yoGERT GIS Toolbox

Capstone 4G06

Software Requirements Specification

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Modified Volere Template

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Table 1: **Revision History**

Date	Version	Notes
October 5, 2022	1.0	Longwei: Sec 1,8; Moksha: Sec 2.1,8; Smita: Sec 2.1,8; Abeer: Sec 2.2,1.4,1.5; Niyatha: Sec 3; Nicholas: Sec 4,5,6,7
Nov 23, 2022	1.1	Longwei: Add new NFRs based on the feedback; Abeer: updated many parts of the document based on rubric feedback.
Feb 3, 2023	1.2	Abeer: updated FR and NFR to clarify project's scope and incorporated the peer feedback.

1 Naming Conventions and Terminology

term	description
Activity Locations (ALs)	ALs are trip stops
ArcGIS	an online geographic information system software that is command line based system for manipulating and visualization data.
CSV/.csv	Comma Separated Values is a file type that contains large amounts of data separated by commas.
Episode	Session
Episode Behaviour Analysis (EBA)	Analysis an episode with the following attributes: transportation mode, speed, direction, duration, distance, and trip trajectory.
GERT	GIS-based episode reconstruction toolkit
GIS	Geographical Information Systems
GPS	Global Positioning Systems
Mode Detection (MD)	Detection of transportation type being used
Point	location coordinate with time stamp.
Potential Activity Locations (PALS)	PALS are potential trip stops
Route	Object path to get from position A to position B
~~Route Choice Analysis (RCA)~~	~~Analyzes route selection from point a to point b~~
Segment	Group of GPS Points combined based on episode attributes .
.shp	geospatial data format files
Session	Object's activity history quantified by GPS points which is a collection of traces.
Trace	Collection of GPS points for one travel behaviour/one user. Each trace is not connected to another.
~~Time Use Diary (TUD)~~	~~records of continuous events and actions through a particular period of time (usually 24 to 48 hours)~~
Trip	GPS points represents an object moving to a different position.

2 Project Drivers

2.1 The Purpose of the Project

Many researchers and companies want to gain information about how people travel, whether that be through the use of personal automobiles, public transit, biking, or even walking. This is because through this data you can derive insights to help inform decisions including but not limited to: public transit design, ad placement, and investment in infrastructure.

When the original GERT toolbox was created, there already existed software to match GPS traces to transportation networks, but the tools suffered had limited usability and functionality [1]. The GERT toolbox solved this problem by extending functionality, and making the toolbox better suited for multiple input data types. Although the project was a success, it was largely inaccessible due to its reliance on the proprietary and expensive ArcGIS software.

The purpose of the project is to re-engineer the toolbox with a focus on on transferability, modularity, and scalability and remove reliance on any proprietary software so it can be used by a wider audience.

2.2 The Stakeholders

2.2.1 The Client

Our main client is Dr. Antonio Paez, a professor in the School of Earth, Environment Society at McMaster University.

2.2.2 The Customers

Researchers who are interested in matching GPS data to transportation networks in the context of travel episodes and route estimation analysis. Furthermore, companies who are interested in matching GPS data for business analysis and managements.

2.2.3 Other Stakeholders

Developers, testers, and operators of this project. Also, the capstone professor, Dr. Smith, ad the marking teacher assistants are stakeholders as they are provide feedback and assess the progress of the project.

2.3 Mandated Constraints

- This project must be completed by the end of April, 2023.
- The final product must be able to run on personal laptops and desktops that uses Linux, Windows, and MacOS operating systems with Python 3 pre-installed. The software works with recent versions of operating system that date from 2018-2022.
- The software requires pre-installed python libraries. These libraries are geopandas, pandas, and kepler.
- The user will input data points via the software using csv files. This is to keep inline with the original implementation. The software will be processing these csv input filees.

2.4 Relevant Facts and Assumptions

- ~~As the project is built in python, we assume that the user should be familiar with python.~~
- Assume users are familiar with CSV files. In other words, users should be able to create such files with sufficient information(e.g. latitude and longitude of the points to be dealed with) for the system to generate data.
- Assume users are familiar with map files such as .shp.

3 Functional Requirements

3.1 The Scope of the Work and the Product

3.1.1 The Context of the Work

The current GERT toolbox is dependent on ARCGIS libraries including arcgisscripting and arcpy. The toolbox currently supports the processing inputted GPS files into

- compatible data types
- accurate and fast choice model estimations'
- extracted travel episodes and information on trips
- potential activity locations and stops

The toolbox processes millions of GPS data points quickly making episode information generation for a large movement session.

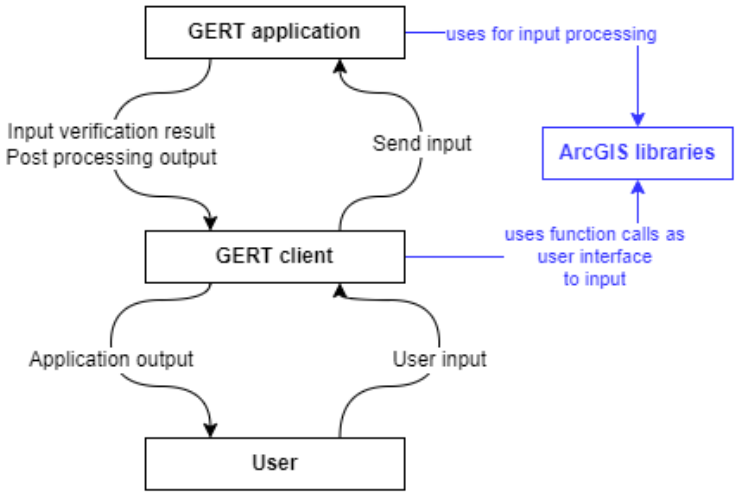

Figure 1: Context Diagram for Existing Toolbox

The PyERT toolbox is the new open source toolbox that will include some of the processing functionality of the GERT toolbox without the user

of ArcGIS libraries. The PyERT will support processing inputted GPS files, CSV formatted, into

