

Peer Effects in Rooftop Solar Adoptions

Bryan Bollinger, Ken Gillingham,
A. Justin Kirkpatrick, Steve Sexton

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Justin Kirkpatrick
Duke University
Michigan State University



Motivation

How do visible peer installations affect solar installation decisions?

- Nearby panels
- Own panels

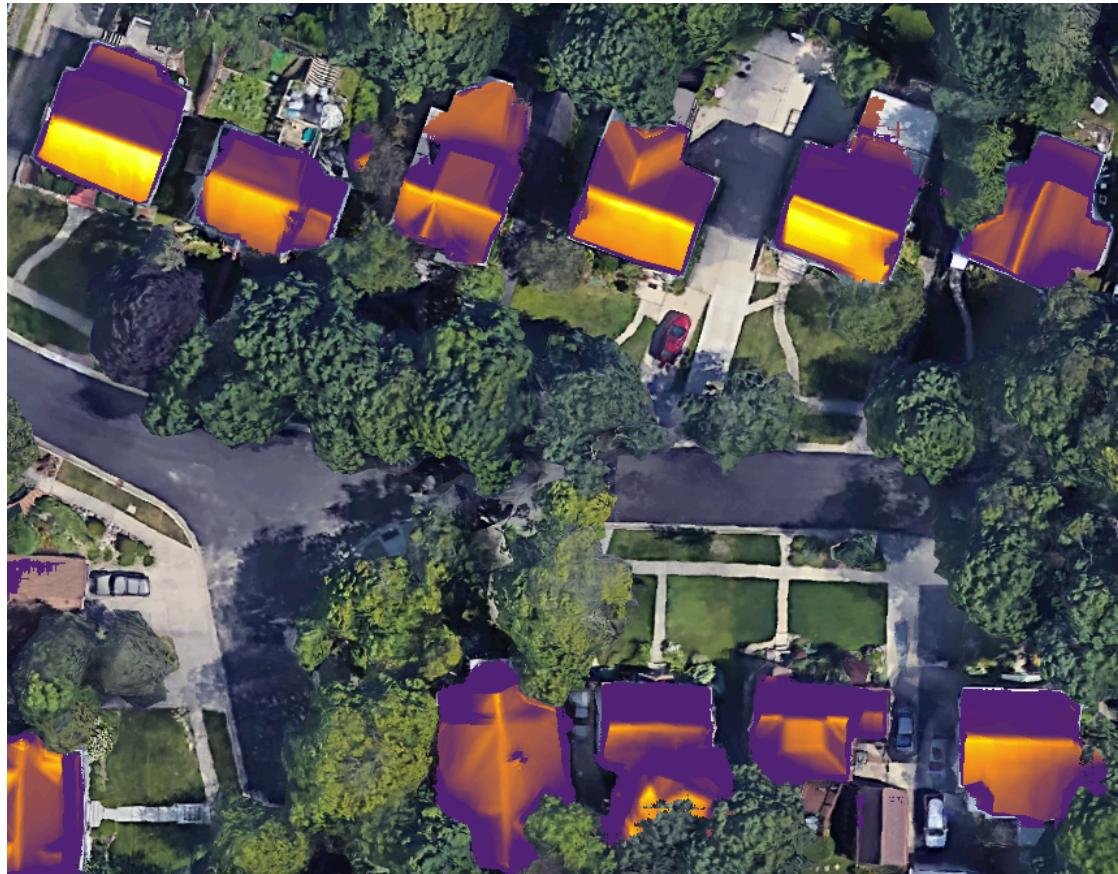
Why?

- Policy implications
 - non-pecuniary inducement for green behavior
 - “Conspicuous green consumption”
 - Externalities
- Marketing implications

Motivation

A common problem in peer effects studies is exogeneity of the peer variable.

