GeoScene

Augmented Reality and POI Geolocation Scenery viewer Android mobile application

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Chapter 1
Introduction

Overview

In recent years Augmented Reality (AR) technology became very popular and limitations of marker-based augmented reality applications, which would require scanning a real-world marker in order to display a model at its location, can now be solved by using marker-less augmented reality.
Both video games and cellphones are driving the development of augmented reality. Everyone from tourists, to soldiers, to someone looking for the closest subway stop can now benefit from the ability to place computer-generated graphics in their field of vision. In this project, we will develop an Android mobile application that uses marker-less AR which relies on location data instead of physical markers in order to display users their surrounding Points of interest (POI) and help them explore the scenery. POIs will be gathered from open-source mapping services and from internal backend source having predefined locations saved by their latitude and longitude coordinates. The application will integrate Google's Augmented Reality SDK called ARCore to render objects at various points of interest in the real world.

1.1 The Problem Domain

This section will primarily focus on presenting and describing the main domains and difficulties that this project will address during the development phase.

Open-Source Usage

The project will mainly use open-source data, SDKs and APIs in order to achieve the desired project goal, as most geospatial tools and APIs online are pre-paid or paid after a monthly/annual requests limit is met. One of the main challenges of using mainly open-source sources is the lower quality, speed reduction and network overhead that may be caused by using those type of sources. The application will need to overcome those obstacles and befit those services to the applications usage scenarios and requirements.

Mobile development

The application will be developed for mobile devices running Android OS. The development will be done using both React Native and Android SDK.
React Native is an open-source mobile application framework created by Facebook, It is used to develop applications for Android enabling developers to use React's framework along with native platform capabilities.
Android software development is the process by which applications are created for devices running the Android operating system. Android apps can be written using Kotlin, Java, and C++ languages using the Android software development kit (SDK). In this application Java will be used in order to develop the Android modules.

Augmented Reality

Augmented Reality (AR) is an enhanced version of reality where live direct or indirect views of physical real-world environments are augmented with superimposed computer-generated images over a user's view of the real-world, thus enhancing one's current perception of reality.
The application will use AR as the main platform in which POI markers will be displayed and integrate with the users surrounding environment.

Geo-Location

Geolocation refers to the identification of the geographic location of a user or computing device via a variety of data collection mechanisms. Typically, most geolocation services use network routing addresses or internal GPS devices to determine this location. As such, an internet connection and GPS-enabled mobile phone will be required for the application usage.
The application will rely on the network provider's internet and the mobile device GPS to identify the user's current location. Location managers and listeners are will be used constantly to update the user's position and re-calculate its relative position to the AR environment.

Geospatial-Analysis

Geospatial analysis includes any of the formal techniques which studies entities using their topological, geometric, or geographic properties. In order to inform the user only about POIs which are currently present in the users FoV (Field of View), The application will use a Viewshed computation algorithm to determine the raster surface locations visible to the user in the observer FoV (Field of View).