- compatible data types
- extracted travel episodes and information on trips
- potential activity locations and stops

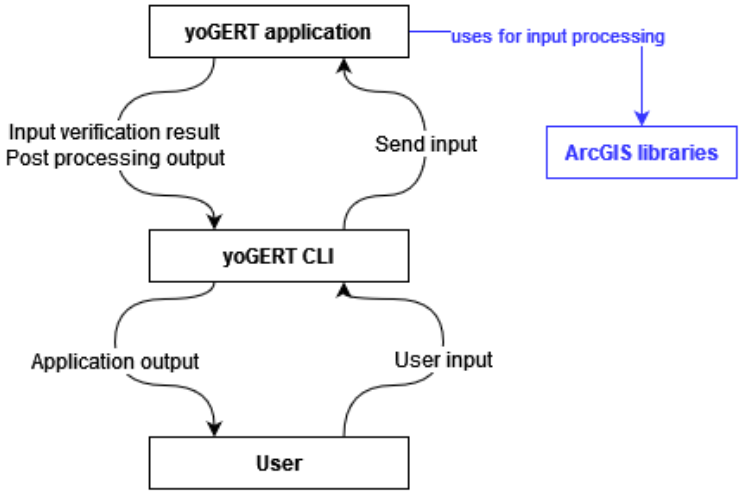

Figure 2: Context Diagram for New Toolbox

3.1.2 Work Partitioning

Event Name	Input and Output	Summary
User requests processed gps data	Input: CSV file Output: CSV file	System outputs normalized GPS data
User requests GPS episode extraction and mode detection	Input CSV file of gps data, Output: CSV file of of GPS episodes	System outputs episode extraction and mode detection CSV file
User requests trip segments based on processed data	Input: CSV file, Output: .shp file	System outputs GPS trip trajectories in a readable format for the user
~~User requests route choice sets~~	~~Input: .shp file, Output: .shp file~~	~~System outputs route choice sets and allows filtering based on set qualifiers~~
User requests activity locations	Input: CSV file, Output: .shp file	System outputs activity locations(stops) .shp file
User requests route choice analysis variables	Input: .shp file, Output: .shp file	System outputs the route choice analysis variables along with justification for user perusal
User requests activity location identification	Input: CSV file, .shp file, .shp file, Output: .shp file	System outputs Activity location with Land Use and potential activity locations information in .shp file.

Table 2: Work Partitioning Diagram[1]

3.1.3 Product Boundary

The product boundary diagram was omitted due to redundancy. There are no external services/data sources that the toolbox interacts with. The toolbox may interact with an external open source GIS software, however that is a stretch goal, and should not be factored into initial designs.