- Visibility of a panel is plausibly exogenous.
 - North vs. South side of the street:



Motivation

Visibility is a function of both angle from street
and obstructions

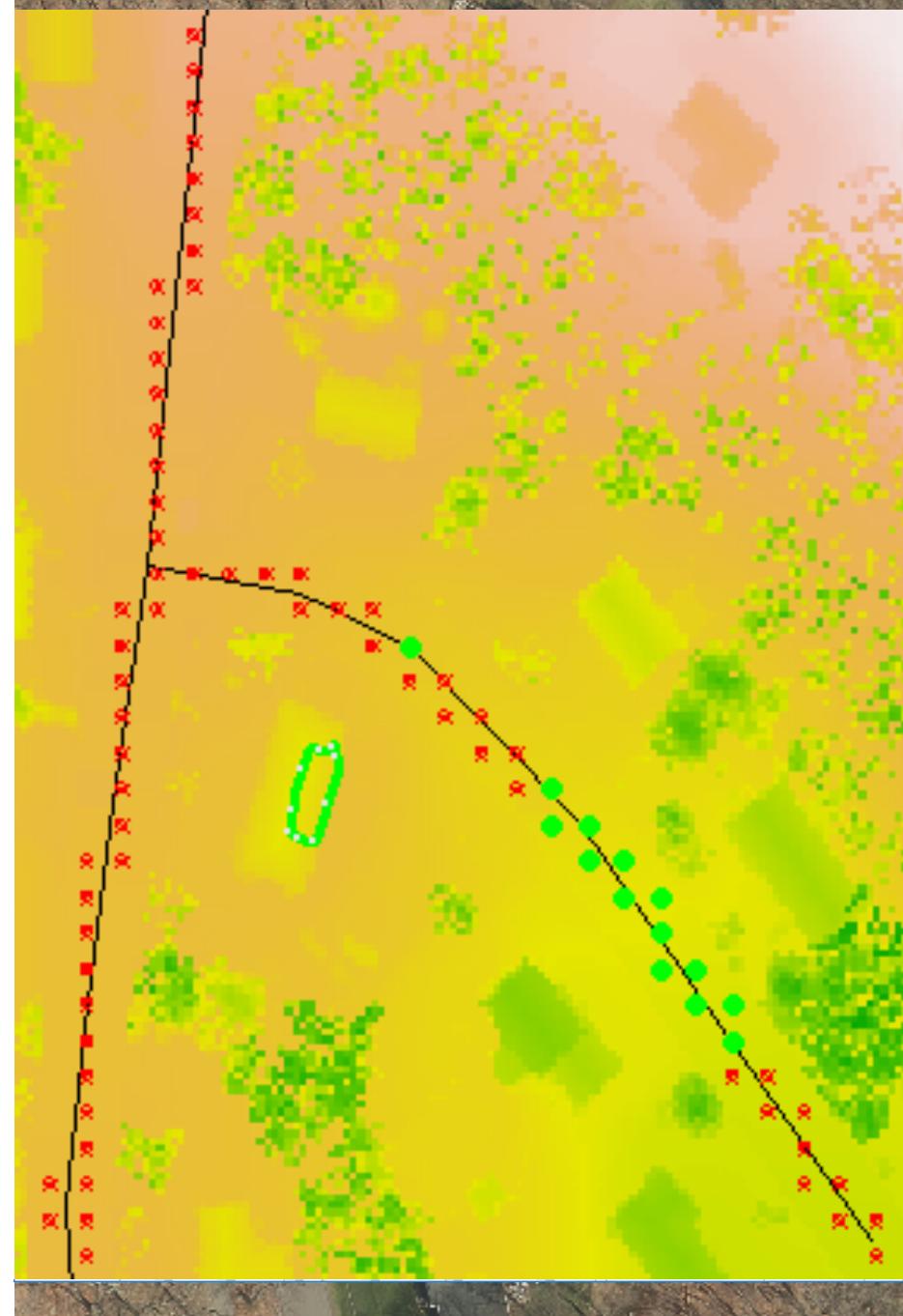
Naïve methods:

- Send RAs out to assess
 - Lang and Opaluch (2014) with turbines in RI
- “North side of street”
 - East/west streets and obstructions ignored

