

Design

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# Introduction

**1. Climate Change**

One of the greatest questions facing modern society is whether or not life on Earth is sustainable. Sustainability is the ability to endure over time. If the environment is destroyed then life would not be able to endure. If this destruction doesn’t get reversed then life on Earth would eventually cease to exist.

This concern of sustainability is largely a result of deforestation. Deforestation is the removal of a forested region or large amount of trees in order to convert the land for farming. According to the World Resources Institute, more than 80 percent of the Earth’s natural forests already have been destroyed. Additionally, up to 90 percent of West Africa’s coastal rain forests have disappeared since 1900. Deforestation, in turn, causes additional effects such as drought and famine. Without trees and plants soil becomes arid and dry, making it much more difficult to plant there in the future. Additionally, trees are natural consumers of carbon dioxide, so a decrease in trees increases the amount of carbon dioxide in the air. This overabundance of carbon dioxide decreases the overall air quality.

The decline in air quality is a result of increased emissions of carbon dioxide in addition to the reduction of trees, which would naturally offset these emissions. Techniques used in these countries cause the deforested land to remain unusable for future crops since the land becomes devoid of nutrients necessary for cultivation. This means the population must move on and deforest additional land in order to plant more crops. There are several companies attempting to reverse the effects of deforestation and teach improved farming techniques to these communities. One such company is our sponsor, Clean Air Action Corporation.

**2. Clean Air Action Corporation (CAAC)**



Clean Air Action Corporation focuses on developing and implementing low-cost solutions to improve air quality and reduce air emissions of their clients. CAAC has implemented their own cost-effective solutions for several companies across the United States to help these companies meet air quality control standards or to reduce their environmental impact. These companies include large corporations such as General Motors, Shell Oil, and Ford Motors along with many other smaller companies.

CAAC helps these companies in one of two ways. Either they find innovative methods of reducing air quality concerns such as installing combustion controls, suggesting gasoline additives that reduce emissions, or upgrading distribution and transmission techniques. If they can’t provide their client with an innovative solution then they offer emission transactions to offset the harmful emissions.

An emission transaction is when the client purchases Carbon, Nitrogen Oxide (NOx), or VOC credits, depending on what emissions they want to offset. These credits are representations of the consumption effect of these gases. For example, trees are able to absorb Carbon; if a large amount of trees are planted then they can be used to offset Carbon emissions for the client. The trees can be quantified in order to verify how much Carbon they are absorbing. A client can then purchase a verified Carbon credit in order to compensate for emissions that they are producing.

These methods have been very successful for Clean Air Action Corporation’s clients. The Connecticut Resources Recovery Authority even noted that because of CAAC they “saved approximately $7 million in capital expenditures, achieved full compliance with the Nitrogen Oxide RACT standard on time, and, in fact, over the past eighteen months has surpassed the regulatory requirements and prevented an additional 220 tons of NOx from being emitted into the air, thereby creating approximately 200 Emission Reduction Credits for marketing to other facilities,” which shows the strength and impact of just one of CAAC’s solutions.

CAAC has helped clients attain emission controls, but has also identified another problem in underdeveloped nations. CAAC has helped reverse the problem of deforestation while also helping to secure their business model. Along with The Institute of Environmental Innovation, they formed one of the world’s largest and most successful reforestation and economic development programs, TIST.

**3. The International Small Group & Tree Planting Program (TIST)**

The International Small Group & Tree Planting Program, or TIST, focuses on empowering Small Groups of subsistence farmers in countries such as India, Nicaragua, Kenya, Tanzania, and Uganda to reverse the effects of deforestation, drought, and famine. TIST encourages farmers to form small groups that plant and care for large groves of trees. These groves are then verified and the Carbon consumed by the trees in the grove can be calculated as Carbon credits and then sold. 

Once a small group of farmers has been formed, they contact TIST indicating their intent to plant some trees. TIST sends a quantifier out to inspect the area, confirms the size of the grove, confirms that the land is owned by the group, and collects other relevant data (like what types of trees will be planted). The quantifier also takes multiple GPS perimeters of the grove for verification. Information such as area, perimeter, density, and shade coverage are calculated and stored. The quantifier then returns to an Internet cafe and uploads the grove data to the TIST database server.