3.1.4 Product Use Case List

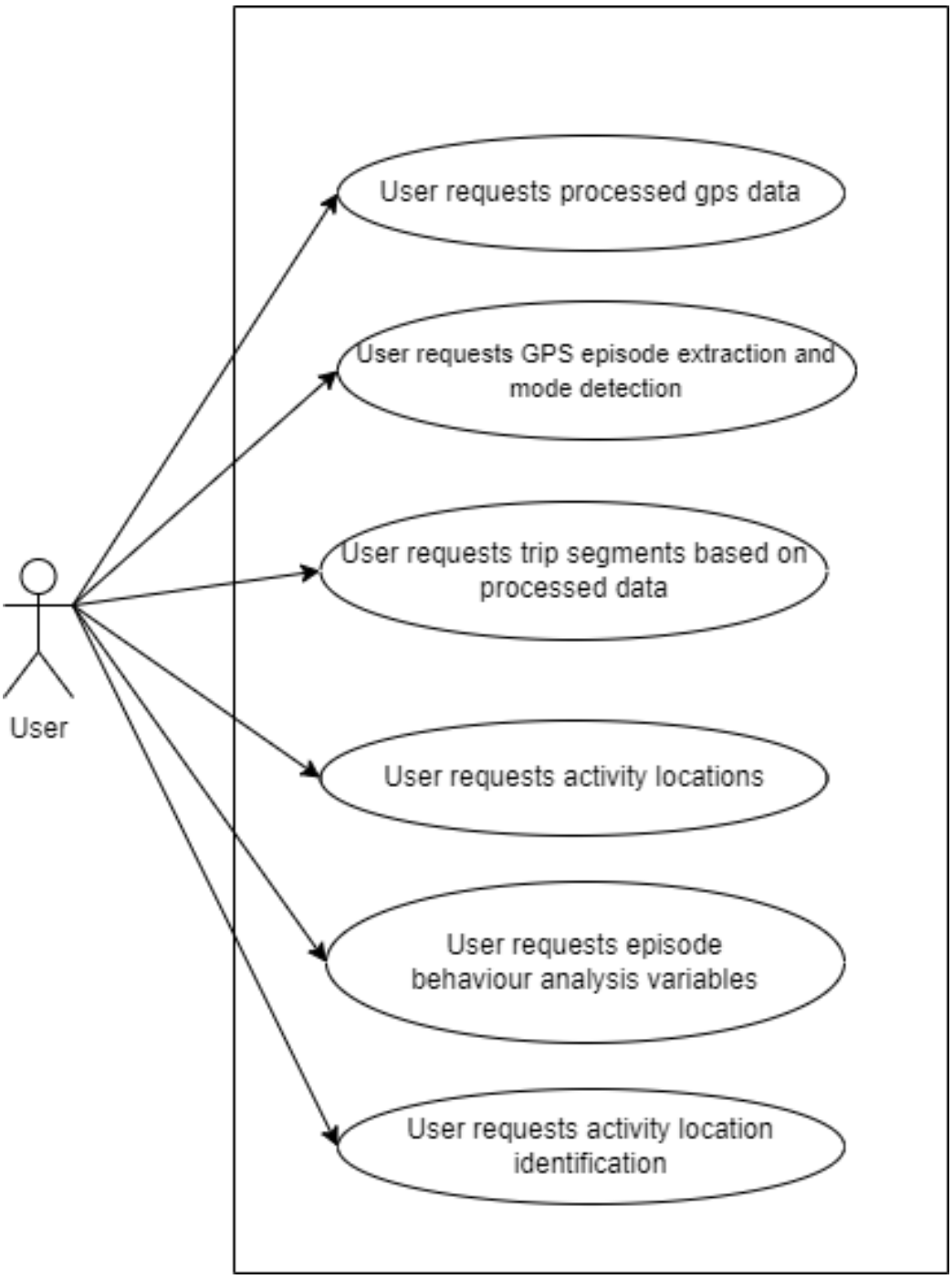

Figure 3: Use Case Diagram for Toolbox

3.1.5 Individual Product Use Cases

UC1: **Name**: Process GPS data
Trigger: User requests processed GPS data of different traces
Preconditions: User has a CSV file of unprocessed GPS data
Stakeholders: User, Professor, Geospatial Analyst
Actors: User, Toolbox
Outcome: System outputs a CSV file of normalized GPS data

UC2: **Name**: Episode extraction and mode detection
Trigger: User requests GPS episode extraction and mode detection
Preconditions: User has already requested processed GPS data
Stakeholders: User, Professor, Geospatial Analyst
Actors: User, Toolbox
Outcome: System presents user with a CSV file including all the episodes and mode detection data in a CSV file

UC3: **Name**: Trip segment generation
Trigger: User requests trip segments
Preconditions: System has preprocessed input GPS data, user may optionally input TUD (time use diary) episodes
Stakeholders: User, Professor, Geospatial Analyst
Actors: User, Toolbox
Outcome: ~~.shp~~ .csv file with GPS trip trajectories in a readable format for the user

UC4: **Name**: ~~Route choice set generation~~
Trigger: ~~User requests route choice sets~~
Preconditions: ~~System has preprocessed input GPS data and generated trip trajectories file~~
Stakeholders: ~~User, Professor, Geospatial Analyst~~
Actors: ~~User, Toolbox~~
Outcome: ~~.shp file with route choice sets~~

UC5: **Name**: Activity locations
Trigger: User requests activity locations

Preconditions: System has preprocessed input GPS data and extracted episodes and mode detection CSV file
Stakeholders: User, Professor, Geospatial Analyst
Actors: User, Toolbox
Outcome: System generates ~~.shp~~ .csv file of activity locations (stops)

UC6: **Name**: ~~Route choice analysis~~ Episode behaviour analysis variable generation
Trigger: User requests ~~route choice analysis~~ episode behaviour analysis variables
Preconditions: System has preprocessed input GPS data and generated trip trajectories file
Stakeholders: User, Professor, Geospatial Analyst
Actors: User, Toolbox
Outcome: .csv file containing ~~Route choice analysis~~ Episode behaviour analysis variables and variable justification

UC7: **Name**: Activity location identification
Trigger:User has requested activity location identification
Preconditions: System has preprocessed input GPS data, extracted episodes and mode detection CSV file, and then extracted activity location ~~.shp~~ .csv file, as well as user has inputted land use ~~.shp~~ .csv file potential activity location ~~.shp~~ .csv file
Stakeholders: User, Professor, Geospatial Analyst
Actors: User, Toolbox
Outcome: System outputs a ~~.shp~~ .csv file of activity location with land use and potential activity location information ~~.shp~~ .csv file

3.2 Functional and Data Requirements

R1: The system shall allow users to upload GPS data in ~~standard format~~ CSV file format.

- **Requirement Type**: Functional
- **Rationale**: The user needs to upload GPS data for processing.

- **Fit Criterion**: The system successfully uploads the file and notifies the user.
- **Priority**: 5
- **Event**: UC1
- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 5
- **Conflict**: None
- **Planned Date**: November 14, 2022

R2: The system shall process GPS data points of multiple traces.

- **Requirement Type**: Data
- **Rationale**: System must analysis activity data.
- **Fit Criterion**: The system outputs GPS data points as latitude, longtude, and time variables.
- **Priority**: 5
- **Event**: UC1
- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 5
- **Conflict**: R1.
- **Planned Date**: November 14, 2022

~~R3~~ : ~~The system shall accept TUD data points.~~

- **Requirement Type**: ~~Data~~
- **Rationale**: ~~System must analysis activity data.~~
- **Fit Criterion**: ~~User successfully upload TUD data in standard format such as CSV.~~
- **Priority**: ~~5~~
- **Event**: ~~UC3~~
- **Customer Satisfaction**: ~~5~~
- **Customer Dissatisfaction**: ~~5~~

- **Conflict**: ~~None~~
- **Planned Date**:~~November 14, 2022~~

R3: The system shall produce output in a ~~standard~~ CSV transferable file format and HTML file format for interactive maps ~~analyzing display format~~.

- **Requirement Type**: Functional
- **Rationale**: User must read data and re-use output data across multiple applications.
- **Fit Criterion**: System successfully outputs data in standard format such as CSV.
- **Priority**: 5
- **Event**: UC1-7
- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 4
- **Conflict**: None
- **Planned Date**: November 14, 2022

R4: The system shall use longitude, latitude, and time variables from GPS data points.

- **Requirement Type**: Data
- **Rationale**: System must use general variables to make computations and produce analysis.
- **Fit Criterion**: System successfully extracts longitude, latitude, and time information from inputs.
- **Priority**: 5
- **Event**: UC1-7
- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 5
- **Conflict**: R2
- **Planned Date**: November 14, 2022

R5: The system shall extract episode attributes including speed, duration, direction, distance, ~~change in direction, acceleration,~~ and status points from GPS data points for each trace.

