AR Navigator App

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Introduction

Augmented Reality (AR) technology enriches user's view of real world by integrating digital model into the real-world environment and showing the integrated scene on the screen of user's device. Unlike Virtual Reality (VR), which separates users from the real world, AR allows users to interact with their surroundings. Google Maps is an amazing tool to plan possible routes to destination with little effort. Within couple of seconds it offers best possible route to destination, landmarks, and provides information about location. However, it still is separated from the real world. In this research work we focus on developing a mobile application that help users to build up the connection between 2D map and real position by using Augmented Reality (AR) technology. Google Direction API provides a convenient way to get the routing path from current location to destination location. Our mobile application is able to get the routing path from Google Direction service and place 3D marker to every turning corners using ARCore. ARCore is Google's platform for building AR applications. With this feature user can find the correct route to destination by scanning around and finding the 3D markers.

Method

The Google Direction API gives a list of location points base on the geographic coordinate system, the job is to build up the connection between the geographic coordinate system and the coordinate system that ARCore uses. So that marker models could be placed to ARCore correctly.

I. World Coordinate Space

ARCore uses *World Coordinate Space* to place models and keep them organized. World Coordinate Space is not fixed in ARCore, instead, every frame has its own unique world coordinate space. But the Y-axis is always pointing vertically up to the sky, and the Z-X plane is parallel to the tangent plane of where user is standing on. Z-axis points to the opposite direction where the user is looking at.[1]

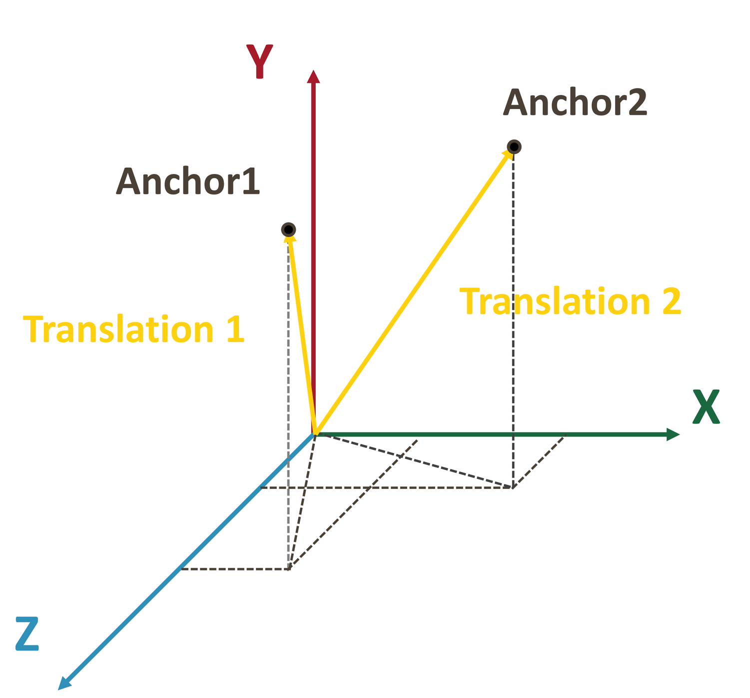

Figure 1. World Coordinate Space in ARCore

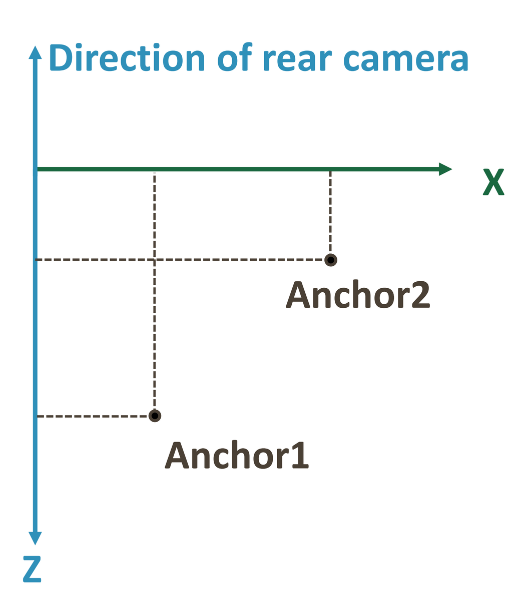

Figure 2. Simplified World Coordinate Space

ARCore uses Anchor to record models' position information in the world coordinate space. The translation is anchor's position vector; it represents how to go to the anchor from the origin of current world coordinate space.

Since in most of the scenarios, user is waling on the street, which has no significant change in height, the world coordinate can be simplify into two dimensions by just keeping the Z and X axis.