Users and Permissions

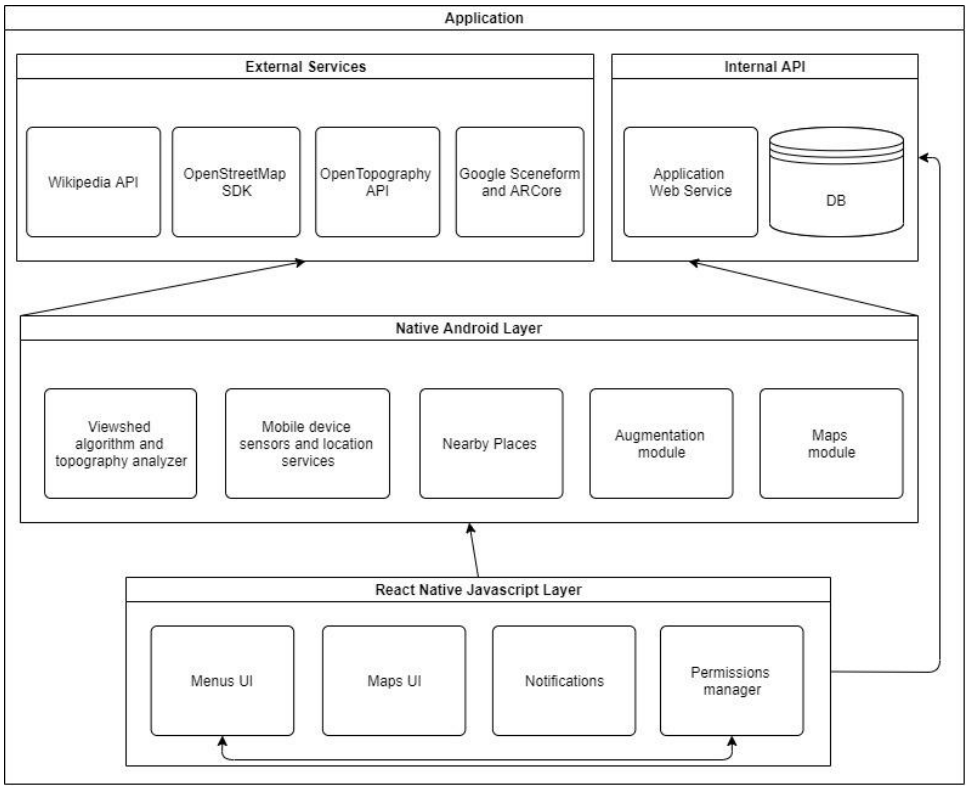
The applications backend will need to use an external web service (web application) that will be used for predefined organizations administrators to add and edit users permissions that will be later used to perform different operation using the application (i.e. adding locations markers, editing those locations information etc.). The application will also need maintain an organization independent users login and permissions system that will be used to determine the operations a user can perform by using the application. In general, users will not have to login in order to use the application. Users that have special permissions and were previously assigned by an organization administrator will login to perform permissions specific operations.

1.2 Context

The application will rely on several external services to perform its goal.
There are a lot of AR SDKs like Wikitude, Vuforia that integrate location to create Geo-location AR apps but all of these AR engines are licensed and do not integrate well with native app development. Therefore, the applications main external service that will be used to display an augmented reality view will be Google's ARCore and Scenform Android libraries As ARCore is available for all users to view and use freely, projects developed with it can be made open-source which address one of the main problem domains mentioned before.

In order to analyze the topographic scenery around the user, the application main algorithm (Viewshed algorithm) will be used according to the topographic elevation raster data that will be provided by the OpenTopography open-source API.
In addition, the application will use Nearby Places and map data provided by OpenStreetMap SDK/API services. A more elaborate description about the POIs that are present in the users FoV will be provided by Wikipedia's open-source API.

The React-Native layer of the application will handle most of the UI components that the user will interact with and will use Android native modules calls to start the AR view.



1.3 Vision

The basic concept of the application is to help travelers, tourists and other users to gain spatial orientation. The application will identify and present information about the POIs currently in the users FoV using marker-less geo-location based AR environment and the mobile device camera. When the user points their camera at a POI, a place marker will be augmented onto their camera view showing the name and distance of the POI from the user. The user can view this object from any angle and interact with it.

1.4 Stakeholders

- Travelers and Tourists – Will be the main expected type of users, as they are usually interested in the surrounding places and scenery they encounter while traveling. Those type of users would possibly like to be able to identify and receive additional information about their viewed locations with the comfort of using their mobile device.

- Israel Nature and National Parks Protection Authority – Will like the people traveling in the nature reserves to have access to information about the scenery and important POIs in the reserve and around it without the need of signs or human directions.

- Prof. Ohad Ben-Shahar – As the founding and acting director of the Interdisciplinary Computational Vision Laboratory would like to have a proof of concept of such a projects feasibility and have a working product to demonstrate it.

  Except of those main expected users and clients the purpose of the application is to be open for free download via the Google Play Store and everyone will be able to gain spatial information by using it.

1.5 Software Context

The application operates on several external input sources, mobile device sensors input and user interaction with the mobile device.
The application workflow can be generally described as follows:
On initial application start the user location and orientation will be measured using the mobile device sensors and a call to an external topographic raster resource will be made. After receiving the answer, the returned raster information will be used as input for a viewshed calculation algorithm that outputs the visible raster cells according to the area's topography. Simultaneously a call will be sent by nearby places module to an external API and to the applications database service which will result in the users nearby locations and their respective bounding boxes. Succeeding to both of this API calls and after the needed calculation output is available the places data will be crossed with the viewshed visible area to determine what places are visible in the users FoV. Subsequently after the determination of the visible surrounding POIs and when the users chooses to launch the application AR capability (Supported by Google's Sceneform and ARCore Android libraries), place markers will be displayed above the visible POIs outputted in the previous process mentioned. By interaction with those place markers a call with the appropriate place name will be made to the Wikipedia API to retrieve the place description and additional information which will then be presented to the user.