- **Requirement Type**: Functional
- **Rationale**: System must categorize data points to useful information for the user to read.
- **Fit Criterion**: System successfully produce reports of episode attributes.
- **Priority**: 5
- **Event**: UC2
- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 5
- **Conflict**: R4, 19
- **Planned Date**: November 14, 2022

~~R6~~ : ~~The system shall extract episode attributes including duration, distance, and change in trajectory from TUD data points.~~

- **Requirement Type**: ~~Functional~~
- **Rationale**: ~~The system needs to validate analysis of GPS points.~~
- **Fit Criterion**: ~~System successfully produce reports of episode attribute.~~
- **Priority**: ~~5~~
- **Event**: ~~UC3~~
- **Customer Satisfaction**: ~~5~~
- **Customer Dissatisfaction**: ~~4~~
- **Conflict**: ~~R3~~
- **Planned Date**: ~~November 14, 2022~~

R6: The system shall classify extracted trace into different types including stop, ~~car~~ drive, and walk ~~, bus, and other travel episodes~~.

- **Requirement Type**: Functional

- **Rationale**: User need to understand travel behaviour of the object's episode.
- **Fit Criterion**: System successfully classify known episodes into correct episode types.
- **Priority**: 5 **Event**: UC2
- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 5
- **Conflict**: R6,7,19
- **Planned Date**: ~~November~~ February 14, 2022

R7: The system shall decompose episode trace into output segments of type stop and trip.

- **Requirement Type**: Functional
- **Rationale**: User need to understand the object's behaviour during a segment.
- **Fit Criterion**: System successfully categorize a moving object in a trip segment and a static object in stop segment.
- **Priority**: 5
- **Event**: UC3
- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 5
- **Conflict**: R8,19
- **Planned Date**: ~~November~~ February 14, 2022

R8: The system shall identify trip trajectory for extracted trip segments.

- **Requirement Type**: Functional
- **Rationale**: The system needs trip trajectory for ~~route~~ object's behaviour analysis.
- **Fit Criterion**: The system successfully identifies the ~~change in the~~ different trajectories when the object changes direction.
- **Priority**: 5

- **Event**: UC3,4
- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 5
- **Conflict**: R9
- **Planned Date**: ~~November~~ February 20, 2022

R9: The system shall identify activity locations **for each trace** based on the episode attributes ~~of the route to the stop~~ from the start point to the end point.

- **Requirement Type**: Functional
- **Rationale**: The system needs location types for land use and road network analysis.
- **Fit Criterion**: The system successfully identifies available activity locations ~~a high activity locations and low activity locations~~.
- **Priority**: 5
- **Event**: UC5,7
- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 5
- **Conflict**: R6,7,19
- **Planned Date**: ~~November~~ February 14, 2022

R10: The system shall generate ~~RCA~~ EBA variables ~~based on trip trajectory~~ after the episode segment generation.

- **Requirement Type**: Functional
- **Rationale**: The system needs to define ~~route choice behaviour~~ a data set to describe the object's movement.
- **Fit Criterion**: The system successfully defines variables to describe the ~~route~~ object's movement from position A to position B.
- **Priority**: 5
- **Event**: UC4,6
- **Customer Satisfaction**: 5

- **Customer Dissatisfaction**: 4
- **Conflict**: R10,19
- **Planned Date**: ~~November~~ February 14, 2022

R11: The system shall store ~~RCA~~ EBA data set.

- **Requirement Type**: Data
- **Rationale**: The system needs to track the ~~RCA for descriptive route~~ EBA variables for descriptive movement analysis.
- **Fit Criterion**: System successfully stored multiple instances of ~~RCA~~ EBA variables.
- **Priority**: 4
- **Event**: UC4,6
- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 4
- **Conflict**: R12
- **Planned Date**: ~~November~~ February 14, 2022

R12: The system shall automate routes from position A to position B based on ~~RCA~~ EBA set for each extracted trace.

- **Requirement Type**: Functional
- **Rationale**: The user wants to request routes from position A to position B.
- **Fit Criterion**: The system produce a mapped route from position A to position B.
- **Priority**: 4
- **Event**: UC6
- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 4
- **Conflict**: R13,19
- **Planned Date**: ~~November~~ February 14, 2022

R13: The system shall ~~allow users to select~~ output alternative routes to the user upon their request of bike ~~options for~~ automated route ~~requests~~. System shall accept customized options that include shortest route by distance and shortest route by time.

- **Requirement Type**: Functional
- **Rationale**: The user needs the option to request an alternative route.
- **Fit Criterion**: The system successfully maps an alternative route with selected options such as shortest distance.
- **Priority**: 4
- **Event**: UC6
- **Customer Satisfaction**: 4
- **Customer Dissatisfaction**: 4
- **Conflict**: R13,19
- **Planned Date**: ~~November~~ February 14, 2022

R14: The system shall store activity location ~~identifications~~ descriptions.

- **Requirement Type**: Data
- **Rationale**: The user needs to search ~~for specific type of~~ through the activity location information to analyze land use.
- **Fit Criterion**: The system successfully stores data and notifies user.
- **Priority**:4
- **Event**: UC5,7
- **Customer Satisfaction**: 4
- **Customer Dissatisfaction**: 2
- **Conflict**: R11
- **Planned Date**: ~~November~~

R15: The system shall classify ~~RCA patterns by route~~ trace episodes by ~~purpose~~ by movement behaviour; which includes details on peak times, peak locations, and stop behaviour.

* **Requirement Type**: Functional
* **Rationale**: The system needs to define trip ~~purpose~~ behaviour attributes.
* **Fit Criterion**: The system successfully defines purpose of a route from position A to position B.
* **Priority**: 2
* **Event**: UC4,6
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 2
* **Conflict**: R16,13,19
* **Planned Date**: ~~November~~ February 20, 2022

R16: The system shall ~~allows requests~~ output files for activity location description ~~by filtering~~ to the user upon their request.

