Rapid Search Area Reduction for Image Geolocation

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Where were these photos taken?

The purpose of this work is to develop technology that augments the task of geolocating outdoor photos and videos lacking geospatial metadata. We present a methodology and toolset to rapidly and interactively reduce the search area and prioritize the most likely location of an image based on simple user annotation of the features, terrain and land cover observed in the image.

The primary goal of our search area reduction platform is to maximize accuracy of capturing the camera location while minimizing the quantity and size of candidate locations returned to the system user.

Approach

Here is a simple example of our approach. Given a search area of 50,000 sqkm, what are the most likely regions where this image was captured?

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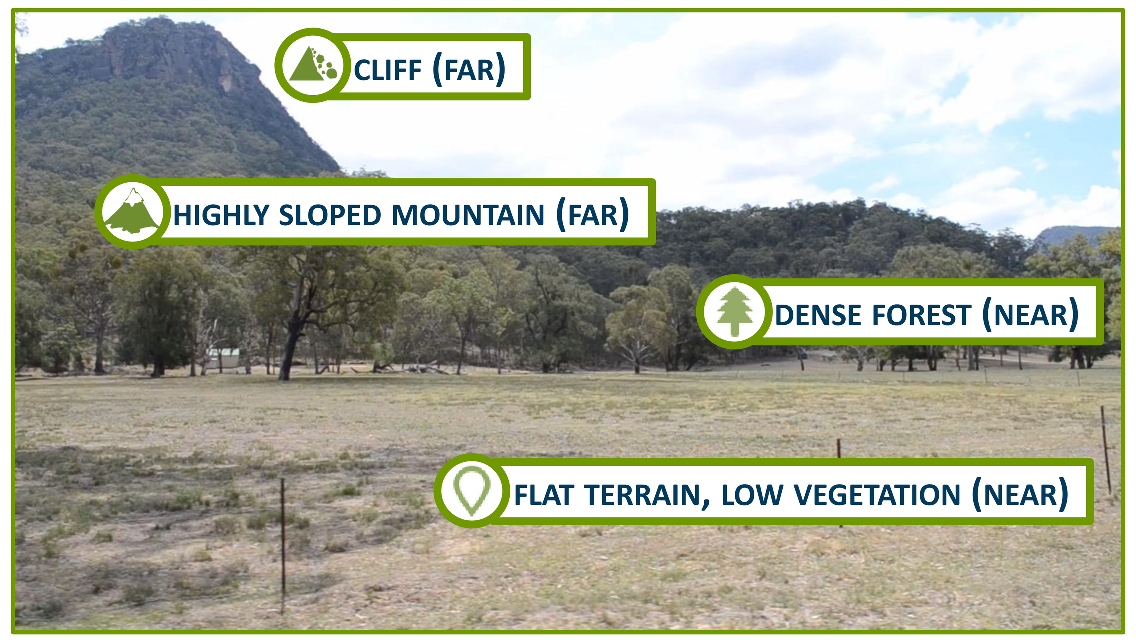
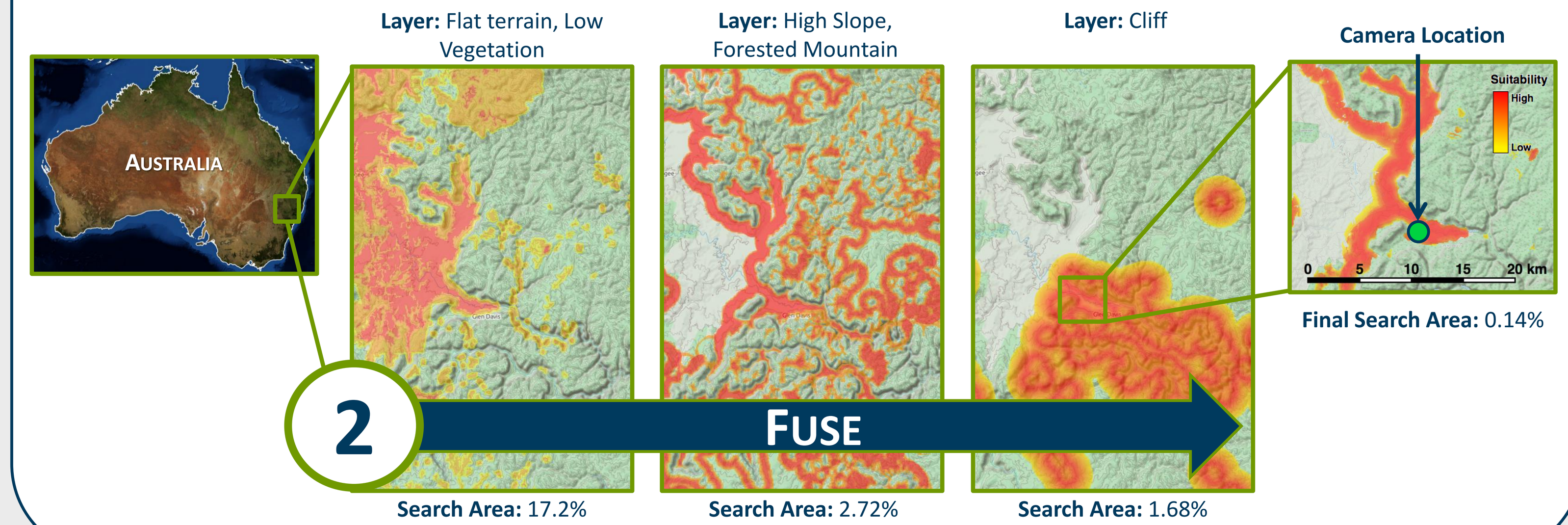
Image Annotation