Furthermore, users with appropriate permissions will be able to login and according to their permission status, they will have additional functionality such as adding new places to be marked (With provided input details) and editing existing locations that were previously added by calling the application database service.

Chapter 2
Usage Scenarios

2.1 User Profiles – The Actors

The actors in our system are mostly end users that are not logged in to the system, they may have several different characteristics but the use cases for all of the users that are not logged in are similar.
We can distinguish the system actors by their user status (not logged in, logged in with permissions and administrators).

Human Actors

- Users that are not logged in to the system – will be the main expected audience of the application and are predicted to consist mainly of travelers and tourists that would like to gain spatial orientation and get information about their surroundings.
- Logged in users with predefined permissions – will be users that were previously assigned by an organization administrator and have some permissions that can affect the state of the project internal database such as adding, editing or removing locations.
- Predefined Organization Administrators – will be users that can add new users under their organization with a set of permissions and edit existing users permissions.

Non-human Actors

- Mobile device sensors – including the mobile device GPS sensor used to retrieve the device location, magnetic sensor that is used to determine the device orientation and compass and barometer used to estimate the altitude of the mobile device.

2.2 Use-Cases

2.2.1.a Viewing nearby places with elevation settings on

Primary actors:
A User that is not logged in to the application

Preconditions:
- Mobile device active internet connection
- Available mobile device GPS signal
- Available mobile device camera
- Given the application permission to use mobile device sensors and camera.
- The applications elevation usage settings are on.

Postconditions (success guaranty):
- A location marker is shown in AR view using the mobile device camera above every place that the user can physically see (Currently in the users FoV).
- Every location marker shown contains the correct name and additional details of the real-world location located in the location markers orientation.

Main success scenario (Basic flow):
1. The user open the GeoScene application.
2. The users chooses to open the AR view feature of the application.
3. The AR view of the application has initialized.
4. The users looks around with the mobile device camera.
5. All the users surrounding places that are currently in his FoV are presented to the user using location markers.

Extensions (Alternate flows):
1. The user open the GeoScene application.
2. The user loses GPS signal/Internet connectivity while the application is loading.
3. The application prompts the user to retry and relaunch the application.

Abstract Example:
The application is being used by the user inside a crater named “Crater” with 20 other locations surrounding the crater. Since the crater’s elevation is 100m below sea level, the user can see a location marker only for the crater itself with the name “Crater” on it.

2.2.1.b Viewing nearby places with elevation settings off

Primary actors:
A User that is not logged in to the application

Preconditions:
- Mobile device active internet connection
- Available mobile device GPS signal
- Available mobile device camera
- Given the application permission to use mobile device sensors and camera.
- The applications elevation usage settings are off.

Postconditions (success guaranty):
- A location marker is shown in AR view using the mobile device camera above every place that is surrounding the user.
- Every location marker shown contains the correct name and additional details of the real-world location located in the location markers orientation.

Main success scenario (Basic flow):
1. The user open the GeoScene application.
2. The users chooses to open the AR view feature of the application.
3. The AR view of the application has initialized.
4. The users looks around with the mobile device camera.
5. All the users surrounding places are presented to the user using location markers.

Extensions (Alternate flows):
4. The user open the GeoScene application.
5. The user loses GPS signal/Internet connectivity while the application is loading.
6. The application prompts the user to retry and relaunch the application.

Abstract Example:
The application is being used by the user inside a crater named “Crater” with 20 other locations surrounding the crater. Although the crater’s elevation is 100m below sea level, and since the elevation settings of the application is turned off, the user can see 21 location markers, one for each surrounding POI and one for the crater itself.

2.2.2.a Adding new locations to internal database

Primary actors:
Logged in user with predefined permissions

Preconditions:
- Mobile device active internet connection
- Available mobile device GPS signal
- Available mobile device camera
- Given the application permission to use mobile device sensors and camera.
- The user has been assigned permissions to add location under a certain organization.