* **Requirement Type**: Functional
* **Rationale**: The user needs the options to search ~~for specific type of~~ through the activity location information.
* **Fit Criterion**: The system successfully outputs relevant ~~types of~~ activity locations to what the user requested.
* **Priority**:4
* **Event**: UC5,7
* **Customer Satisfaction**: 4
* **Customer Dissatisfaction**: 2
* **Conflict**: R16
* **Planned Date**: ~~November~~ February 14, 2022

R17: The system shall ~~allow users to request~~ output trip segments' description for a given GPS data set to the user upon their request.

* **Requirement Type**: Functional
* **Rationale**: The user needs to review intermediate analysis steps.
* **Fit Criterion**: The system successfully produce trip segment reports.
* **Priority**: 5
* **Event**: UC3

- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 5
- **Conflict**: R9
- **Planned Date**: ~~November~~ February 14, 2022

R18: The system shall ~~allow users to request~~ output episode descriptions of GPS inputs to the user upon their request.

- **Requirement Type**: Functional
- **Rationale**: The user needs to access intermediate details about episode attributes.
- **Fit Criterion**: The system successfully produces a ~~standard output~~ CSV file with the requested details.
- **Priority**: 5
- **Event**: UC2
- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 5
- **Conflict**: R6-8
- **Planned Date**: ~~November~~ February 14, 2022

R19: The system shall identify different traces from GPS data set.

- **Requirement Type**: Functional
- **Rationale**: The user needs to be able to analyze multiple traces for each input GPS file.
- **Fit Criterion**: The system successfully produces identification number for each trace.
- **Priority**: 5
- **Event**: UC1
- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 5
- **Conflict**: R2-4
- **Planned Date**: February 14, 2022

4 Non-functional Requirements

4.1 Look and Feel Requirements

4.1.1 Appearance Requirements

NFR1: The system shall be responsive on all desktop or laptop devices it is run on.

- **Rationale**: The system needs to be fully visible and functional for a range of screen widths and heights ~~like an iPad vs a computer~~.
- **Fit Criterion**: The system's primary functionality as depicted by the user interface is not skewed based on the device it is run on.
- **Priority**: 5
- **Event**: UC1-7
- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 5
- **Conflict**: None

NFR2: The system shall display episodes through informative descriptions.

- **Rationale**:
- **Fit Criterion**: The system is successful if it shows appropriate images of the travel along with appropriate descriptions of its objects on its route.
- **Priority**: 5
- **Event**: UC1
- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 5
- **Conflict**: NFR3,4,6; R8

4.1.2 Style Requirements

NFR3: The system shall display text in font size not less than 10pt ~~a modern design templates for its user interface~~.

* **Rationale**: The system needs to be catered for different user groups with different sight abilities. ~~age groups. Considering typical ages 18 onwards, a modern aesthetic would be more appealing~~.
* **Fit Criterion**:The system is successful if its text clear to read 60cm from the display screen ~~incorporates modern design frameworks for design of its GUI~~.
* **Priority**: ~~5~~ 4
* **Event**: UC1-7
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: ~~5~~ 4
* **Conflict**: NFR2,4,6; R8

4.2 Usability and Humanity Requirements

4.2.1 Ease of Use Requirements

NFR4: The system must be intuitive in terms of its design.

* **Rationale**: The system must be designed such that its layout of selecting various options ~~(like adding more stops)~~ and position of header descriptions are understandable without a need of additional help.
* **Fit Criterion**: The system is successful if the user is able to interact with the system using one function without customer support.
* **Priority**: ~~5~~ 3
* **Event**: UC1-7
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 5
* **Conflict**: NFR2,3,6; R8

4.2.2 Personalization and Internalization Requirements

NFR5: ~~The system shall provide a feedback option.~~

* **Rationale**: ~~The system needs to be updated based on user demand and suggestions.~~

* **Fit Criterion**: ~~The system is successful if it provides a feedback option for users and protects the anonymity of the user for their feedback.~~
* **Priority**: ~~5~~ 1
* **Event**: ~~UC3-7~~
* **Customer Satisfaction**: ~~5~~
* **Customer Dissatisfaction**: ~~5~~
* **Conflict**: ~~None~~

4.2.3 Learning Requirements

NFR6: The system's functionality must be easy to understand with in-built product descriptions.

* **Rationale**: The system must be easy to understand for any user on their first use as long as they fall under the appropriate age group of 18+ years ~~onwards and follow the instructions presented during use~~.
* **Fit Criterion**: The system provides information dialogues for complex components of the system that users are able to follow the instructions presented during use.
* **Priority**: 5
* **Event**: UC1-7
* **Customer Satisfaction**: ~~5~~ 4
* **Customer Dissatisfaction**: 5
* **Conflict**: NFR2,3,4; R8

4.2.4 Understandability and Politeness Requirements

NFR7: The system's must provide a respectful session to the user with salutation greetings.

* **Rationale**: In the case of first time users, the system must display more dialogues for showing the spatial arrangements of icons. ~~After more use of the system, the system must greet the on return~~.

* **Fit Criterion**: The system should display dialogues near icons on first use of the software ~~and allow these icon dialogues to be clickable for future uses~~.
* **Priority**: ~~5~~ 1
* **Event**: UC1-7
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 5
* **Conflict**: None

4.2.5 Accessibility Requirements

NFR8: The system's functionality must allow the user to track their progress.

* **Rationale**: The ~~system must~~ user must be able to store previously requested GPS points that could be used for future ~~episodes~~ uses.
* **Fit Criterion**: The system is able to process a request using previously requested GPS data upon user's request.
* **Priority**: ~~5~~ 1
* **Event**: UC3-7
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 5
* **Conflict**: None

4.3 Performance Requirements

4.3.1 Speed and Latency Requirements

NFR9: The system must render the require information within 6000 seconds upon request.

