Novel uses of smartphones in transportation

Christoph Mertz

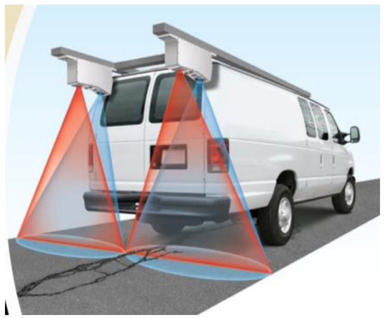
11/01/2015

Smartphone Revolution

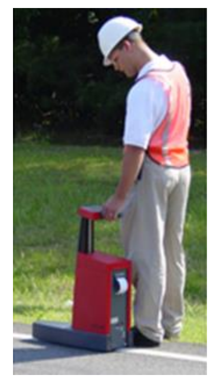
Nice for entertainment, especially for the kids…

Smartphones for infrastructure monitoring

Road damage



Lane marking retroreflectivity



Traffic sign retroreflectivity


...

Consumer Sensors

Smartphone
$300
Camera
GPS
Wi-Fi
Accelerometer
Compass
Computing
3G/4G

Vehicle State

Samsung Galaxy Camera
$500
Android (everything but the phone)

16 MP => 4 Hz for 20 images
1040p => 30Hz
640x480 => 120 Hz
21x zoom
Optical stabilization
Select ISO, exposure, aperture
Gyro

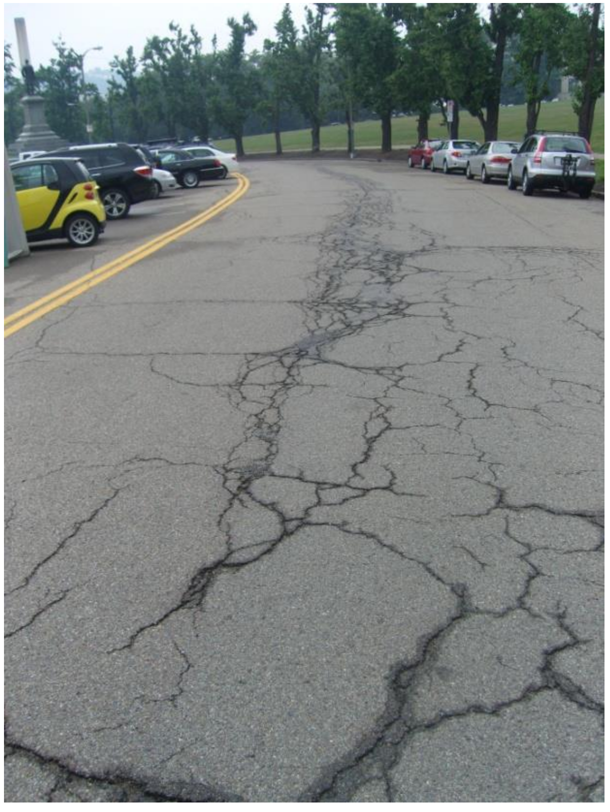
OBDII
$15
Bluetooth or Wi-Fi
Ignition on/off
Speed
Temperature
Barometric pressure
RPM
Many more

The inventory of public infrastructure maintained by the streets/parks Maintenance Division includes:

- **866 lane miles of asphalt streets.**
- **90 lane miles of concrete streets.**
- **80 lane miles of brick and block stone streets.**
- **620 signalized intersections**
- **655 sets of city steps, covering 22 lineal miles.**
- **4400 street lighting fixtures.**
- **850,00 street signs.**
- **1,672 City lots part of parks, greenways and City government facilities.**
- **7,600 City, County ,and Board of Education jointly owned lots.**
- **195 park facilities and various green spaces.**
- **330 Athletic Courts**
- **128 Athletic Fields**
- **134 play areas consisting of playgrounds, parklets, and tot lots.**

Public Works Headquarters 301 City-County Building 414 Grant Street Pittsburgh, PA 15219 412-255-8850