Postconditions (success guaranty):
- A new location with the user current real-world coordinates has been added to the applications internal database.
- The new location inserted contains the additional details provided by the adding user.
- The new location added is now visible to all other users that the new location coordinates is in their FoV.

Main success scenario (Basic flow):
1. The user open the GeoScene application.
2. The user navigates to the applications login screen.
3. The user inserts his credentials in order to login.
4. The user is presented with a menu option that allows him to add a new location at his current real-world position.
5. After choosing the Add location functionality the user is automatically navigated to the correct screen.
6. The user inserts the location name and additional information in the appropriate text boxes presented in the screen.
7. The user is prompted that the new location was added successfully.

Extensions (Alternate flows):
1. The user open the GeoScene application.
2. The user navigates to the applications login screen.
3. The user inserts wrong credentials in order to login.
4. The user is notified that the credentials inserted are not valid.
5. The user is re-routed to the login screen.

2.2.2.b Editing previously added locations

Primary actors:
Logged in user with predefined permissions

Preconditions:
- Mobile device active internet connection
- Available mobile device GPS signal
- Available mobile device camera
- Given the application permission to use mobile device sensors and camera.
- The user has been assigned permissions to edit locations information under a certain organization.
- The place the user is trying to edit information for, exists in the system under the same organization as the user.

Postconditions (success guaranty):
- A previously added location is updated with new information.
- The edited location will be visible with the new edited place information to all other users that the edited location coordinates is in their FoV.

Main success scenario (Basic flow):
1. The user open the GeoScene application.
2. The user navigates to the applications login screen.
3. The user inserts his credentials in order to login.
4. The user is presented with a menu option that allows him to view and edit the location previously added under his associated organization.
5. The user chooses the location he wished to edit information for from the presented locations.
6. After choosing the Edit location functionality the user is automatically navigated to the correct screen.
7. The user edits the location information in the appropriate text boxes presented in the screen.
8. The user is prompted that the location was edited successfully.

Extensions (Alternate flows):
1. The user open the GeoScene application.
2. The user navigates to the applications login screen.
3. The user inserts wrong credentials in order to login.
4. The user is notified that the credentials inserted are not valid.
5. The user is re-routed to the login screen.

2.2.3 Adding a new user and setting user permissions

Primary actors:
Predefined Organization Administrator

Preconditions:
- Internet connectivity

Postconditions (success guaranty):
- A new user is added under the organization that the organization administrator is associated with.
- The new user is added the permissions that were defined by the organization administrator in the user adding process.
- The new user can now login to the application with the credentials that were defined in the user adding process.
- The new user will be able to perform all and only the operations that the organization administrator assigned him for.

Main success scenario (Basic flow):
1. The organization administrator opens the GeoScene web service.
2. The organization administrator chooses to option to add a new user under his organization.
3. The organization administrator inserts the new user credentials (i.e. email).
4. The organization administrator chooses the wanted permission types or permission group to associate the user with.
5. The organization administrator approves the user by pressing the Add button.
6. The organization administrator is prompted with a message indicating that the user was added successfully.

Extensions (Alternate flows):
1. The organization administrator opens the GeoScene web service.
2. The organization administrator chooses to option to add a new user under his organization.
3. The organization administrator inserts the new user credentials (i.e. email).
4. The organization administrator is prompted with a message indicating that the chosen credentials already exist in system.
5. The organization administrator is re-routed to the Add user page of the web service.