* **Rationale**: The system must process GPS data and display the required episode or stops within a reasonable time. The selected reasonable time of 6000 seconds is just enough time before a device goes into sleep mode after being idle. This is under the assumption that users are not using the device for anything else and are waiting on the software.

* **Fit Criterion**: The system takes the GPS data and provides the user with the requested information before 6000 seconds elapses.
* **Priority**: 5
* **Event**: UC7
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 5
* **Conflict**: NFR12,13;R2,4,6,7,8,12

4.3.2 Safety Critical Requirements

NFR10: ~~The system must not make the user's location public.~~

* **Rationale**: ~~The user's personal information centers around their GPS location. Hence, the system must not make it accessible by the public.~~
* **Fit Criterion**: ~~The system allows the user to only access their location within their individual session.~~
* **Priority**: ~~5~~
* **Event**: ~~UC2-7~~
* **Customer Satisfaction**: ~~5~~
* **Customer Dissatisfaction**: ~~5~~
* **Conflict**: ~~None~~

4.3.3 Precision of Accuracy Requirements

NFR11: The system must render the route ~~accurately~~ matching the GPS data points provided with an accuracy of 80%.

* **Rationale**: The route or episode displayed must align with the data points provided to display a relevant and accessible route.
* **Fit Criterion**: The GPS data points requested match the GPS points in the rendered episode.
* **Priority**: 5
* **Event**: UC3-7
* **Customer Satisfaction**: 5

* **Customer Dissatisfaction**: 5
* **Conflict**: NFR12; R1-20

4.3.4 Robustness or Fault Tolerance Requirements

N/A

4.3.5 Capacity Requirements Requirements

NFR12: The system must be able to process 47.3 million points of GPS data.

* **Rationale**: The route to be generated must be rendered while incorporating precise GPS data. Since, accommodating for more data points would result in an accurate route, the system should process ~~about a~~ 47.3 million data points.
* **Fit Criterion**: The system successfully parses an edge case test with 47.3 million GPS data points requested.
* **Priority**: 5
* **Event**: UC4-7
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 5
* **Conflict**: NFR9; R2,4,6,7,8,12

4.3.6 Scalability Requirements

N/A

NFR13: ~~The system shall be used by multiple users at a time.~~

* **Rationale**: ~~The system will allow multiple users to request for GPS data within their own session at the same time.~~
* **Fit Criterion**: ~~Two or more users have succesfully rendered their requested GPS data at the same time.~~
* **Priority**: ~~5~~
* **Event**: ~~UC1-7~~
* **Customer Satisfaction**: ~~5~~
* **Customer Dissatisfaction**: ~~5~~
* **Conflict**: ~~NFR17,18~~

4.3.7 Longevity Requirements

N/A

~~NFR14~~ : ~~The system must be independent of the version of Python.~~

* **Rationale**: ~~The system must be upgradable using version updates to the open source software it uses like Python.~~
* **Fit Criterion**:~~The system successfully renders the required GPS data independent of the Python version.~~
* **Priority**: ~~5~~
* **Event**: ~~UC1-7~~
* **Customer Satisfaction**: ~~5~~
* **Customer Dissatisfaction**: ~~5~~
* **Conflict**: ~~None~~

4.4 Operational and Environmental Requirements

4.4.1 Expected Physical Environment

NFR14: The system shall be able to run on personal laptops and desktops that uses 2018-2022 versions of Linux, Windows, and MacOS operating system with Python 3 pre-installed.

* **Rationale**: Since it is an open source toolbox, the system only depends on having a valid OS with Python installed.
* **Fit Criterion**: The systems renders the requested GPS data on a valid environment with the stated prerequisites.
* **Priority**: 5
* **Event**: UC1-7
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 5
* **Conflict**: NFR16

4.4.2 Requirements for Interfacing with Adjacent Systems

N/A

4.4.3 Productization Requirements

N/A

4.4.4 Release Requirements

N/A

4.5 Maintainability and Support Requirements

4.5.1 Maintenance Requirements

N/A

4.5.2 Supportability Requirements

N/A

4.5.3 Adaptability Requirements

NFR15: The system must be functional on Linux, Windows, and MacOS operating systems.

- **Rationale**: The system must be functional on a valid OS.
- **Fit Criterion**: The systems renders the requested GPS data on a valid environment with the stated prerequisites.
- **Priority**: 5
- **Event**: UC1-7
- **Customer Satisfaction**: 5
- **Customer Dissatisfaction**: 5
- **Conflict**: NFR15

4.6 Security Requirements

4.6.1 Access Requirements

~~NFR17~~ : ~~The system must ensure that the user session is password protected.~~

* **Rationale**: ~~The user session stores private data of the user and hence, the system must protect it by validating the user through an appropriate password.~~
* **Fit Criterion**: ~~A user with a password that does not match the stored password can not log into that session.~~
* **Priority**: ~~5~~
* **Event**: ~~UC1-7~~
* **Customer Satisfaction**: ~~5~~
* **Customer Dissatisfaction**: ~~5~~
* **Conflict**: ~~NFR13,18; R16~~

NFR16: The system must allow users to have access to read and modify the data they've uploaded

* **Rationale**: This would allow users to edit inputted data and make any necessary changes. If a problem occurs, the user should be able to retrieve their data instead of having to restart the process or software which would be time consuming
* **Fit Criterion**: N/A
* **Priority**: 5
* **Event**: UC1-11
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 5
* **Conflict**: NFR13,18; R16

NFR17: The system shall allow access to all system services and data outputs.