Overview

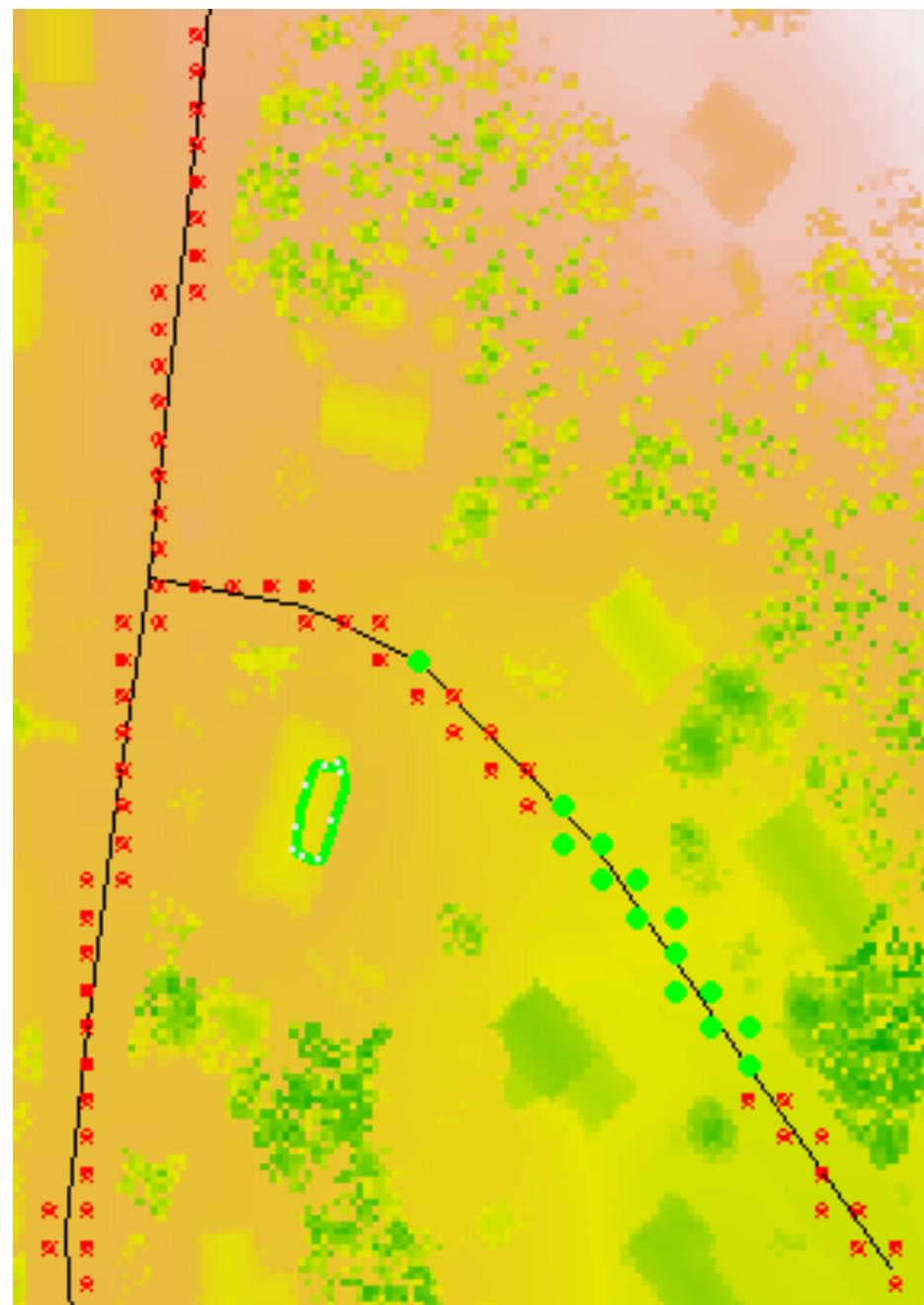
To assess the angle of visibility and obstructions in each solar panel:

1. CNN to recognize and bound panels
2. LiDAR (3-D point cloud) to test angle of visibility
3. LiDAR to assess obstructions
4. Generate panel-level measure of visibility



Overview

- Machine learning
 - Panel recognition
- Novel data application
 - LiDAR for visibility