Chapter 3
Functional Requirements

No.	*Description*	*Priority*	*Risk*
1	The application will support displaying nearby locations data over real-world view using the mobile device camera.	MH	High
1.1	The application will have the capability of showing nearby POIs location markers from official mapped locations.	MH	High
1.2	The application will have the capability of showing nearby POIs location markers tagged by users with the appropriate permissions.	MH	High
1.3	The application will display the name, distance and additional information regarding the user surrounding POI (points of interest).	MH	High
1.4	The application should handle overlapping location markers by flattening them horizontally to avoid location markers being concealed.	MH	High
1.5	The application will support filtering surrounding locations according to the user's field of view (FoV).	MH	High
1.5.1	The application will be able to analyze topographic elevation data and determining the users viewshed (FoV).	MH	High
1.5.2	The application will enable the user to specify the visible areas circular radius to display POIs in.	NTH	Low
1.6	The application will identify when a user is in a closed space by determining surrounding vertical surfaces and will have the option to not display POIs in that scenario.	NTH	High
1.7	The application should enable the user to minimize or maximize location marker information.	NTH	Low
1.8	The application will display the location markers sized relative to their real-world distance from the user in order to distinguish closer location.	NTH	High
2	The application will use the mobile phone sensors (GPS, magnetic) to determine the user location and device orientation.	MH	Low
3	The application will support displaying a map of the users surrounding area.	NTH	High
3.1	The application should support showing the map view side-by-side to the real-world view as well as independently.	NTH	Low
3.2	The application will support showing the current visible POIs on the map.	NTH	High
4	The application will support displaying a compass showing the users current real-world orientation.	NTH	Low
5	The application will enable users setting their ground relative height to increase their FoV depending on their non-topographic elevation.	NTH	Low
6	The project will have manually defined organization administrators for every supported organization using the application.	MH	Low
7	The project will contain an external resource (i.e. web application service) where defined organization administrators will be able to edit user permissions, add new users under the organization and set their application permissions.	NTH	High
7.1	The organization administrators will be able to add permissions groups and set users as part of those groups determining their permissions.	NTH	Low
8	The application will have predefined users logging system.	MH	High
8.1	The application will have predefined permissions for each user under their respective organization determining the operations this user is capable of doing within the application.	MH	High
8.1.1	The application will allow users with the appropriate permissions to add new two-dimensional points of interest to be viewed by other users determined by their current location.	MH	High
8.1.2	The application will allow users with the appropriate permissions to add new two-dimensional points of interest to be viewed by other users determined by a chosen map location.	NTH	High
8.1.3	The application will allow users with the appropriate permissions to add additional information regarding tagged places.	NTH	Low
8.1.4	The application will allow users with the appropriate permissions to edit or remove previously tagged locations.	MH	Low

Chapter 4
Non-Functional Requirements

4.1 Implementation constraints

Performance

- The application will be responsive enough to refresh the AR view at-most one second from pointing the mobile device at a location marker until it appears on screen.
- The application loading time will not exceed 30 seconds including web-requests and topographic analyzing.
- The application will make and handle independent unrelated web-requests and computations concurrently.
- The application will make requests to retrieve at least $50km^2$ raster data per request in order to lower network overhead (less requests over a period of time will be needed).

Reliability and Stability

- The application will not crash except as the result of operating system error.
- The app will handle exceptions gracefully and inform about error occurrence and will allow for repair if it is possible.
- The application will retry to recover from external web-requests error by resending the request and informing the user of the ongoing issue.
- The application will cache data from latest requests or operation to be recovered in the case of a failure or sudden operation abort by system or the user.

Security

- The application will only store encrypted user data.
- The application will only receive data from open-source resources and will not send data to those resources.
- The application will not make use of user's location data outside of the applications scope.
- The application will enforce user's permission so that users without the appropriate permissions will not be able to perform permission specific operations and will not be presented with the option (i.e. UI buttons) of doing so.

Environmental and Portability

- The application will support all Android based mobile phones with versions later than Android 8.0(Oreo).
- The application will use AR (Augmented reality) technology provided by Google's ARCore using Sceneform.
- The user must have access to download the app from Google play store.
- The mobile device that uses the application must support OpenGL3.
- The mobile device that uses the application must have an active camera.
- The mobile device that uses the application must have a GPS and network connectivity.
- The applications native device language must be supported by the application (English or Hebrew).

Availability

- The application will always require the user to have an active network connectivity during application use.
- The application will always require the user to have an enabled GPS sensor on the operating mobile phone during application use.
- The application will require the user to give mobile device camera permissions.
- The application will require the user to give the application location permissions.
- The application should always be available for the users.
- The application will not require users to login except for permission specific operations.

Useability

- The application will contain an attractive and performant UI (user interface), 90% satisfied users according to a UI survey that will be held pre-launch.
- Learning this app shall be very easy as the user interface is easy to navigate, 85% satisfied users according to a UX survey that will be held pre-launch.
- The application will use Wikipedia open-source service in order to retrieve places information for POIs.
- The application will enable the user to navigate to Wikipedia page for specific information about the POI's.
- The application is intended to use in both portrait and landscape mobile device orientation.
- The application AR view location markers occupy at most 50% of the screen to avoid clutter and so that the real-world view will not be concealed.
- The application will support English and Hebrew languages.