Users select from a pre-defined list of curated map layers and estimate the distance to each feature.

Map layers include points of interest, terrain, land cover and road networks.



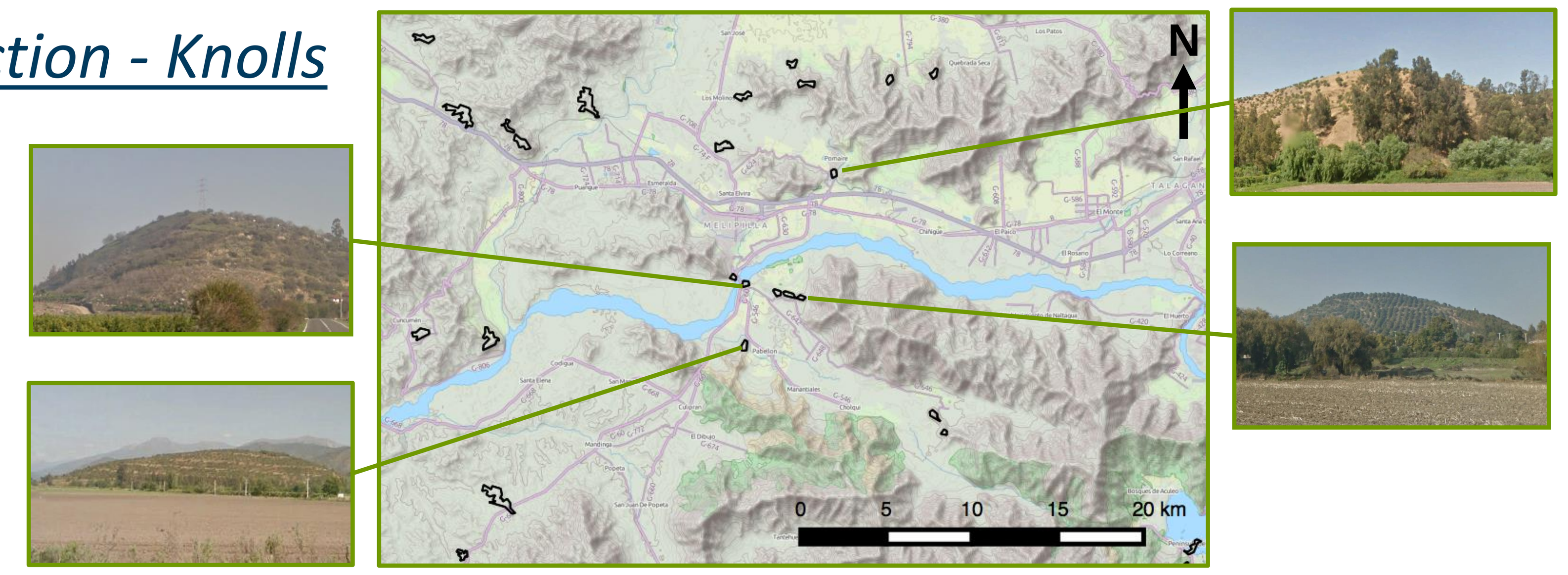


Reducing the search space

Image search walkthrough using a single map layer - knolls

Terrain Object Extraction - Knolls

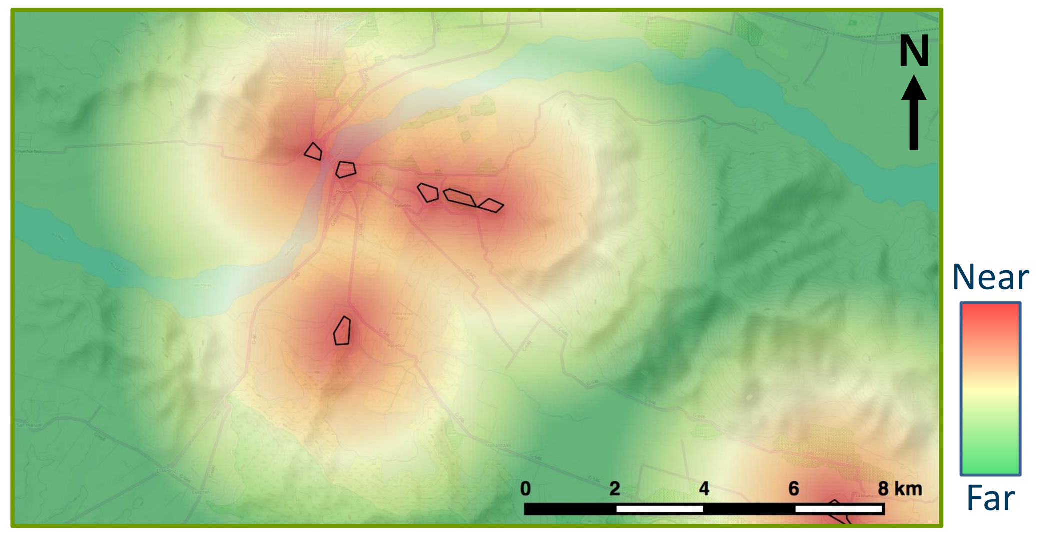
