Street-Level Green View Index (GVI) Estimation from Satellite Image

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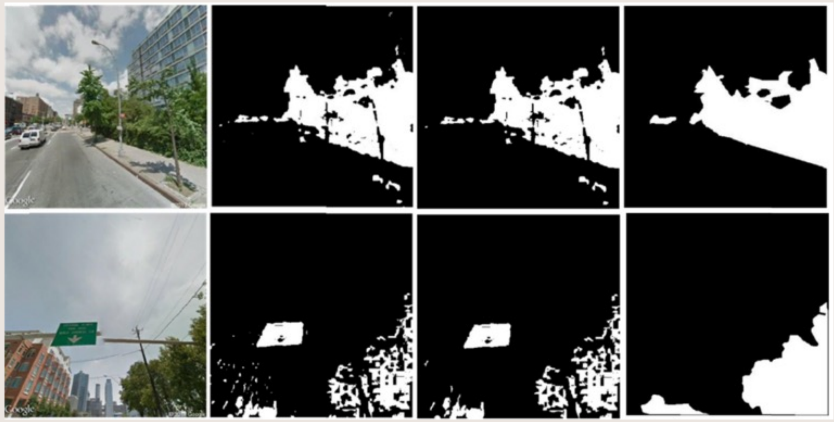
Background

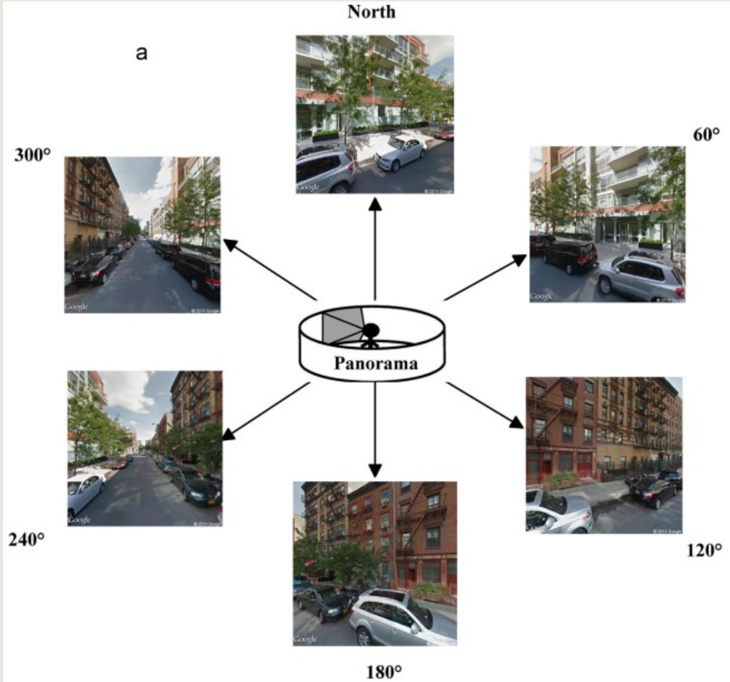
- **GVI (Green View Index)**:
  - An index to measure how much green one can experience when walking on the streets.
  - Can be calculated by the percentage of green pixels in **street view images**.
  - Can be used to describe **urban greenery quality**, e.g., how much the vegetations are benefiting citizens' living experience, especially along transport networks.

Source: Treepedia by MIT Senseable City Lab - Exploring the Green Canopy in cities around the world

Background

- **GVI (Green View Index) Computing**
  - **Street view images** can be created as the previews of the panorama from Google Street Views, for a specified location (coordinate)
  - Simply, the green percentage can be calculated by **green pixels**, while some other more advanced semantic-based CV models are available.





Source: https://doi.org/10.1016/j.ufug.2015.06.006

Background

- **Current gap/limits - mostly computed using Street View Images, therefore:**
  - **Poor data availability**: low update frequency, high collecting cost, limitedly available area, for it requires vehicles to drive through.
  - **Difficult format-control**: different panorama collecting configuration, different update frequency.
  - **Computing resource-consuming**: each point requires several panorama previews to process