4.2 Platform constraints

The native modules of the application (i.e. the AR view and threaded calculation and requests) will be developed using the Android Studio development environment due to the restriction of using the Android SDK which is best supported on that platform. The React-Native modules of the application will not have such a restriction and therefore will be developed on any IDE/Code editor with support for TypeScript types inference (Such as Visual Studio Code). The native modules will be packaged and build using the Gradle build tool to better support new versions of libraries that the application rely on (i.e. ARCore and Sceneform).

The main restriction regarding the external platform that will be used in this project were the requirement of the platform to be open-source yet robust enough to support our application required features and requirements. The platform choices for topographic raster data was chosen to be OpenTopography API due to the non-limited web requests that can be made to the API, in daily web-request count and in the API's response size.

The nearby locations platform the application will use is OpenStreetMap API/SDK due to the need of the application to have the bounding box area of each retrieved location, a limitation that OpenStreetMap API/SDK solves.

4.2.1 Software engineering project constraints

- Since the application will be developed for Android, the project team members personal Android mobile devices will be used for developing and testing purposes.
- During development fabricated location coordinates will be used in order to simulate the mobile device GPS placements with the goal of exploring places that may have edge cases that the application will need to be able to deal with. Real testing data will also be used by outdoor testing that will be held in nature reserves and other known scenery locations sometime pre-launch.
- During project presentation, we expect that the application will be available for download via the Google Play Store and therefore any mobile device that meets the application requirements will be able to be used as the demonstrating device.
- During project presentation we will use live location data along side with pre-prepared edge cases data that will be used for demonstration purposes (by fabricating the mobile device location).

4.3 Special restrictions and limitations

- The application will assume the correctness of data retrieved from external resources (i.e. elevation data, nearby places, etc.).
- The application will conform to the Material UI design language.
- The applications internal API will use No-SQL based database (i.e. Firebase, mongoDB etc.) and will support CRUD (Create, Update and Delete) operations.

Chapter 5
Risk assessment and Proof of concept plans

5.1 Risks assessments

- The open-source libraries, APIs and SDKs that will be used in the project may be too limited for the expected requests that the application will need to make to perform its intended functionality.
- When trying to determine the users FoV, precision is especially important because a too sensitive error tolerance can cause visible areas to not be marked and the opposite, place markers can be accidently placed for places that can't be seen by the user.
- Since the application does not take external sources height that are not represented in the areas topographic information (i.e. construction, trees, entities, etc.) into account, error regarding the shown place markers can be made and an elegant way to solve it needs to be formed.
- The algorithms that will be used to compute the users viewshed can be computationally expensive and can potentially be too resource-hungry for mobile device usage.
- Because the application is intended to support adding custom locations by users with permissions, there is a difficulty validating the correctness, reliability and precision of the inserted information. Some sort of revision is required on the inserted data.

5.2 Plans for the proof of concept

In the next phase of the project, in order to achieve our goals, we will take several steps that will be concluded with a limited functionality working prototype.
We can divide the needed steps to three main processes that will take place sequentially:

i. *Research*
   - Learning and understanding important geographical and topographical terms used frequently in written professional documentation.
   - Better understanding the Android development paradigm using both Android SDK and React-Native.
   - Better understanding of Augmented Reality, especially Google's ARCore and Sceneform libraries, and how we can use it the realize our project goals.
   - Researching for open-source libraries that supply our needed demands and that we will be able to use in the development phase.

ii. *Preliminary work*
   - Developing a custom viewshed algorithm (Identify the visible raster tiles from the users FoV) that will be sufficiently accurate and fast enough for the application usages. The algorithm will be tailored for the application needs and resources.
   - Testing the most suitable way to use the AR capabilities for the application needs in a closed testbed (i.e. location markers placement capabilities, compass and GPS calibration, identifying surfaces).
   - Implementing utilities that will support the application with topographical and geographical calculations and conversions (i.e. bounding box calculations, latitude and longitude conversions to xy plane, Web Mercator projections)

iii. *Proof of concept implementation*

   Implementing a working version with basic capabilities while focusing on the must have and highest risk functional requirements and the intermediate steps to achieve them:

   - Fetching the users nearby POIs and their respective bounding boxes.
   - Calibrating the mobile device sensors to be able to convert real-world placements to device-relative placements while keeping an accurate sense of orientation.
   - Fetching and analysing topographic elevation data to be used as input for the viewshed algorithm that will be used to determine the users FoV.
   - Developing a basic AR environment with location markers placement capability while taking only the users FoV into account by applying the viewshed algorithm on the users location and crossing it with the nearby places bounds.
   - Implementing a basic UI with the option to execute the AR environment capability and some basic UI enabled settings modifications that will also contribute to debugging the application at its initial phases.
   - Supporting some optional functionalities that will be present in the released version of the project (i.e. maps integration, compass integration, basic UI menu system, custom viewing distance settings etc.)

Appendices

Resources

- GeoScene github page https://github.com/itaybou/GeoScene-App

Development Tools references

- React Native official website https://reactnative.dev/
- TypeScript official website https://www.typescriptlang.org/
- Android SDK API website https://developer.android.com/reference
- Google Firebase website https://firebase.google.com/
- Google ARCore platform website https://developers.google.com/ar
- Google Sceneform API website https://developers.google.com/sceneform/develop
- Retrofit android HTTP client website https://square.github.io/retrofit/

External resources references

- OpenTopography website https://opentopography.org/
- OpenStreetMap website https://www.openstreetmap.org/
- osmdroid Android Maps SDK https://github.com/osmdroid/osmdroid
- MediaWiki API https://www.mediawiki.org/wiki/API:Main_page

UI design standards

- Material UI design https://material.io/

File Formats

- Esri Grid raster GIS file format https://en.wikipedia.org/wiki/Esri_grid

Additional Materials

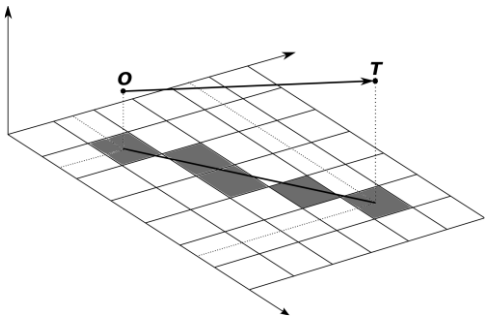
- Web Mercator projection https://en.wikipedia.org/wiki/Web_Mercator_projection
- Bresenham's line rasterization algorithm https://en.wikipedia.org/wiki/Bresenham%27s_line_algorithm
- Midpoint circle algorithm https://en.wikipedia.org/wiki/Midpoint_circle_algorithm
- Bounding Box Finder http://bboxfinder.com/

Geo-Analysis Viewshed Problem Overview

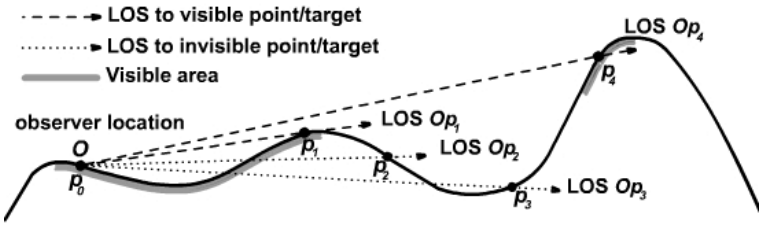
Most of GIS problems related to visibility involve the viewshed computation and in general. The applications main problems involve the area of visibility queries. The visibility queries consist in checking if a given point is visible or not from an observer (another point) on the terrain. In this section we will present the main ideas behind the viewshed computation algorithms.

Given point O where O is the observer's WGS84 datum latitude/longitude coordinates, raster grid T, line of sight radius r and $p_{i,j}$ $\forall\ 0 \leq i,j \leq |T|$ POIs we can say that $p_{i,j}$ is in O's viewshed if $p_{i,j} \in viewshed(O,r) = \{q \in T \mid dist(O,q) \leq r \text{ and } q \text{ is visible } from\ O\}$.