We extract a number of features from digital elevation models to build out the world model. These features include simple layers like slope and curvature, and more complex features like ridges, cliffs and **knolls**.



Two approaches to encoding distance information

Nearest Neighbor

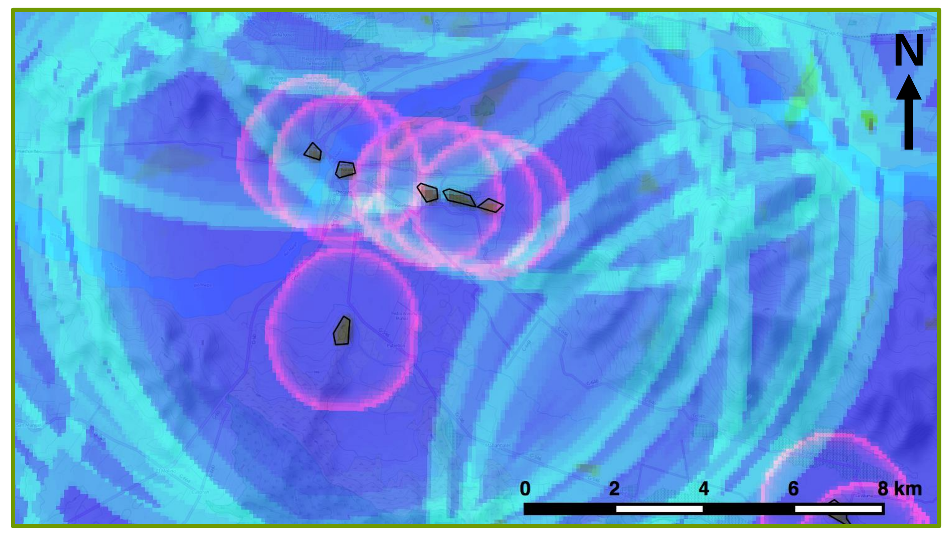
Simple, intuitive and fast. Nearest neighbor distance (NND) rasters encode distance to the nearest feature out to a maximum radius. This approach assumes closer is better.



