# 3D Navigational Insight using AR Technology


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*Abstract*— **Navigation, the ability to relocate from one place to another, is a critical skill for any individual or group. Navigating safely across unknown environments is a critical factor in determining the success of a mission. While there is an existing body of applications in the field of land navigation, they primarily rely on GPS-enabled technologies. Moreover, there is limited research on Augmented Reality (AR) as a tool for navigation in unknown environments. This research proposes to develop an AR system to provide 3-dimensional (3D) navigational insights in unfamiliar environments. This can be accomplished by generating 3D terrestrial maps leveraging Synthetic Aperture Radar (SAR) data, Google earth imagery and sparse knowledge of GPS coordinates of the region. Furthermore, the 3D terrestrial images are converted to navigational meshes to make it feasible for path-finding algorithms to work. The proposed method can be used to create an iteratively refined 3D landscape knowledge-database that can assist personnel in navigating novel environments or assist in mission planning for other operations. It can also be used to help plan/access the best strategic vantage points in the landscape.**



***Keywords—*** **navigation, three-dimensional, image processing, mesh, augmented reality, mixed reality, SAR, GPS**


## I. Introduction

Spatial knowledge or memory is a form of memory responsible for the recording of information about one's environment and spatial orientation. It is typically acquired from one or more spatial perspectives; most commonly survey or route. Though people typically navigate by using spatial knowledge acquired through direct navigation or extended experience with area maps, there are many cases where people must navigate environments on short notice and without conclusive spatial knowledge. For example, military personnel and emergency first responders are projected to navigate unfamiliar environments without sufficient time to study the route. For instance, military personnel may view a two-dimensional (2D) map during a mission briefing, and then be transported directly to the site of an emergency [1, 2]. Studies have shown the relative positive effectiveness of spatial learning perspectives during simulated transport for supporting eventual navigation of an environment [1, 2].

Basic map and compass land navigation training are used to continue dominance in ground warfare. The Military Grid Reference System uses a compass, map, and protractor to pinpoint regions during land navigation. However, typical map and compass land navigation training exercises do not provide the optimal spatial knowledge. The U.S. Department of Defense (DoD) developed the Global Positioning System (GPS), which is a satellite-based navigation system. Its capabilities are limited in remote terrains and in GPS denied regions. Some of the other navigation techniques include Wi-Fi positioning system (WPS), Bluetooth, and visual positioning systems [3]. However, none of these systems can provide sufficient visual simulation for spatial learning.

Moreover, over reliance on the GPS signal may result in significant loss of life and equipment if the GPS signal is lost. The current threats to GPS ranging from anti-satellite weapons to solar storms expose a critical vulnerability of over-reliance on GPS technology for moving on the battlefield as well as communicating and engaging targets. Currently, unfamiliar or unexplored open environments are studied using 2D imagery such as aerial satellite images or surveillance images. Although training scenarios (or camps) are conducted to simulate such environments, they are not similar to the exact environment. Robot mapping is another technique used to obtain 3D/2D maps. For instance, state-of-the-art visual SLAM algorithm tracks the pose of the camera, while, simultaneously, building an incremental map of the surrounding region [4]. There is a significant need for a system that can visualize environments unknown to such military and emergency first responders. Moreover, this system should be capable of automatically identifying paths in these environments.

Humans are capable of learning complex unknown environments in a variety of guidance tasks and use the knowledge to determine near-optimal (e.g., minimum-time) performance and remain versatile and adaptive to unexpected changes in the environment. Augmented reality (AR) is a technology that superimposes a visual imagery on a user's view of the real world, thus providing a composite view. Using AR technology, users can perceive virtual and real objects as co-existing in the same environment. Moreover, it is possible to apply machine learning algorithms on AR systems. Standalone augmented reality (AR) systems have great potential for interactive three-dimensional (3D) geo-visualization. Emerging AR technologies can display rich graphical imagery of large-scale environments and permit intuitive interaction through gestural and voice inputs. Where unfamiliar environments must be navigated efficiently and without online guidance, studying interactive 3D environment visualizations with real-time navigation aids could support environmental learning and navigational efficiency. The proposed method will integrate 3D augmented reality and navigation into operations such as land navigation and unit position tracking. AR is a new development in the area of mobile learning. AR apps use the cameras on mobile devices


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to produce live views of the physical world and add information from digital sources, such as maps.

Studies have shown the relative positive effectiveness of spatial learning perspectives during simulated transport for supporting eventual navigation of an environment. However, such visualization data is limited. There is a need for a system that can visualize environments unknown to such military and emergency first responders. Moreover, this system should be capable of automatically identifying paths in these environments.