II. Geographic Coordinate System

Geographic coordinate system uses latitude and longitude to descript the position of a geographic location on the Earth's surface. If we flattened the Earth, we could find that even though two points have same change in longitude, the higher latitude they have, the shorter distance they will come out with[2]. But since this application is for navigation of walking, user will just use this application in a small area, compare to the Earth. In this case, geographic location points can be transformed into a cartesian coordinate system, whose vertical axis represents North-South and the horizontal axis represents East-West.[3]

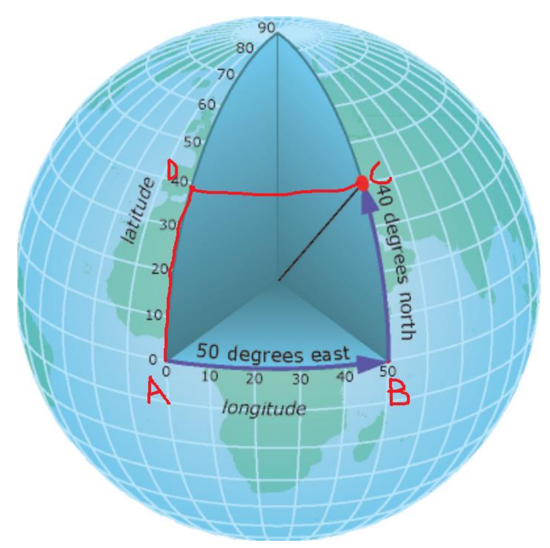

Figure 3. Geographic Coordinate System

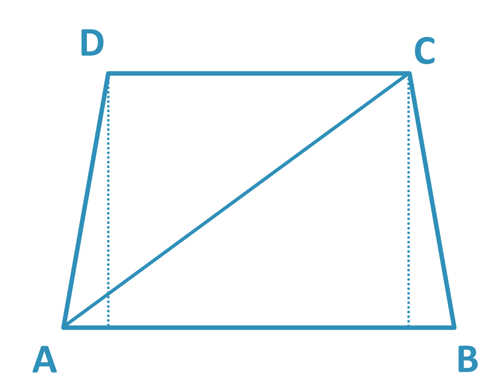

Figure 4. Flatted surface

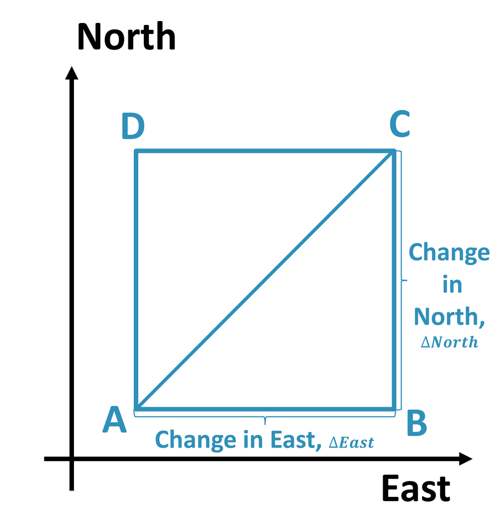

Figure 5. Simplified geographic coordinate system

To go to point C from point A, we can move to point B first, and then move from point B to point C. The line AB is how many meters requires when move from A to B in East-West direction. The line BC is how many meters requires to move from B to C in North-South direction.

$$\Delta North = R_{Earth} * 2\pi * (Lat_C - Lat_B) * 360$$

$$\Delta East = R_{Earth} * 2\pi * cos\left(\frac{Lat_B + Lat_C}{2}\right) * (Lng_B - Lng_c) * 360$$

III. Combining two Simplified Coordinate System

Now we have two paralleled coordinate systems. One is the simplified world coordinate space, the other is the simplified geographic coordinate system.

Record the geographic location point and world coordinate space point from two different physical location. Using those two sets of points to calculate the rotation matrix of those two coordinate systems. Finally according to the rotation matrix we can find the corresponding point in world space of the location point in geographic system.