Once a year, a quantifier will be sent to return to the grove and re-quantify the tract. This is called a secondary audit. Auditing involves first downloading the original tract data at an Internet cafe. Then the quantifier makes their way to the grove to collect the data once again. This data is verified with the original data to ensure that the size of the grove hasn’t changed and that the trees are healthy. After a grove is verified by TIST, the data collected can be used to calculate how much carbon dioxide the trees are absorbing, which is then converted to the virtual commodity of Carbon Credits. CAAC can then find buyers for these Carbon Credits.

This process provides income to both the quantifiers who are employed by TIST and the small groups that maintain the groves. Small groups receive small stipends for every tree that they continue to maintain. This encourages them to provide care and attention to ensure that the trees stay alive as well as providing income. TIST has been very successful in their endeavors to both provide income to local farmers and to help reforest areas in need. The TIST program began in only Tanzania with less than 40 small groups of 10-12 people each. Now TIST spans over 6 countries in East Africa, Asia, and Central America. TIST now includes over 60,000 participating members, and over 10 million trees have been planted as a result. On average, about 6,000 trees are being planted by TIST small groups every day.

**4. TIST’s Current Implementation**

In order to verify the Carbon Credits, quantification must occur. Quantification is where a TIST quantifier visits a grove tract, an area where trees will be grown, and audits it in order to gather information about the tract. The current TIST quantification process contains several inefficiencies. The quantification process includes:

1. Receiving tract data from the TIST servers via an Internet cafe. This data is stored on a Palm device.
2. The quantifier must then leave the Internet Cafe and head out for the actual grove, which can take a while.
3. Once the quantifier reaches the grove then they must gather the perimeter of the grove in GPS points as well as additional information that confirms the maintenance of the grove.
4. After this is completed, they must then return to the Internet cafe.
5. Once back at the Internet Cafe, the quantifier will sync their Palm Device and upload data back to the TIST Server.

This process is inefficient for several reasons. Initially it is apparent that requiring an Internet Cafe is a large time overhead. However, since there are little-to-no wireless Internet signals in most of these areas, they must commute to the local Internet Cafes. In addition to this, the actual gathering of data at the grove can be extremely time consuming. This is due to the current software used to collect the GPS locations, Acreage.

Acreage suffers from several faults that can lengthen the overall process considerably. These faults range from simple hindrances to causing a complete restart of the quantification process. In addition to this, the faults can’t be fixed because the developers of Acreage did not distribute any source code. The major implementation issues of Acreage include:

 **Figure 1:** TIST Data Flow

* Data Restriction
	+ 750 point limit.
* Error Prone Nature
	+ Fatal errors cause device crashes.
	+ Poor Bluetooth support causes numerous fatal errors.
* User Interface Flaws
	+ Buttons that have no function.
	+ Buttons without any user feedback/confirmation.
	+ Actions that have no reaction.
	+ No reversal of action on GPS collection.
		- To reverse accidentally added points the tract must be deleted and restarted.
	+ Awkward context switching between multiple applications.
	+ Navigation towards a tract is done by awkwardly manipulating GPS points.
* Extensive Training Requirement
	+ Training quantifiers to use the software takes multiple weeks due to the numerous amounts of errors that they may encounter as well as the above UI flaws.
* No Source Code / Documentation
	+ Acreage can not be extended in order to address issues, it must be used and handled as-is.

**5. GroveTrotter**

Our solution to the problems TIST is facing with their current software is to replace the functionality of Acreage, while addressing as many of these faults as possible. Our system, GroveTrotter (GT), must replace the existing functionality of Acreage while allowing for a more extensible system. Currently, Acreage has no source code available. GT will instead be highly documented and as modular as possible. This will allow future extensions or potential usage on different platforms as possible.

The functionality that GT needs to replace is important because if GT does not function at least as well as Acreage, or if GT is lacking key functionality, then it won’t be used. The functionality that GT will be able to accomplish can be summarized in these requirements:

* Integrate with current TIST work-flow and existing data.
	+ Import data stored by Acreage in the past.
	+ Export collected data to Pendragon Forms.
* External Protocols
	+ Connect to the Magellan GPS device via the Serial port.
	+ Connect to the VisionTac GPS device via Bluetooth.
* GPS Data
	+ Retrieve GPS data from device and store the data into tracts.
	+ Draw tract to the screen during collection.
	+ Store at least 2 grove tracts at a time.
	+ Convert Lat/Long GPS data to UTM coordinates.
	+ Use UTM coordinates to calculate area and perimeter.
* Reviewing Data
	+ View each tract that was collected.
	+ View 2 tracts simultaneously for comparison.
	+ Allow selection of which tract is best.