Goal of proposed system



Monitor road surface damage

- inexpensively

- accurately

- continuously

Mounted in car

Smartphone mounted on the windshield

Powered from cigarette lighter

Install it on any vehicle that regularly drives in the city

Low Cost

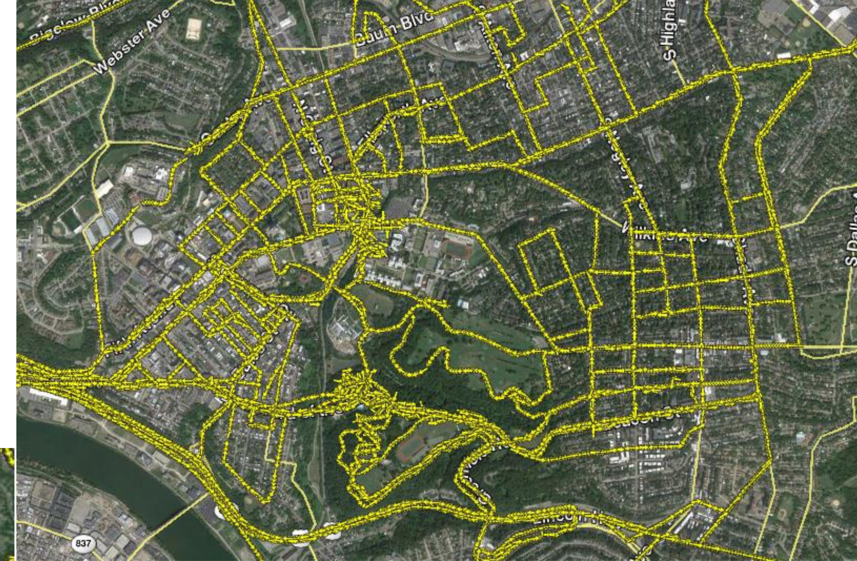
- Consumer Device

- Free/inexpensive/existing software and services
  - Dropbox, Google Earth, Open Source software, GIS
- Minimal labor
  - Collection by vehicle that drive for other purposes
  - Automate processes and analysis