Data Sources

- 816k homes in CT (CoreLogic; Zillow Ztrax)
- 15,440 known solar installations w/address
 - Date applied, date completed
- Voter affiliations for 663k households
- Misc:
 - Geocode addresses to lat-lon
 - Streets from ESRI CT streetmap

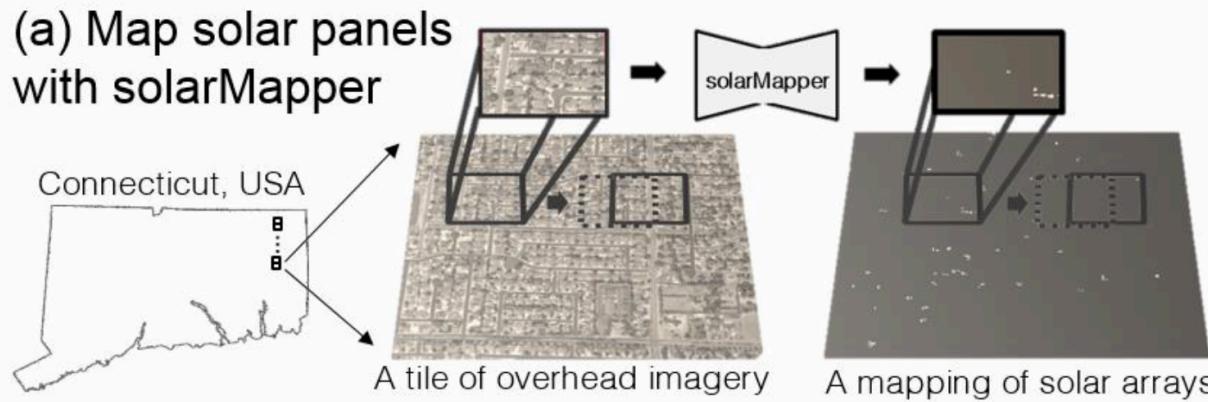
Data Sources

- Google Project Sunroof (515k homes in CT)
 - Ordering of rooftop locations (w/ pitch, azimuth)
 - NPV of installation accounting for electricity rates
 - Spatial match to houses
 - Proprietary data

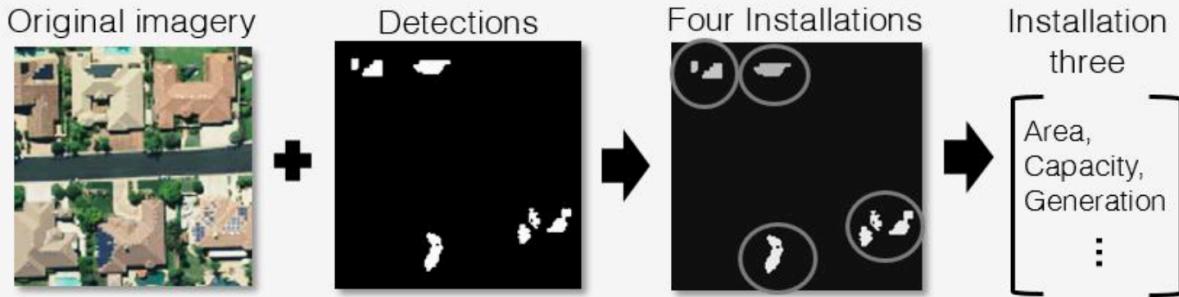


Methods

- CNN semantic segmentation (Malof et al., 2016, 2019)



(b) Infer useful information



- Pixelwise prediction of presence of solar panel
- Fit to maximize *Intersection over Union* (IOU)

Methods

- Trained on publicly accessible Duke California Array Dataset (Bradbury et al., 2016)
- 16,000 labeled arrays in 400km² of imagery