* **Rationale**: This is the main objective to the application to satisfy user goals. If a problem occurs, the system will be completely ineffective and not workable.
* **Fit Criterion**: N/A
* **Priority**: 5
* **Event**: UC1-12

* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 5
* **Conflict**: N/A

4.6.2 Integrity Requirements

~~NFR19~~ : ~~The system shall encrypt user information.~~

* **Rationale**: ~~The system must store information to validate a user for accessing their session. Hence, the system must encrypt such information to maintain integrity of their user.~~
* **Fit Criterion**: ~~The system stores user's personal data using encryption libraries.~~
* **Priority**: ~~5~~
* **Event**: ~~UC1-7~~
* **Customer Satisfaction**: ~~5~~
* **Customer Dissatisfaction**: ~~5~~
* **Conflict**: ~~NFR13,17~~

NFR18: The system shall output correct calculated or modified data

* **Rationale**: The user should not have to question the accuracy of the data outputted. If the data is not accurate or correctly calculated it is contrary to the goal of the system.
* **Fit Criterion**: The system will test along side a reliable computing software such as Matlab.
* **Priority**: 5
* **Event**: UC1-13
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 5
* **Conflict**: N/A

NFR19: The system will only modify necessary data

* **Rationale**: The system would be wasting resources and time if any other modification or unnecessary calculations occur.

It would also be unethical to use the data in a way that the user is unaware of and has not consented to.

* **Fit Criterion**: The user is aware at all times of the system modifications.
* **Priority**: 3
* **Event**: UC1-13
* **Customer Satisfaction**: 2
* **Customer Dissatisfaction**: 1
* **Conflict**: N/A

NFR20: The system shall produce accuracy of 80% when graphing location data points on a map.

* **Rationale**: The graphics produced to the system should be consistent to produce valuable information to be reused. When the graphic points deviate from the actual location the system will be counterproductive and user will be alarmed
* **Fit Criterion**: The system mapping outputs will be compared to a known mapping software such as Google Maps.
* **Priority**: 3
* **Event**: UC1-8
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 3
* **Conflict**: N/A

NFR21: The system shall provide warning log messages of improper or unexpected system uses.

* **Rationale**: The system should provide helpful information when navigating around the system. This ensures a mitigation response to unexpected user activity.
* **Fit Criterion**: The system is able to predict common misused function call with warning messages with tips on how to fix the problem.
* **Priority**: 3

* **Event**: UC1-8
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 4
* **Conflict**: N/A

NFR22: The system shall confirm upload and output files are not larger than 1GB.

* **Rationale**: The system needs to provide secure methods of handling system files. This ensures safe saving and uploading of files.
* **Fit Criterion**: The system does not process files larger than 1GB and throws an error message.
* **Priority**: 5
* **Event**: UC1-8
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 5
* **Conflict**: N/A

4.6.3 Privacy Requirements

NFR23: The system shall not leak sensitive user data.

* **Rationale**: Since the user's requested locations are stored, the system must only allow valid users to access their session's requested locations.
* **Fit Criterion**: The systems does not allow users from another session to access GPS data outside their session.
* **Priority**: 5
* **Event**: UC1-7
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 5
* **Conflict**: NFR13,17,18; R16

NFR24: The system shall keep all the data locally.

* **Rationale**: Since the system is running on user's computer locally, the system must make sure that all the data are kept on the machine only to satisfy the privacy requirement.
* **Fit Criterion**: The system only keeps the executed data on the machine locally.
* **Priority**: 5
* **Event**: UC1-8
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 5
* **Conflict**: N/A

4.6.4 Audit Requirements

NFR25: The system should be verifiable against the requirements and MIS

* **Rationale**: The system must be verified with logical and deductible methods. Failure to meet the requirement results with poor demonstration of requirements.
* **Fit Criterion**: All requirements and design elements are presented in the system.
* **Priority**: 5
* **Event**: UC1-8
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 5
* **Conflict**: N/A

4.6.5 Immunity Requirements

N/A

4.7 Cultural and Political Requirements

4.7.1 Cultural Requirements

NFR26: The system shall display proper language.

* **Rationale**: Since the users of the system have different backgrounds, we must make sure that the words the system displays do not offend them.
* **Fit Criterion**: The words the interface displays to the users are proper, with no violate words.
* **Priority**: 5
* **Event**: UC1-9
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 5
* **Conflict**: N/A

4.7.2 Political Requirements

N/A

4.8 Legal Requirements

4.8.1 Compliance Requirements

N/A

4.8.2 Standards Requirements

N/A

4.9 Health and Safety Requirements

NFR27: The system shall generate safe or reasonable outputs.

* **Rationale**: Since some of the data points are lacked of accuracy when the users collect them (e.g. the points in the water or the points that cross the border of the country), the system must ignore those points when processing the data.
* **Fit Criterion**: The system should ignore unreasonable data points when generating the outputs.

* **Priority**: 5
* **Event**: UC1-10
* **Customer Satisfaction**: 5
* **Customer Dissatisfaction**: 5
* **Conflict**: N/A

5 Likely Changes

Automate routes using RCA

- Using RCA may require extra supporting requirements for functionality and could take more time given. It may not be possible to add this feature into the project.

Time Use Diaries

- Currently users are able to input TUD episodes to generate trip segments. This might require extra supporting requirements in order to accomplish. However, based on time constraints and as it is not one of the main requirements for this project it may not be possible to add this functionality into the final product.

GUI for open source GIS software

- This was mentioned as a stretch goal when the project was started. However, after getting the supervisor's, Dr. Paez, feedback, the team realized it was not appropriate to include this point part of a potential change. The open source software needs to be interactive from command-line and guided instructions of the intended uses will be provided.

6 Unlikely Changes

Python as Primary Language

- Python has many libraries to facilitate mapping and analysing geospatial data which will be integral to creating this software.

GPS Coordinates as Inputs

- Map matching and extracting episode is dependant on GPS data gathered by the user.