However, the functional requirements are not the only things to be considered in the creation of GroveTrotter. GT also needs to improve upon Acreage. Improvements over Acreage can increase the efficiency and decrease the overhead that Acreage currently causes. As mentioned in the above section, there are several faults that can be addressed. The way that we plan on addressing these faults are as follows:

* Data Restriction
	+ Storing the data as a database file rather than in fields removes the point limit.
* Error Prone Nature
	+ Improve error handling to reduce device failures.
	+ Using a Pendragon Forms software to handle GPS improves Bluetooth handling.
* User Interface Flaws
	+ Provide UI feedback for all actions.
	+ Add Undo functionality to remove erroneous GPS points.
	+ Contain logic underneath Pendragon Forms to provide the illusion of only a single application.
* Training Requirement
	+ Removing errors and remaining similar to the functional interface of Acreage should significantly reduce training and re-training requirements.
* Source Code / Documentation
	+ A major consideration is providing all source code in well-documented manner that facilitate future changes, extensions, or otherwise.

These decisions have been made in order to ensure that GroveTrotter retains the previous functionality of Acreage while also improving on several aspects. Some of the decisions made to accommodate these improvements do have limitations attached to them, such as utilizing the Pendragon Forms software to handle GPS communications. However, these decisions have several benefits that outweigh the costs. The manner in which our decisions and considerations come together is highlighted within our architecture.

**Architecture Overview**

Our architectural design is that of a Three Tiered architecture (3T); this is quite similar to the Model View Controller (MVC) architectural style where the Presentation Tier (top) acts as the view, the Logic Tier (middle) acts as the controller and the Data Tier (bottom) acts as the model. The difference between 3T and MVC is an explicit layering in which the presentation tier (view) can only access the data tier (model) via the logic tier (controller); see Figure 2.

 

**Figure 2:** GroveTrotter Architecture

**Module Descriptions**

**Presentation Tier**

Pendragon Forms: This is an application on our customer’s devices which provides both a user interface development environment via Microsoft Access and a communication bridge to the Logic Tier via a proprietary scripting language. The primary functions of Forms is providing user interface elements and allowing users to invoke logic via user interface controls - triggering scripts which invoke the Logic Tier. It also acts as a communication bridge between the GPS Custom Control and other Logic Tier elements.

* Primary user interface provider.
* Handles user input events.

Custom Rendering: Rendering arbitrary sets of data, such as GPS tracts, are outside the capabilities of Pendragon Forms; ergo, custom rendering is performed by GroveTrotter logic via Palm API rendering functionality.

* Secondary user interface provider.

**Presentation-Logic Bridge**

Pendragon Script: Since Forms uses a proprietary scripting language, its method of communication with the Logic Tier is simply a local memory address; anything can be placed in this memory address, but for communication purposes XML strings will be used as indicators of required action.

* Propagates action requests downwards (Presentation to Logic).
* Communication between GPS Custom Control and XML Parser.
* Invokes GPS Custom Control and XML Parser.
* Invoked by user input events via Pendragon Forms.

Palm API: The rendering capabilities of the Palm API act as a bridge between the Display Module in the Logic Tier and the user view of the Presentation Tier.

* Propagates rendering commands upwards (Logic to Presentation).
* Invoked by the Display Module.

**Logic Tier**

The elements within the Logic Tier are to be implemented in C and perform the necessary actions based on messages received from the Presentation Tier; these elements include GPS Custom Control, XML Parser, Command Manager, Database Module and Display Module.

GPS Custom Control: This logical element was not developed by Team Hakuna Matata nor can any additions or changes be made to it as it was developed by Pendragon Software Corp and packaged with Pendragon Forms. The GPS Custom Control handles GPS device connection of a specified port and can be queried by Pendragon Script for GPS data in XML form. The full specification of this control can be found at: http://pendragonsoftware.com/forms3/gpscontrol.html.