Synthetic-aperture radar (SAR) is a type of radar that is used to create three-dimensional models of objects such as the surface of planets. SAR can acquire imagery during the day and night as illumination is provided by the SAR itself. This research proposes a proof-of-concept to construct 3D data that can be used in Augmented Reality (AR) and Virtual Reality (VR) based systems to provide 3-dimensional (3D) navigational insights in unfamiliar environments. The proposed method will create an iteratively refined 3D landscape knowledge-database that can assist personnel in navigating familiar or un-familiar environments or assist personnel in mission planning. The main objectives of this proposal are to (1) develop a proof-of-concept method to generate 3D terrestrial maps leveraging Synthetic Aperture Radar (SAR) data, Google earth imagery, (2) tag the generated map with information such as cardinal directions, traversable surfaces, and navigational paths, and (3) Use the generated knowledge base to perform virtual navigational operations. This will be achieved using a combination of data fusion and artificial intelligence.

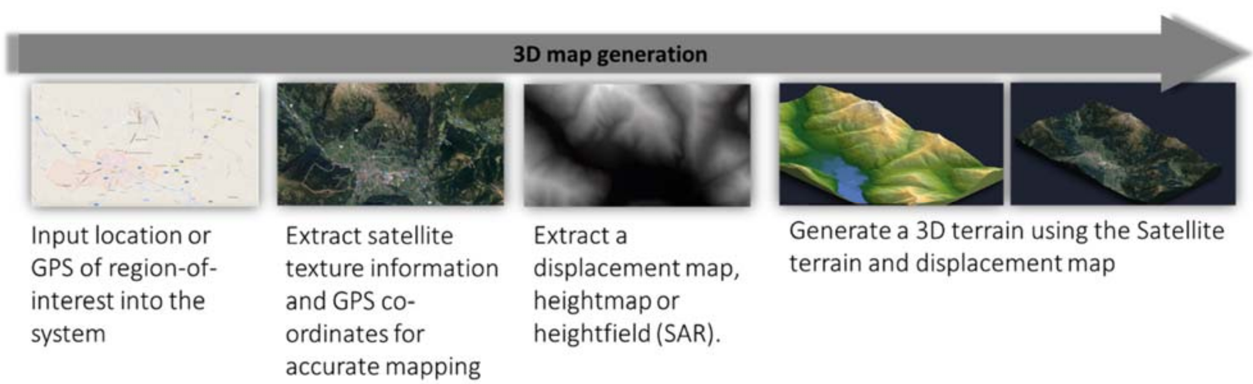


Fig. 1. shows the method proposed for generating the 3D terrain. Images obtained from [5]

## II. Technical Approach

The proposed method for developing 3D maps of open terrain and its 3D map development is described in the following steps:

### A. 3D map development using existing data

This project develops 3D terrain using Google images and SAR data . The SAR data at the UNAVCO Data Center [6] includes satellite-transmitted and received radar scans of the Earth's surface. SAR data, analyzed using Interferometric SAR (InSAR) techniques, can be used to model millimeter-to-centimeter scale deformation of the Earth's surface over regions tens to hundreds of kilometers across [7]. Fig. 1 describes the method used for generating the 3D maps. SAR data is essentially a volume file without texture.

### B. Map Rectification

This module can be used to both rectify the maps and register the 2D maps with the SAR maps. A common problem in artificially generated terrains is accurate measurements for path-finding and navigation. Using GPS co-ordinates and real-world images, we can map these metrics into the 3D terrain. The higher the transformation order, the more complex the distortion that can be corrected.

### C. Artificial Intelligence (AI) based Navigational Mesh

Using AI and the 3D terrain that was generated, an abstract data structure can be created that can aid individuals in pathfinding through complicated spaces. A navigation mesh is an abstract data structure used in artificial intelligence applications to aid agents in pathfinding through complicated spaces.

A navigation mesh is a collection of two-dimensional convex polygons (a polygon mesh) that define which areas of an environment are traversable by agents [8]. Adjacent polygons are connected to each other in a graph [8, 9]. Only the traversable polygons are used as available input paths to the path-finding algorithm. This reduces memory-overloading. The path between polygons can be obtained in the mesh using one of the large numbers of graph search algorithms, such as A*[10]. Therefore, paths developed using navigational meshes tend to avoid computationally expensive collision detection checks with obstacles that are part of the environment [11, 12]. This process is widely used in game

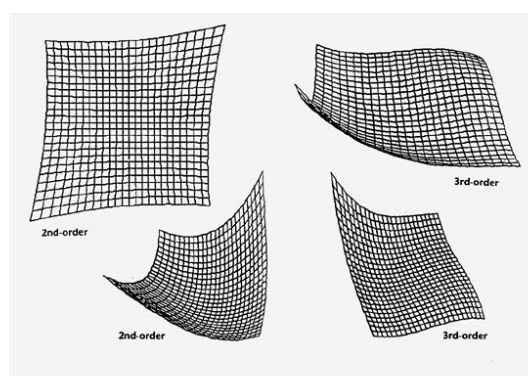


Fig. 2. Shows the map rectification for different orders

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development and with the advent of augmented reality devices, a similar technique can be developed for real 3D data-based navigation as shown in Fig. 3.

paths to the desired location in the map. This tool when ready can be used to train military and emergency first responders to traverse an unfamiliar environment from any remote location. Moreover, it can also be used to provide real-time visual navigational aids. Also, the information from this tool can be used to develop simulation camps for training personnel.

