Predicting Andeans Mountain Paths Using Geographic Information Systems (GIS)

Michael Tirone, Class of 2021

Introduction:

Paths are central parts in any social environment, they structure the flow of people and goods. While doing field research, movement paths are difficult to spot. Therefore, archaeologists often rely on satellite imagery and computer programs to find and model walking paths. The introduction of Geographic Information System (GIS) software provides tools to study movement pathways over large study areas and can reveal potential routes that used by people in the past. Least Cost Paths (LCPs) are the most common method to reveal these routes and there are various ways of determining an LCP for a given origin and destination.

The study area is the Colca Valley in southern Peruvian Andes. People from towns and villages often rely primarily on walking to get to fields and travel long distances. This movement can reveal well-trod pathways that are visible in satellite imagery. Therefore, these paths can be marked using GIS software.

Methods and Objectives:

The aim of this project was to examine the effectiveness of GIS-generated Least-Cost Paths (LCP) in predicting actual walking paths. To do this, I compared two commonly-used methods for calculating how the "cost" of walking varies depending on the slope of the terrain: Tobler walking model[1] or Naismith's walking model.[2] First, I identified and marked actual paths using high-resolution satellite imagery across a 3000 km^2 region in the central Andes. This 'involved systematically surveying the study area by 1 km^2 blocks and marking visible paths point by point. I created 2702 paths throughout the region. From that group I chose 20 paths that traveled out of the valley and were very visible. Each path was assigned a unique ID number, origin and destination based on where the path began and ended.

Two LCPs were created from each origin and destination pairs, one using Tobler's model and one using Naismith's models. Then, I measured their accuracy by calculating the percentage of the actual path that fell *within* a 100 m and a 200 m buffer around each LCP.

Results and Future Project

The results from both comparisons revealed that neither formula had a statistical advantage over the other.[3] No one method was significantly more accurate in predicting actual paths. The LCPs captured anwhere from 8% to 99% of the actual path. A general pattern observed is that LCP is more accurate when predicting shorter paths rather than longer paths

Further LCP analyses include different formulas, such as Bell and Lock's walking model and other version of Tobler and Naismith. The substantial computing power needed to complete each analysis means that I wasn't able to explore other methods as indepth as desired. I plan to continue comparing multiple other cost formulas to find one that yields a comparable LCP to an actual path.

Potential uses for finding a "best" LCP creation can lead to the creation of Artificial Intelligence (AI) which can efficently map worldwide social environments like this one.

Faculty Mentor: Professor Lauren Kohut who helped me throughout the project. Many thanks.

References:

[1]Tobler, Waldo "Three presentations on geographical analysis and modeling: Non-isotropic geographic modeling speculations on the geometry of geography global spatial analysis." National center for geographic information and analysis. 92. February 1993. **Formula:** $W = 6e^{-3.5\left|\frac{dh}{dx} + 0.05\right|}$

[2]Naismith, W. W. Scottish Mountaineering Club Journal II:136. 1892. **Formula:** Naismith's 1 h / 3 mi + 1 h / 2000 ft

[3] Both Two-Tailed Pair T-test revealed values larger than 0.05, therefore there is *no statistical* significance comparing the accuracy of each method

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Test Case	100 m Buffer		200 m Buffer	
	Tobler	Naismith	Tobler	Naismith
1	10.6682995973762	8.84438982148226	18.98705001	18.02582
2	9.9634275903964	6.93692939065885	18.92306245	12.05134
3	36.0837808938869	32.5154255980741	48.1286475	43.33638
4	30.8771851492256	31.7036338422325	39.05100322	47.13231
5	78.1408312870956	82.6964977757902	95.46948369	92.80557
6	20.8877869984251	18.9450622743188	26.33289326	30.25861
7	53.289895753227	53.7242576297171	77.74207498	92.24532
8	57.4823257369128	56.9538228909637	65.75717862	78.53562
9	48.5898476827832	24.5718803689465	69.9605441	36.30508
10	33.2834449146073	25.0252130974515	48.69520624	49.30119
11	21.8194056846023	17.4847003872619	28.41709742	26.72256
12	10.4212606754965	14.52042384717	32.14606181	37.76997
13	59.7576809592892	35.9526791284795	69.38775251	67.30101
14	18.5209174790873	20.2823480817652	23.83135623	34.74272
15	21.9388656255638	16.4551872909	34.08618172	27.38857
16	10.0633624962835	15.2841689325411	14.37848961	26.18855
17	23.065657799895	18.1563083333824	33.2862879	33.0296
18	64.3713045048241	85.1482793347378	97.00988941	99.16649
19	14.7472430593799	17.6340483585962	26.99654083	28.50697
20	29.9328111277596	53.5725180927165	56.18016731	73.81619
Two-Tailed Paired T-Test P-Value	0.729750427		0.549477919	