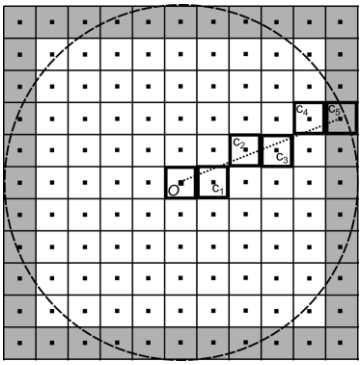
In order to determine O's entire viewshed we need to rasterize a circle with radius r on the raster T and from each point of the rasterized circle, rasterize a line to determine the visible cells from T on that line by using the slopes from O to every $p_{i,j}$ that intersects with the rasterized line.



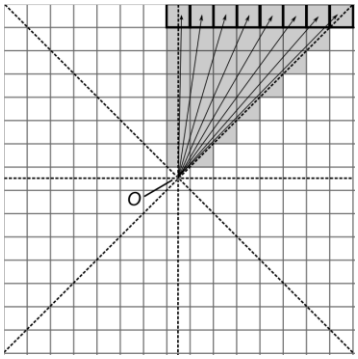
Line rasterization



Viewshed calculation along a line



Circle rasterization



Viewshed computation along raster lines

Glossary

User - A user is a person who utilizes a computer or network service. In the context of the application, the majority of users are expected to be travellers, tourists and workers of the Israel Nature and National Parks Protection Authority**.**
Israel Nature and National Parks Protection Authority - The Israel Nature and Parks Authority is an Israeli government organization that manages nature reserves and national parks in Israel.
Mobile Device - A mobile device is a computer small enough to hold and operate in the hand.
Android - Android is a mobile operating system based on a modified version of the Linux kernel and other open source software, designed primarily for touchscreen mobile devices.
Open-Source - Open source is a source code that is made freely available for possible modification and redistribution. Products include permission to use the source code, design documents, or content of the product.
OpenGL - OpenGL (Open Graphics Library) is a cross-language, cross-platform application programming interface (API) for rendering 2D and 3D vector graphics.
UI – User Interface, In the industrial design field of human-computer interaction, a user interface (UI) is the space where interactions between humans and machines occur.
UX - User experience (UX or UE) is a person's emotions and attitudes about using a particular product, system or service.
API - An application programming interface (API) is a computing interface which defines interactions between multiple software intermediaries.
SDK - A software development kit (SDK) is a collection of software development tools in one installable package.
Augmented Reality (AR)– Augmented reality (AR) is an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated perceptual information.
Markerless AR - Markerless Augmented Reality is used to denote an AR application that doesn't need prior knowledge of a user's environment to overlay 3D content into a scene and hold it to a fixed point in space.
Field Of View (FoV)– The field of view (FoV) is the extent of the observable world that is seen at any given moment.
Point of interest (POI) – A point of interest, or POI, is a specific point location that someone may find useful or interesting.
GPS - The Global Positioning System (GPS), provides geolocation and time information to a GPS receiver anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. Obstacles such as mountains and buildings block the relatively weak GPS signals.
Topography - Topography is the study of the forms and features of land surfaces. The topography of an area could refer to the surface forms and features themselves, or a description (especially map depiction).
Geospatial - geospatial data and information is data and information having an implicit or explicit association with a location relative to Earth (a geographic location or geographic position).
Elevation - The elevation of a geographic location is its height above or below a fixed reference point.
Raster - raster graphics or bitmap image is a dot matrix data structure that represents a generally rectangular grid of pixels.
Rasterization - Rasterization is the task of taking an image described in a vector graphics format (shapes) and converting it into a raster image.
Viewshed - A viewshed is the geographical area that is visible from a location. It includes all surrounding points that are in line-of-sight with that location and excludes points that are beyond the horizon or obstructed by terrain.
WGS84 (World Geodetic System) - The World Geodetic System (WGS) is a standard for use in cartography, geodesy, and satellite navigation including GPS.
Web Mercator Projection - is a variant of the Mercator projection and is the de facto standard for Web mapping applications.
Latitude - In geography, latitude is a geographic coordinate that specifies the north–south position of a point on the Earth's surface.
Longitude - Longitude is a geographic coordinate that specifies the east–west position of a point on the Earth's surface.
Bounding Box - A bounding box is an imaginary rectangle that serves as a point of reference for object detection and creates a collision box for that object.