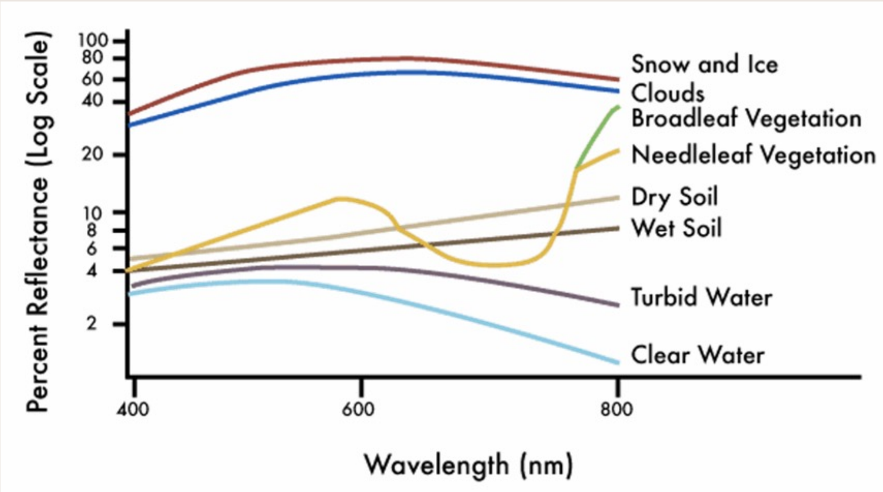
Question:

Can we make GVI calculation **less computing resource-consuming**, and **available at anytime & anywhere with low acquisition cost**?

Figure source: ArchDaily

Background

- **Satellite imagery & remote sensing (RS):**
  - Collected by sensors installed on satellites.
  - Different materials / surfaces display unique spectral signature.



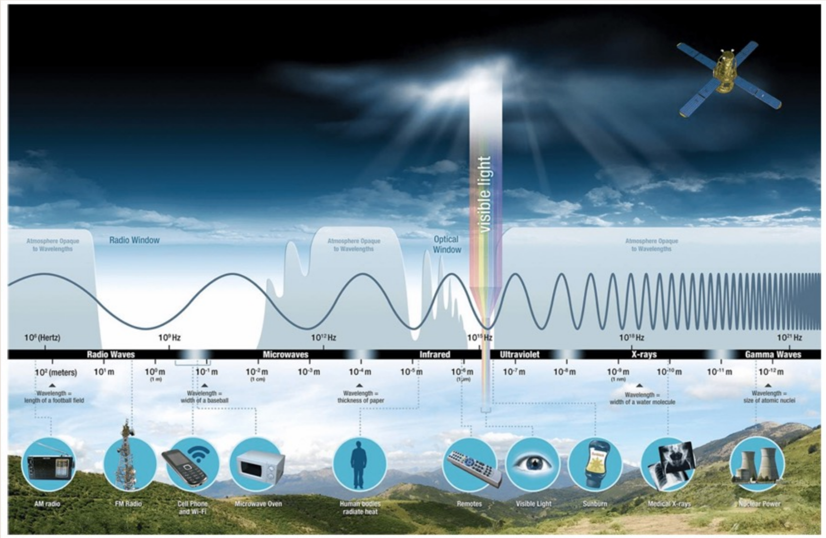


Figure source: NASA's Applied Remote Sensing Training Program

Methodology

- **Input features**
  - Eight interpretable ground features derived from Sentinel-2A (updated every five days; open access. Resolution of used bands: 10-20 meters). Positive correlation to the described feature.

NDVI Vege. Health & Density	**EVI** Enhanced Vege. Index	**MNDWI** Water Body Index
UI Urban Index	**MSAVI** Soil-Adjusted Vege.	**GNDVI** Green Vegetation
NDRE Chl Density	**BSI** Bare Soil index	

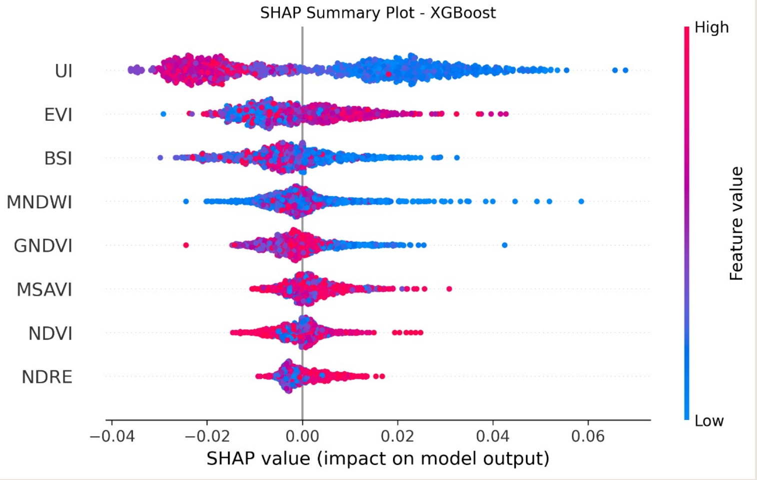
  - Multiple buffer sizes for scale impact analysis, ranging from 200m to 1000m.
- **True label processing**
  - Computed based on Google Street View (GSV) images.
  - Four directions a point for GSV retrieval. Mean value to represent the ground truth GVI.
  - Semantic / color range-based kernel for vegetation detection -> pixel percentage as GVI value.