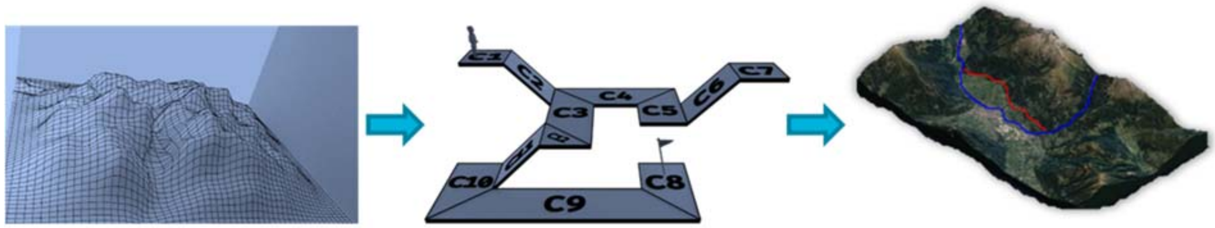


Fig.3. Shows an illustrative example of the steps required to generate a navigational mesh. [5]

### D. Deploy the application in AR devices

This application/software can be deployed on AR-enabled Personal computers, laptops, mobiles or augmented reality-based glasses. This tool facilitates an interactive 3D environment visualizations with real-time navigation aid. For instance, the military emergency first responders can view this 3D map and identify the routes during a mission briefing, and then be transported in a vehicle near to the site of an emergency.

## III. Gated Metrics to Control the Technical Risks

Some of the risks involved in this proposed research involve: (1) Visual quality of the 3D map generated may be below par. (2) Inaccuracy of the map: The generated map may not have the correct scale, or the generated map may not be the in the desired location. (3) Inaccuracy of the elevation estimation: The elevation of the map is dependent on the SAR data and can be erroneous. (4) Extending the application in Virtual Reality devices: Although they look similar, VR and AR technologies are very different from each other. Moreover, VR devices are prone to cause motion sickness. (5) Limitation of AR eyewear devices: Use of AR devices is restricted in an indoor environment.

Some of the gated metrics that we used to control the technical risk are:

1. Human visual system (HVS) based quality: Use HVS based quality metrics [13, 14] to identify low quality images.
2. Use input data with high correlation of GPS: Inaccurate maps may have been generated due to low quality data or inaccurate input data.
3. Utilize VR techniques to avoid motion sickness: Using inbuilt eye tracking technology, to restrict the movement of camera. In other words, to move the camera along with the user's eye movements. Keep a minimum of 60 frames per second to avoid motion blurriness.

## IV. Application

This research will assist military personnel to visualize unknown terrain using AR devices from any location, with information such as cardinal directions and walkable surfaces, and with path-planning agents that will automatically generate paths to the desired location in the map. This tool when ready can be used to train military and emergency first responders to traverse an unfamiliar environment from any remote location. Moreover, it can also be used to provide real-time visual navigational aids. Also, the information from this tool can be used to develop simulation camps for training personnel.

Concurrently, individuals using the system will build and expand the 3D map by providing additional data collects that occur in the background and without any explicit user intervention. This information will create an iteratively refined 3D landscape knowledge-database that can assist personnel in navigating novel environments or assist in mission planning for other operations. It can also be used to help plan/access the best strategic vantage points in the landscape. The ultimate purpose of this testbed will be to visualize environments unknown to military personnel and to identify paths in these environments automatically. A modified version of this tool can be used to facilitate navigation for visually or/and hearing-impaired individuals.

## V. Conclusion and Future work

This work presented a theoretical proof-of-concept on generating 3D traversable paths for 3D navigation. This information will create an iteratively refined 3D landscape knowledge-database that can assist personnel in navigating novel environments or assist in mission planning for other operations. This research will assist military personnel and first responders to visualize unknown terrain using AR and VR devices from any location with information such as cardinal directions and walkable surfaces, and with path-planning agents that will automatically generate paths to a desired location in the map. This article proposed a concept to develop a novel AR based system to provide 3D navigational insights in known or unknown environments. 3D terrestrial maps were generated using SAR data and Google earth imagery. A modified version of this tool can be used to facilitate navigation for visually or/and hearing-impaired individuals. The future work of this project entails (1) creating and releasing a 3D terrestrial dataset, (2) developing multi-agent pathfinding to find the paths for multiple agents from their current locations, and (3) adapting the navigation algorithm to handle elevation

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