fall
R 5.1.4 - PC	The device frame should have a flat surface to mount hardware components
R 5.1.5 - PC	The device should be able to take a stable picture for analysis
R 5.1.6 - PC	The device should have an indicator to know whether the power is on/off
R 5.1.7 - PC	The device should be light enough for an able-bodied adult to easily move around
R 5.1.8 - PC	The camera and sensors on the device should be fastened tightly to avoid components moving and reduce noise during data acquisition
R 5.1.9 - PC	The camera/ sensor component should have a high enough resolution to achieve an accuracy of one slope point per 50 cm^2 in the 2D representation
R 5.1.9 - PT	The camera/ sensor component should have a high enough resolution to achieve an accuracy of one slope point per 15 cm^2 in the 2D representation
R 5.1.9 - FP	The camera/ sensor component should have a high enough resolution to achieve an accuracy of one slope point per 5 cm^2 in the 2D representation
R 5.1.10 - PC	The data collected should be able to be transferred to the processing unit

Table 5.1.1 - Hardware General Requirements

5.2 Electrical Requirements

Requirement ID	Description
R 5.2.1 - PC	The microcontroller should have enough pins to connect with all other required hardware components
R 5.2.2 - PC	The microprocessor should have between 7 - 12V DC to operate
R 5.2.3 - PT	All input and output signals connected to microcontroller should be soldered to PCB
R 5.2.4 - PT	All solder points should have heat shrinks

Table 5.2.1 - Hardware Electrical Requirements

6 Safety and Sustainability

The safety and sustainability of the product is of the utmost importance. As a service operating on both public and private property with diverse surroundings it is important that the safety of operators and the public is a priority. Further, the team will be required to adhere to leading environmental standards concerning our chosen technology and its reusability. As we further define our solution our standards will be revised and become more specific.

Requirement ID	Description
R 8.1.1 - PC	Throughout operation of our data collection device, the device should not pose an unreasonable risk of injury and any reasonable risk must be mitigated to the best of our team's ability.
R 8.1.2 - PT	Data collected must be processed in accordance with Canada's *Personal Information and Electronics Documents Act*
R 8.1.3 - PT	At end of lifecycle, the data collection system must be able to be recycled as e-waste

Table 6.1.1 - Safety and Sustainability Requirements

7 Engineering Standards

To successfully build our solution and deploy it to Canadian markets we will need to ensure we are adhering to the standards and laws relevant for our project. Our system will involve collecting data on property that can be both private and public, our greens can also be located in a wide array of locations that pose various challenges and limitations. As we develop our solution we will be able to identify more specific standards that would apply to those technologies. We will meet all standards specified to the best of our ability.

7.1 General

Standard	Description
IEEE 29148:3.1	Requirements Engineering — Requirement Elicitation, Analysis, Specification, Validation et. al

Table 7.1.1 - General Engineering Standards

7.2 Software

Standard	Description
IEEE 29148:3:1	Requirements Engineering — Requirement Elicitation, Analysis, Specification, Validation et. al
ISO/TS 19159:2016	Geographic information — Calibration and validation of remote sensing imagery sensors and data
CAN/CSA-ISO/IEC/IEEE 12207:18	Systems and software engineering — Software life cycle processes

Table 7.2.1 - Software Engineering Standards

7.3 Hardware

Standard	Description
CAN/CSA-C22.2 NO. 61508-1:17	Functional safety of electrical/electronic/programmable electronic safety related systems — Part 1: General requirements
CSA C22.2 No. 0.23-15 (R2020)	General requirements for battery-powered appliances

Table 7.3.1 - Hardware Engineering Standards

8 Conclusion

Putt from the sky will benefit golfers of all levels by providing them detailed information of the putting greens. The system will provide this information in an accessible way that will give players a competitive edge out on the course. We will acquire and create accurate results directly from the course using a technical solution.

This system will require several components to achieve the main task of creating 2D representations of golf greens, including processing units and sensors. Some of these hardware components will require remote battery power to operate and need to work in varying weather conditions. Putt from the sky will be utilized at any golf course where it is permitted by owners, and will have the ability to be applied to any green regardless of shape or size.

The systems back end will be created to process data efficiently as the dataset gathered from golf greens will be large. The system user will be able to easily operate the system with a small amount of training and will be able to visualize the data as it moves through the post processing stages. The final result will provide easily accessible 2D maps that can be viewed on a smartphone or printed out.

9 Appendix

9.1 Proof of Concept Deliverables

In April 2022 we will demonstrate our Proof of Concept. The below section outlines what will be demonstrated during the poster presentation.

We intend to demonstrate that the core challenges we face in our project have been accomplished to some degree. Below we have outlined the requirements that will be demonstrated and how we plan to do so.

Our demonstration will consist of completing a scan of a randomly selected outdoor region of green mimicking a golf green in addition to demonstrating the results from a scan completed on a different day.

R 3.1.7 - PC, R 3.1.8 - PC, R 5.1.2 - PC, R 5.1.8 - PC- We completed a scan of a single region of green mimicking the size and shape of a golf green

R 3.2.1 - PC - We will select a random region mimicking a green shape and size to demonstrate the ability to customize our data acquisition plan

R 4.1.3 - PC - After scanning our green region we will import the data to our processing unit and begin the rendering process

R 4.1.6 - PC, R 4.1.7 - PC, R 5.1.8 - PC, R 5.1.9 - PC, R 5.1.10 - PC - Prior to the demonstration, we will map a real green surface and produce a 2D representation to demonstrate the functionality and accuracy

R 5.1.4 - PC, R 5.1.6 - PC, R 5.1.10 - PC, R 5.2.1 - PC, R 5.2.2 - PC - We will provide our data acquisition device for inspection to demonstrate its functionality and verify the listed requirements

R 8.1.1 - PC - We will outline the safety measures taken to ensure our device does not pose any unreasonable risk to those using it or around it.

10 References

[1] "Digital elevation model - Wikipedia", En.wikipedia.org, 2022. [Online]. Available: https://en.wikipedia.org/wiki/Digital_elevation_model. [Accessed: 13- Feb- 2022]