* Invoked by Pendragon Script.
* Populates XML string with GPS data.

XML Parser: This logical element is invoked by Pendragon Script accompanied by an XML message which indicates what action should occur.

* Invoked by Pendragon Script.
* Discovers required action based on XML tags.

The XML tags which indicate required action are as follows:

* <ADD>
	+ User needs to collect a new GPS point.
* <UNDO>
	+ User needs to remove the previous GPS point.
* <CREATE>
	+ User needs to collect a new tract.
* <DUMP>
	+ User needs to export their tract data to CSV.
* <IMPORT>
	+ User needs to import data.
* <VIEW>
	+ User needs to view a single tract or compare two tracts.
* <CLEAR>
	+ User needs to clear session data.

Supplemental XML tags for indicating specifics of the actions are as follows:

* <ONE>, <TWO>, <PRIM>, <SEC>
	+ Indicates which tract database to effect with the supplemented action.
* <ISTART>, <ICONT>, <IEND>
	+ Indicates the start, continuation and end of an import; necessary as imports can take up to twenty-five continuations as the data is too large to send all at once.
* <GPS>, <LAT>, <LONG>
	+ Indicates GPS data and data elements created by the GPS Custom Control.

Command Manager: Invokes sub-routines within the Database Manager and Display Manager based on XML Parser invocation and supplemental XML tags.

* Invoked by the XML Parser.
* Invokes the Display Module and Database Module.

Database Module: Acts as the gate keeper to the Palm Database and an abstraction of ugly Palm API calls. Performs actions such as adding data points, removing data points, querying data for rendering operations, etc.; no other logical component should be able to access the Local Database without going through the Database Manager.

* Invoked by the Command Manager.
* Accesses the Palm Database(s) in the Data Tier via Palm API calls.
* Mutates the Palm Database(s) in the Data Tier via Palm API calls.

Display Module: Performs calculations such as converting GPS data to screen coordinates and performs rendering operations such as clearing the screen and rendering a tract.

* Invoked by the Command Manager.
* Performs conversion calculations.
* Performs rendering operations via Palm API calls.

**Logic-Data Bridge**

Palm API: To access and mutate Palm Databases, Palm API calls must be used.

* Invoked by the Database Module.
* Grants access and mutation to Palm Database(s) in the Data Tier.

**Data Tier**

Palm Database: Best practice in Palm development is the use of database files for storing large quantities of data. This data is stored locally as a Palm Database file (.pdb). The contents of local databases include GPS tract points along with necessary rendering data.

* Accessed and mutated by the Database Manager via Palm API calls.
* Stores local GPS tracts and rendering data.
* Best-in-practice data storage technique.

**Implementation Plan**

Our implementation plan has been separated into large modules in order to complete core functionality. This was done so that we could use an agile design methodology. The modules were adaptable in order to change as new challenges approached. The timeline we follow is shown in the Figure 3.



**Figure 3:** Development Timeline

**Milestone 1 (Friday, February 18) Requirements & Design**
Complete preliminary requirements and design in order to prepare for the future implementation. Highlights functional requirements, needs, wants, and sample architectures.

**Milestone 2 (Wednesday, March 16) Database Module**
Develop modules to store and manage data for multiple candidate tracts and a secondary audit tract. Database needs to be accessible in order to modify the data or attach it for exporting. This module also includes importing and exporting data from Pendragon Forms.

**Milestone 3 (Wednesday, April 6) Command Manager**
Command Manager needs to set a protocol for messages that it can interpret and then call the appropriate sub-commands in either the Display or Database modules.

**Milestone 4 (Wednesday, April 13) Pendragon Forms Scripting**
Create the UI and UI flow via Pendragon Forms as well as enabling the sending of messages to the external GroveTrotter application.

**Milestone 6: (Wednesday, April 20) Display Module**
Develop Grove Tracts display module to manage, edit and delete grove tracts as well as plotting module tract information.

**Milestone 8: (Wednesday, May 4) User Testing**
Conduct Usability Analysis, including User Testing and Performance metrics. Change application as necessary to meet Usability and Performance requirements.

**Milestone 9: (Thursday, May 12) Delivery**
Address any remaining errors or issues with the application, add finishing touches to application.

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