Nearest neighbor distance to knolls

Distance Bitmask

A novel approach, distance bitmasks (DBM) encode distance to every feature in a multiband raster, thus overcoming limitations inherent to NNDs while maintaining rapid search area reduction.

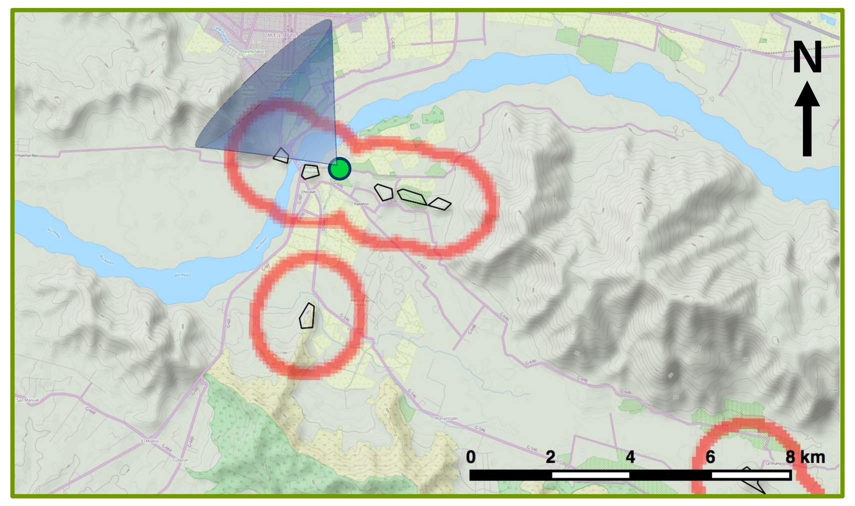


Distance bitmask of knolls

Search: NND vs DBM

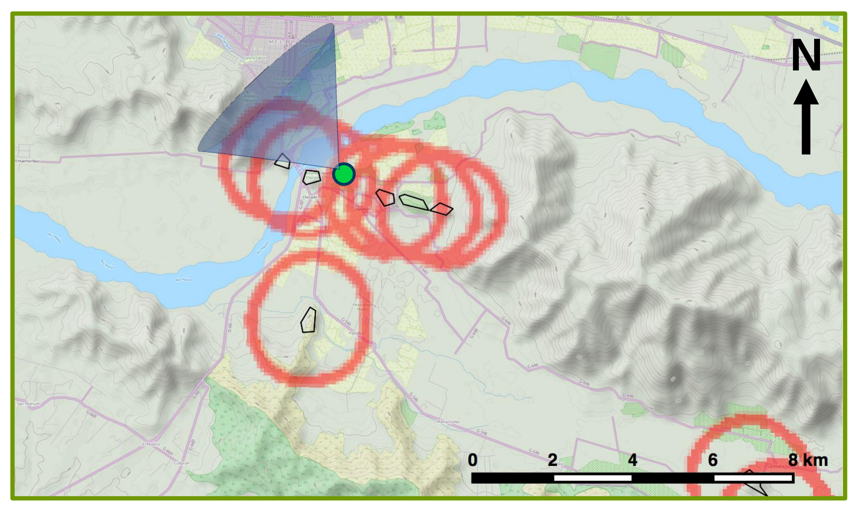
In the image to the right a user might select the knoll map layer and estimate its distance from the camera to be around one kilometer. Using a NND approach the actual camera location is missed due to a closer knoll not visible in the field of view.

Annotated test image, zoom shows knoll in detail



Distance to nearest knoll, range of 1-1.5km

MISS!



Distance to any knoll, range of 1-1.5km

HIT!

Why use distance bitmask?

- Distance to all objects encoded up to 32km.
- Objects binned in multi-resolution bands of three band, 16 bit raster.
- Overcome limitations of NND model, distances to all objects captured rather than distance to the closest object.
- Handle scenarios where object seen in image is not the closest object of that type to the camera.
- Maintain speed of search and efficiency of cached layer storage.