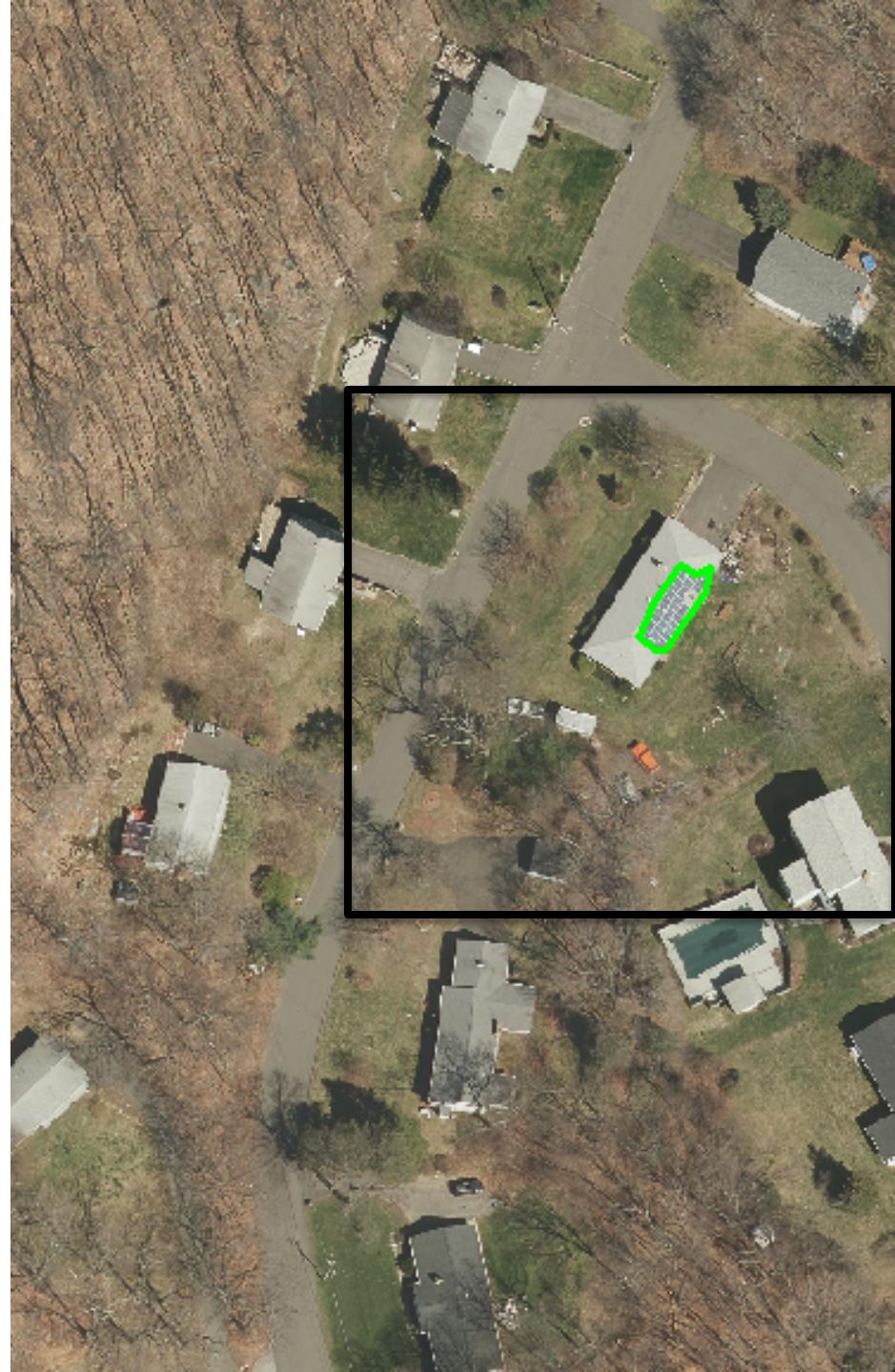
The screenshot shows a figshare dataset page. At the top, there is a logo for figshare, a 'Browse' button, and a search bar with the placeholder 'Search on figshare...'. Below the header, there is a thumbnail icon followed by the title of the dataset: 'Full Collection: Distributed Solar Photovoltaic Array Location and Extent Data Set for Remote Sensing Object Identification'. To the right of the title, it shows '3323 views' and '1 citations'. Under the title, there is a 'AUTHORS' section listing several names: Kyle Bradbury, Raghav Saboo, Timothy Johnson, Jordan Malof, Arjun Devarajan, Wuming Zhang, Leslie Collins, and Richard Newell. Below the title, there is a red 'Follow' button and a yellow 'Version 2 (old) ▾' button. It also states 'Published on 25 Sep 2016 - 14:28 by Kyle Bradbury'. A descriptive paragraph at the bottom explains that Earth-observing remote sensing data, including aerial photography and satellite imagery, offer a snapshot of the world from which we can learn about the state of our environment, anthropogenic systems, and natural resources. The components of energy systems that