Step to record two sets of points A and B(Fig 6) are as follows:

1. Record the geo location for A, which is (aLng, aLat); record the world position for A, which is (aX, aZ)
2. Record the geo location for B, which is (bLng, bLat); record the world position for B, which is (bX, bZ)

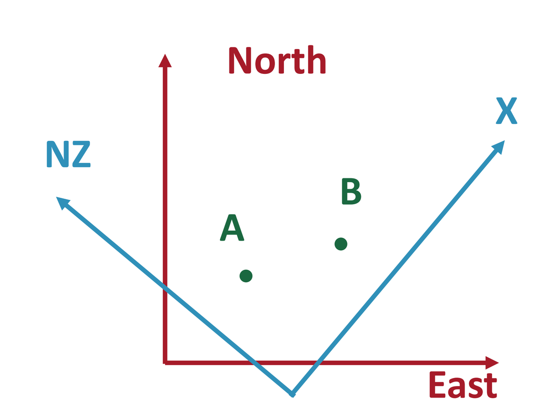

Figure 6. Record two sets of points

IV. Calculate the Rotation Matrix

Since those two simplified coordinate systems are all Cartesian coordinate system, rotation of axes can be used to build up the connection of those two coordinate systems. Fig 7 shows the coordinates were use the preform the calculation of rotation matrix.

1. Set the origin to point A
2. For geo coordinate, B becomes $(\Delta East, \Delta North)$ and $(\Delta X, \Delta NZ)$

$$\cos\boldsymbol{\theta} = \frac{\Delta NZ * \Delta North + \Delta X * \Delta East}{\Delta East^2 + \Delta North^2}$$

$$\sin\boldsymbol{\theta} = \frac{\Delta X * \Delta North - \Delta NZ * \Delta East}{\Delta East^2 + \Delta North^2}$$

Where,
ΔEast is the east-west distance from A to B,
ΔNorth is the North-South distance from A to B,
ΔX=bX −aX , and ΔNZ=bNZ −aNZ

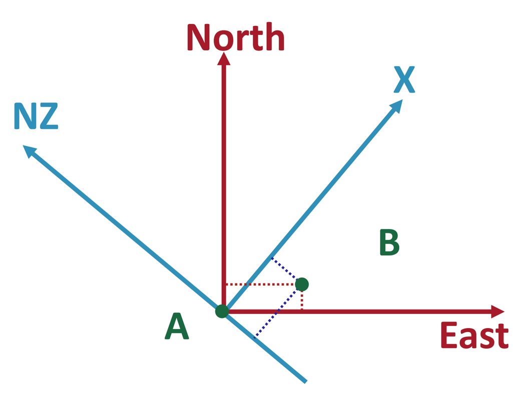

Figure 7. Calculate the Rotation Matrix

V. Use the Rotation Matrix to Calculate Other Geo Locations' Corresponding Points in the World Space

Assume that we have the point C and we have it point in geographic coordinate system. We can use the rotation matrix and point B to find the relative connection about B and C.

1. Set the origin to point B
2. The geo point of C is now $(\Delta East, \Delta North)$
3. $\Delta X = \Delta East * \cos\boldsymbol{\theta} + \Delta North * \sin\boldsymbol{\theta}$
4. $\Delta NZ = \Delta North * \cos\boldsymbol{\theta} - \Delta East * \sin\boldsymbol{\theta}$

Where,
ΔNorth is the North-South distance from C to B,
ΔEast is the East-West distance from C to B.
Because ΔX=cX−bX , and ΔNZ=cNZ −bNZ;
cX=bX+ΔX , and cNZ= ΔNZ+bNZ

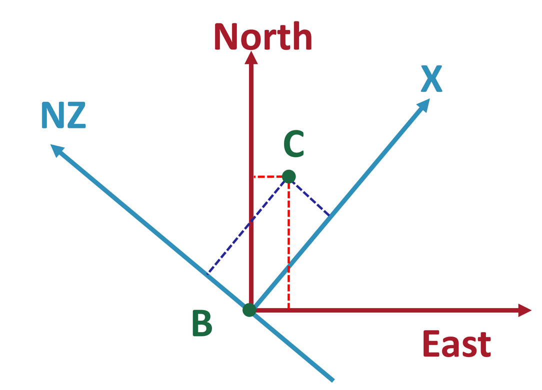

Figure 8. Calculate the location of C in World Space

Result

The picture below is the screenshot of this application. We can see that markers were placed at the street as expected. The blue line in the small map is the routing path generated by Google Direction API. Markers show the same direction as the blue line in the small map. Users can have a more direct view about how to go to the destination.

The coming works are majorly about fixing the accuracy problem. From the result picture we can see that the last marker is not being put in front of the destination. The major problem is first the projecting coordinate system is an estimated system, it will cause accuracy problem. Finding a more accurate way is needed.

Figure 9. Running result 2

Key References

1. *Feature Request: Provide a geo-oriented world coordinate space #119* https://github.com/google-ar/arcore-android-sdk/issues/119
2. *Geographic Coordinate System* http://desktop.arcgis.com/en/arcmap/10.3/guide-books/map-projections/geographic-coordinate-system.htm
3. *The calculation of two locations* https://blog.csdn.net/u011001084/article/details/52980834

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