GPS Episodes as Outputs

- As the main requirements of the project depends on the usuage of GPS episodes the output is unlikely to change.

7 Traceability Matrix

	NFR1	NFR2	NFR3	NFR4	NFR5	NFR6	NFR7	NFR8	NFR9	NFR10	NFR11	NFR12	NFR13	NFR14	NFR15	NFR16	NFR17	NFR18	NFR19	NFR20
NFR21	NFR22	NFR23	NFR24	NFR25	NFR26	NFR27														
R1	X			X		X			X	X		X							X	
R2	X X	X	X	X		X		X	X		X	X	X							X
R3	X		X	X	X X	X X		X	X	X	X								X	
R4	X X	X	X	X					X		X									
R5					X	X X					X			X						X
R6		X		X		X		X	X		X									X
R7		X		X		X		X	X		X									X
R8		X		X		X X		X			X									X
R9		X		X X		X X		X			X									X
R10	X	X	X	X		X X			X		X									X
R11	X	X X	X			X			X		X									
R12	X	X	X						X	X	X									
R13	X X		X		X	X			X	X	X									X
R14	X	X	X						X	X	X									
R15	X	X	X X	X X	X	X X														X
R16			X	X		X			X							X	X	X		X
R17	X		X	X		X			X	X	X									X
R18	X	X	X X	X X		X		X	X	X										X
~~R19~~	~~X~~	~~X~~	~~X~~	~~X~~				~~X~~	~~X~~	~~X~~										
~~R20~~	~~X~~	~~X~~	~~X~~	~~X~~												~~X~~	~~X~~	~~X~~		

Table 3: Traceability Matrix Showing the Connections Between Functional Requirements and Non Functional Requirements

8 Project Issues

8.1 Open Issues

- Understanding the ArcGIS Architecture
- Researching Similar Open Source software to ArcGIS

8.2 Off-the-Shelf Solutions

The GERT toolbox is the current solution for map matching software. However, it comes with limited functionality and specific data requirements for usage. It is also not open source and expensive to licence.

8.3 New Problems

The software being created is a reworking of the original GERT toolbox and will not interfere with the original toolbox as it is designed separately from it.

8.4 Tasks

- Hazard Analysis 0
- VV Plan Revision 0
- Proof of Concept Demonstration
- Design Document Revision 0
- Revision 0 Demonstration
- VV Report Revision 0
- Final Demonstration
- Expo Demonstration
- Final Documentation

8.5 Migration to the New Product

The design architecture for the program(e.g. modular design) can ensure that it can be added with new features/function easily.

8.6 Risks

One potential risks is that when the user is trying to run the program in new platforms(i.e. new operation system,) he/she may have compatibility issues.

8.7 Costs

There will be no cost towards making this toolbox as it is being created completely open source and free from proprietary software.

8.8 User Documentation and Training

Documentation will be made using Quarto which is open-source scientific and technical publishing system. This will allow us to put snippets of code within the documentation and will behave as a training manual for users wanting to work with the software.

8.9 Waiting Room

The current plan to for project is a complete re engineering of the GERT toolbox. Once this is completed extra functionality will be added, these include:

- The use of route choice analysis for trip generation
- Using time use diaries for route validation

8.10 Ideas for Solutions

At this point in time we are still actively researching different libraries and frameworks to use for this project and they will be added into this section in later revisions of this document.

9 Appendix

This section has been added to the Volere template. This is where you can place additional information.

9.1 Symbolic Parameters

The definition of the requirements will likely call for SYMBOLIC_CONSTANTS. Their values are defined in this section for easy maintenance.

9.2 Reflections

To successfully complete this project and gain a complete understanding of the project's domain, the team must acquire knowledge related to the content of the toolbox including but not limited to: route choice variables/models, travel episode verification and categorization, trip trajectory generation, GIS software tooling, and understanding various GPS data types. Each member of the team will be responsible for acquiring knowledge on each module of the toolbox. Smita and Moksha will be responsible for route choice variables/models. Longwei will be responsible for trip trajectory generation. Niyatha will be responsible for travel episode verification and categorization. Abeer will be responsible for GIS tooling. Nicholas will be responsible for understanding the GPS data types.

To approach this, we meet with domain-specialists including the project's Supervisor, Dr. Paez, past developers of the toolbox, and potential toolbox users. Through interviewing these stakeholders we will learn about the goals of models we are implementing, what is lacking in current tooling, standard GIS software usage, domain specific knowledge regarding trips/routes, and how this information will be used to derive insights. We will also be reading published papers to gain insight on standard GPS data processing algorithms and help discover optimizations for our toolbox.

Another skill our team has to acquire is team management to increase the productivity of the project. As a group project, a successful team management strategy will help members complete their tasks more efficiently. We have already established a team communication strategy and methodology for pushing/reviewing content (code, docs, etc.), to complement this, we will routinely schedule retrospectives regarding management strategies to update processes and maximize efficiency. These retrospectives will often consist of identifying productivity blockers, researching better methods, and implementing them into our tooling.

Another skill our team has to acquire is writing and presentation skills to help structure our project demonstration and supervisor's meetings. Since every member of the team has different writing experiences, our method of writing varies drastically from person to person. Learning how to write as a team, create formal documentation that is thoroughly consistent with one another will be a challenge. Therefore we will investigate formal writing conventions and ensure that each member of the team is aware and actively uses the predetermined methods. Similarly for the end of the year capstone presentations, the team will have to work together to come up with a method of presentation that will fit all of us as well as be consistent with formal presentation styles. This will require more investigation and practise as a team.

References

[1] R. Dalumpines and D. M. Scott, ""gis-based episode reconstruction toolkit (gert): A transferable, modular, and scalable framework for automated extraction of activity episodes from gps data,"," Travel Behaviour and Society, 21-Apr-2017., January 2011.