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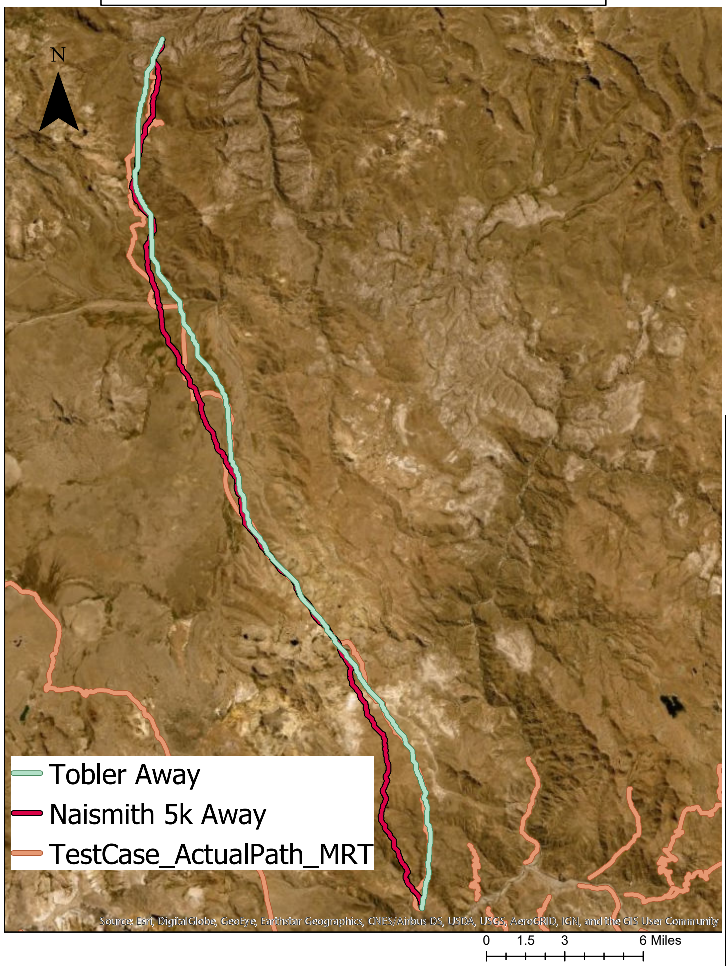
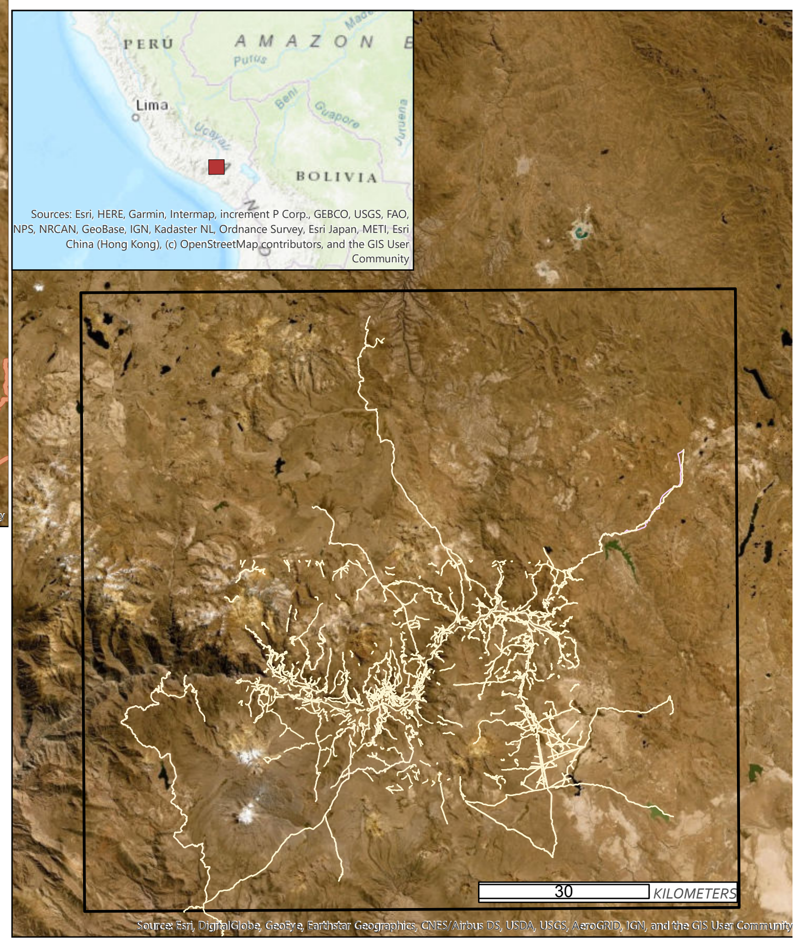
Actual Path Comparison
Example Number 3



Study Area



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[1]Tobler, Waldo "Three presentations on geographical analysis and modeling: Non-isotropic geographic modeling speculations on the geometry of geography global spatial analysis." National center for geographic information and analysis. 92. February 1993. **Formula:** $W = 6e^{-3.5\left|\frac{dh}{dx}+0.05\right|}$

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