Methods

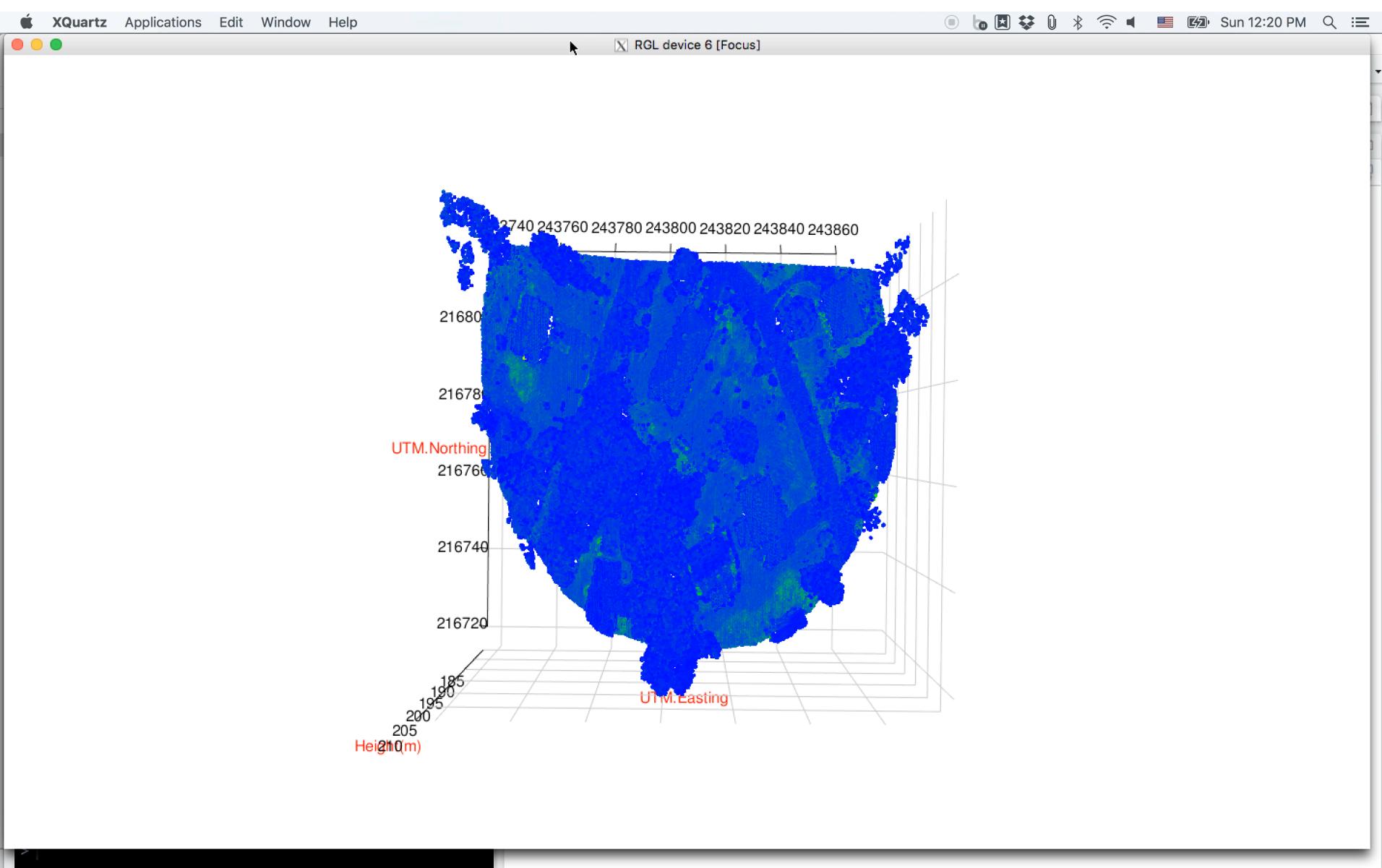
Transfer learning
method to apply to
Connecticut.