DBM Band Definitions

Bit	Band 1	Band 2	Band 3
0	Contained	1000-1499m	8500-9999m
1	0-99m	1500-1999m	10000-11499m
2	100-199m	2000-2499m	11500-12999m
3	200-299m	2500-2999m	13000-14499m
4	300-399m	3000-3499m	14500-15999m
5	400-499m	3500-3999m	16000-17499m
6	500-599m	4000-4499m	17500-18999m
7	600-699m	4500-4999m	19000-20499m
8	700-799m	5000-5499m	20500-21999m
9	800-899m	5500-5999m	22000-23499m
10	900-999m	6000-6499m	23500-24999m
11	1000-1099m	6500-6999m	25000-26499m
12	1100-1199m	7000-7499m	26500-27999m
13	1200-1299m	7500-7999m	28000-29499m
14	1300-1399m	8000-8499m	29500-30999m
15	1400-1499m	8500-8999m	31000-32499m

Future Work

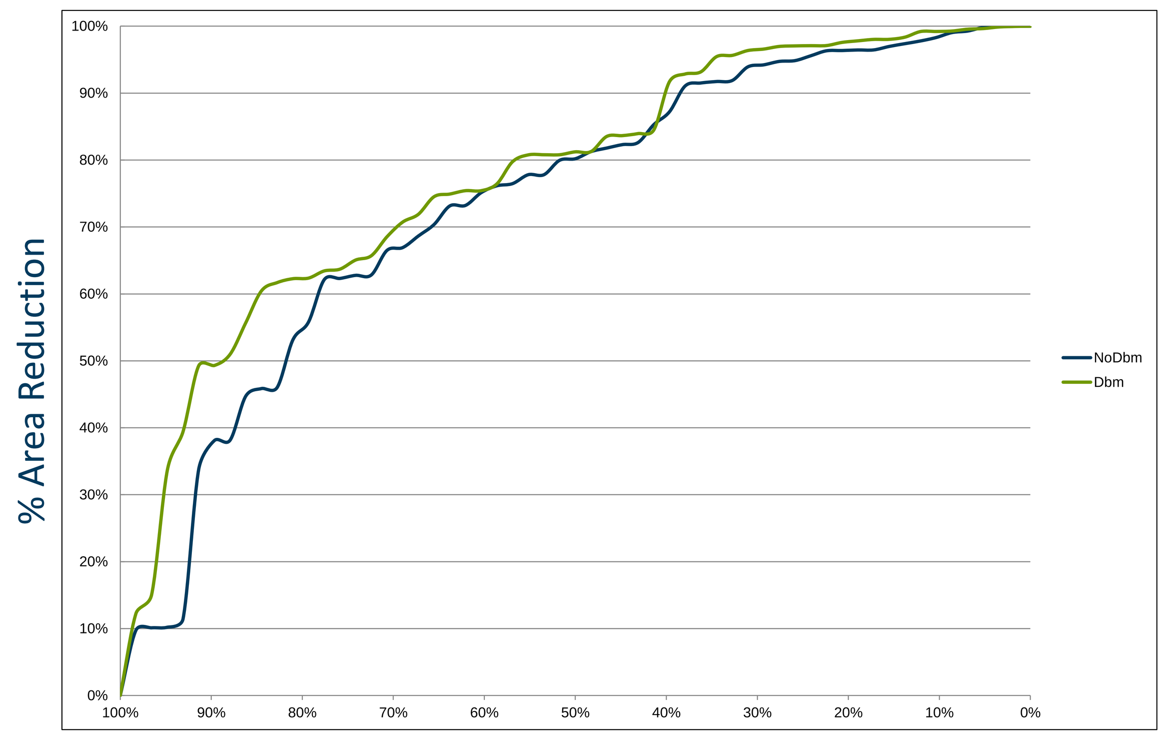
The current implementation of distance bitmasks includes features whether or not they are actually visible. Modern GPU technologies enable rapid viewshed computation. This can be used to perform visibility filtering of objects so that only distances to features that are visible are encoded into the distance bitmask. As many features within 32km are not actually visible, this will vastly improve area reduction performance.

Impact

Evaluation of distance bitmasks was performed on 200 test images with known camera locations in a 250,000km^2 study area.

- 83 out of 376 curated map layers were processed into DBMs.
- 58 out of 200 test images utilized at least one DBM layer.
- The average area reduction improved by **15.6%**.
- At a threshold of 5% of the search area we observed a **40%** increase in the number of captured camera locations.

Area Reduction Performance – DBM vs No DBM



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