Methodology

- **Tree-based models**
  - Input mean-aggregated values for each sample.
  - Focus on large-scale impact.
  - Tested models: Random Forest, XGBoost, LightGBM, Gradient Boosting.
- **CNN-based models**
  - Input raster data for each sample.
  - Focus on fine-scale analysis.
  - Tested structures: light-weighted CNN, simplified CNN, ResNet18 backbone pretrained on ImageNet.
- **SHAP analysis**
  - Conducted for feature importance investigation and explainable results.

Case study

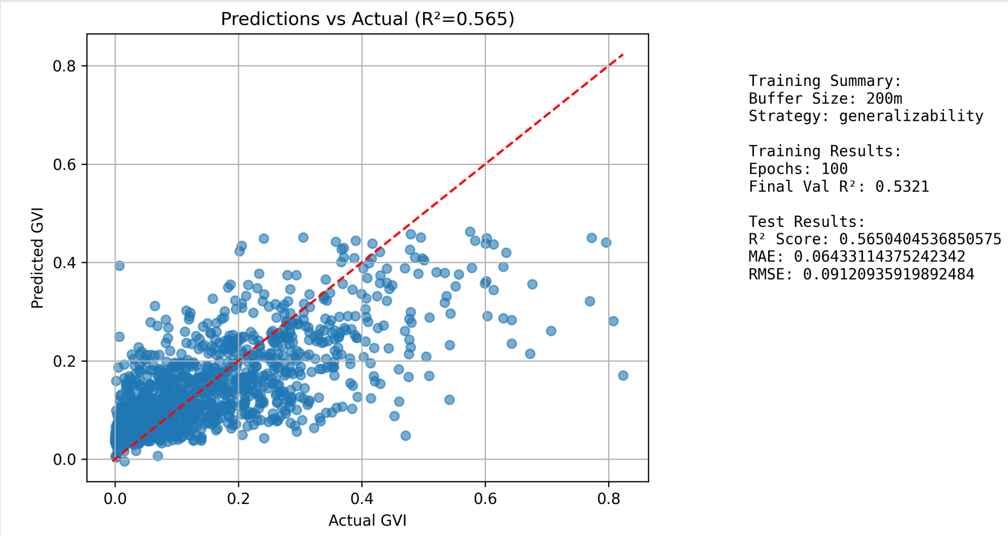
- **Single-city analysis**
  - ~6,300 sampled locations in densed area of Helsinki.
  - Tree-based model tested, R-square: 0.670; buffer size: 1000m; resolution: 20m).
  - SHAP analysis conducted for feature importance investigation.



Model	Test R^2	Test MSE	Test MAE
Linear Regression	0.3054	0.0021	0.0345
Ridge	0.3071	0.0021	0.0345
Lasso	-0.0008	0.0030	0.0431
ElasticNet	-0.0008	0.0030	0.0431
Decision Tree	0.4015	0.0018	0.0284
Random Forest	0.6600	**0.0010**	0.0218
Gradient Boosting	0.6554	**0.0010**	0.0226
XGBoost	**0.6704**	**0.0010**	**0.0221**
LightGBM	0.6687	**0.0010**	**0.0221**
SVR	0.0512	0.0028	0.0447
KNN	0.5901	0.0012	0.0248

Case study

- **Multi-city analysis**
  - Totally ~11,000 samples from 13 European cities:
    - Sweden / Stockholm
    - Finland / Helsinki
    - Denmark / Copenhagen
    - Germany / Berlin, Hamburg, Dusseldorf
    - Spain / Barcelona
    - UK / London, Manchester
    - Greece / Athen
    - Italy / Bologna, Milan
    - Estonia / Tallin



  - Generalizability test for CNN training
    - Forming test set using samples from unseen cities (marked with underlines).
    - Test R-Square = 0.565 (buffer size: 200m; resolution: 20m)

Key findings and discussions

- **For the single-city analysis (Helsinki):**
  - Tree-based models, despite poor generalizability, performs better under large buffer (1000m).
  - In SHAP analysis, UI, BSI, and EVI dominate for feature importance, while NDVI is not the most influencing among vegetation-related features.
- **For the multi-city analysis, the CNN models:**
  - Display better performances under smaller buffer (200m), and show potentials in good generalizability.
  - Achieve higher accuracy in low-value samples. This may be due to lack to of high-value samples for the model to learn about the patterns, or high-value cases require finer scales of information.

References

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