Using [UCONN CTEO](#)
satellite imagery (2016)

Publicly available as
SolarMapper



Methods – LiDAR

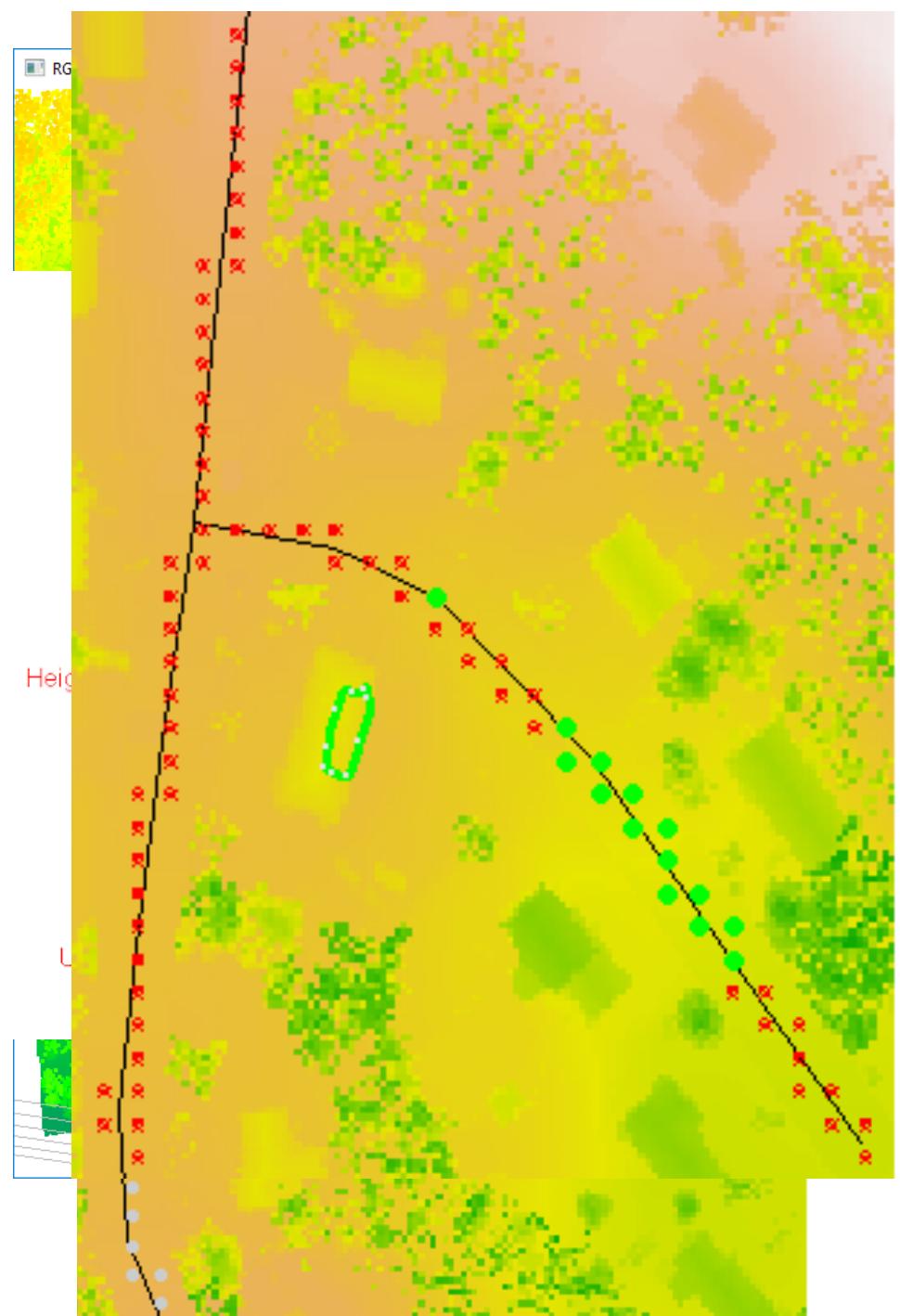


Data Sources - LiDAR

- “Light Detection and Ranging”
 - 3-D Point Cloud
- Publicly available: NOAA and USGS
 - Hurricane Sandy, floodplain mapping
 - Frequently found alongside DEM and DSM surface models
- Processing with *r/rlas* in R
 - Generate queryable tile mapping
 - Process over 15,400 known solar installations

Methods - LiDAR

- For each panel, download all LiDAR within 120m
- Subset to those LiDAR points within the panel polygon
- Regress Z on X + Y to get pitch
- For obstructions, rasterize surrounding area.
 - Fill grid cells with some function (max, median) of LiDAR points



Methods - LiDAR

The screenshot shows the RStudio interface with the following details:

- Top Bar:** RStudio, File, Edit, Code, View, Plots, Session, Build, Debug, Tools, Window, Help.
- Toolbar:** Go to file/function, Addins.
- Source Panel:** Contains R code for visualizing LiDAR data. The code includes logic for determining line colors based on visibility (red for not visible, green for visible, yellow for angular visibility but obstructed), plotting lines, and points. It also handles text output for each point and includes a sleep function for visualization.
- Environment, History, Files, Packages, Viewer Panels:** Standard RStudio navigation tabs.
- Plots Panel:** Shows a blank plot area with various controls like Zoom, Export, and Help.
- System Status:** Top right shows battery level, signal strength, and system time (Sun 12:15 PM).

```
## Visualize the process:
if(draw==T){
  if(text.vis.n=="Not
visible") linecol = 'red'
  if(text.vis.n=="VISIBLE") linecol='green'
  if(text.vis.n=="Ang.
vis but obstructed") linecol='yellow'
  plot(view.line.n, add=T, col=linec
ol, lwd=3)
  cat(paste('For (ud,t,n)=(',ud,',',
t,',',n,), angular visibility is', tn.hol$vis[n],
'and is.obstructed is li
kely', tn.hol$obs[n],'-->',text.vis.n, '\n', sep=" "))
  if(pause>0) Sys.sleep(pause)
} # end visualize process
} # end n loop
test.coords[t,"angular.vis"] = sum(tn.hol$vis)>0
test.coords[t,"angular.vis.and.not.obstructed"] = sum(
tn.hol$vis*(!tn.hol$obs))>0 #--> gives 1/0 for "is angular
rly visible and is NOT obstructed"
if(draw==T){
  point.color='red'; point
.pch=13; point.size=1
if(test.coords[t,"angular.vis.and.not.obstructed"]>0) { po
int.color='green'; point.size=2; point.pch=16}
plot(test.coords.spat[t,], add=T, col=point.color, cex=poi
nt.size, pch=point.pch)
} # end t loop
Detection ID 1547-1
```



Other uses

- Assessing disamenity value
 - Wind turbines (Lang and Opaluch, 2014)
 - Presence of fracking
 - Hedonic models
- Proxy for information set
 - Knowledge of environmental bad
 - Questions regarding salience

Model

Linear probability model:

$$y_{it} = \alpha[CT]_{it} + \gamma_1[Vis]_{it} + X_{it}\beta + \epsilon_{it}$$

$$y_{it} = \alpha[CT]_{it} + \gamma_1[Vis]_{it} + \gamma_2[EV_i \times Vis]_{it} + X_{it}\beta + \epsilon_{it}$$

$[y_{it}]$ Binary indicator for installation in month t

$[CT]_{it}$ Count of peer installations.

$[Vis]_{it}$ Degrees of visibility from the street of **peer** installations.

$[EV]_i$ Own-value (NPV) of installation (Google Sunroof)

X_{it} Control variables, including fixed effects, Solarize.

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justin.kirkpatrick@duke.edu