Example Input Video - 10 Hz

Data overview

2 years
250 hours
11k videos
7M images
1000 km unique roads



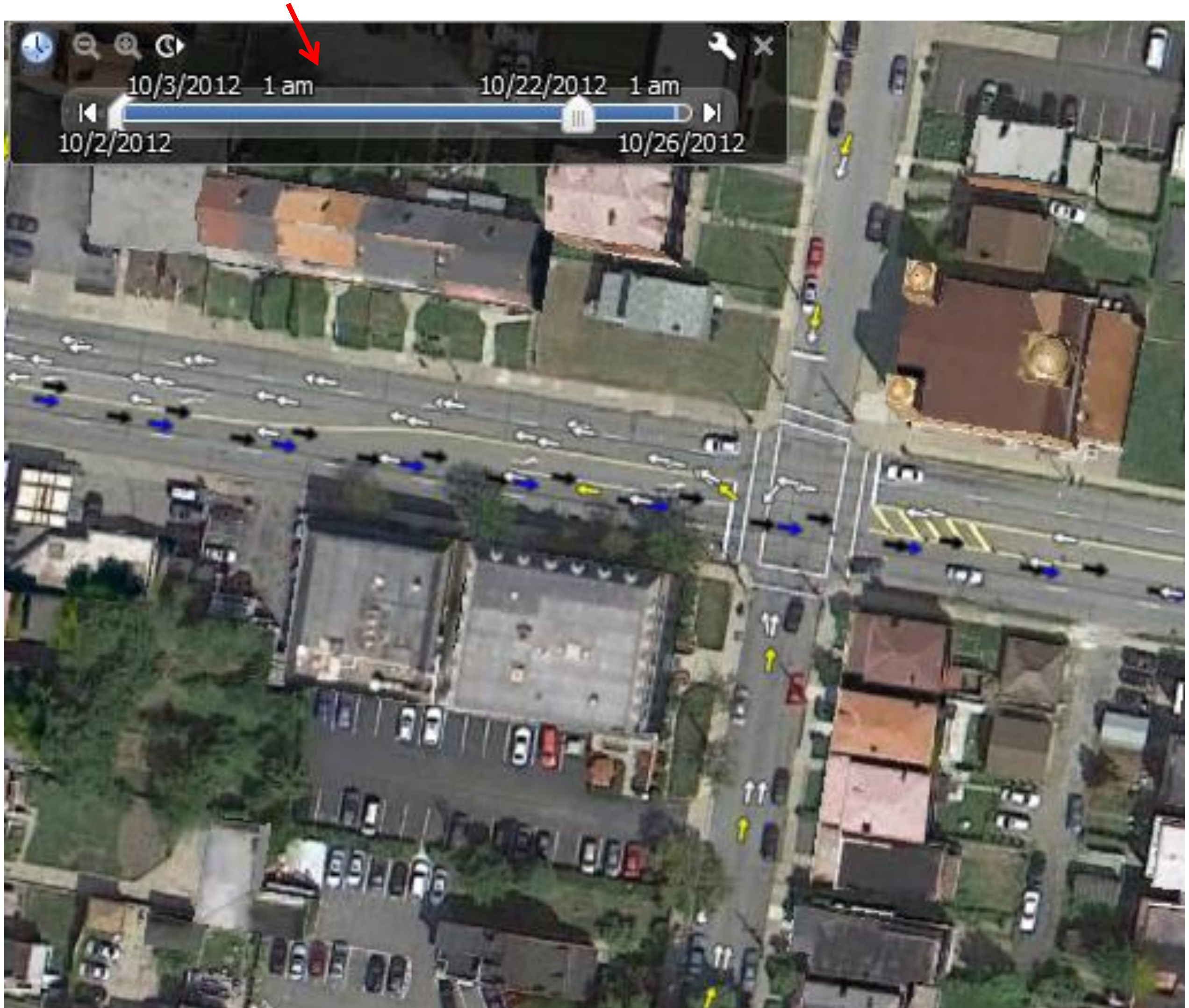
CMU

Pittsburgh

Pennsylvania

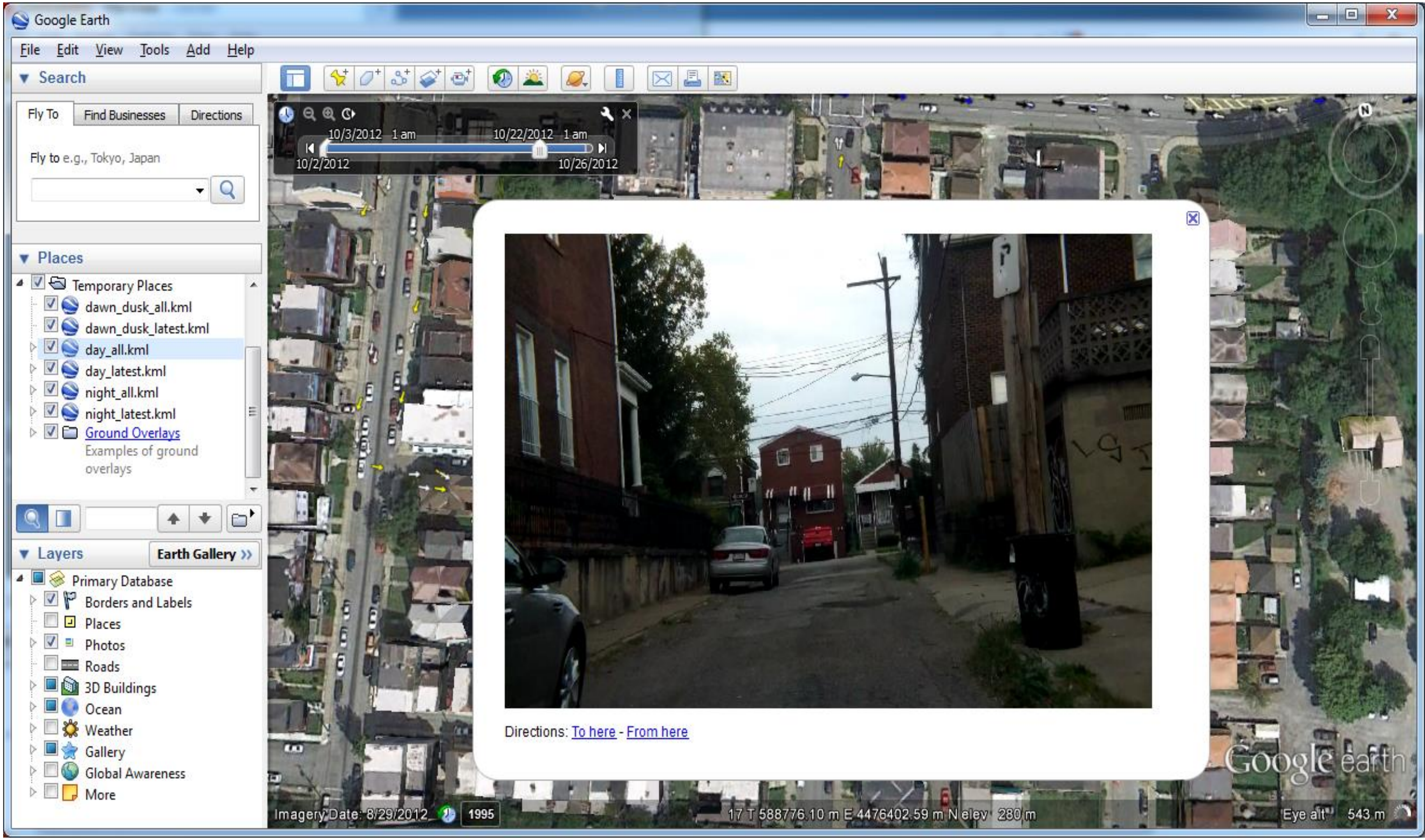
Display: Google Earth

Select time window

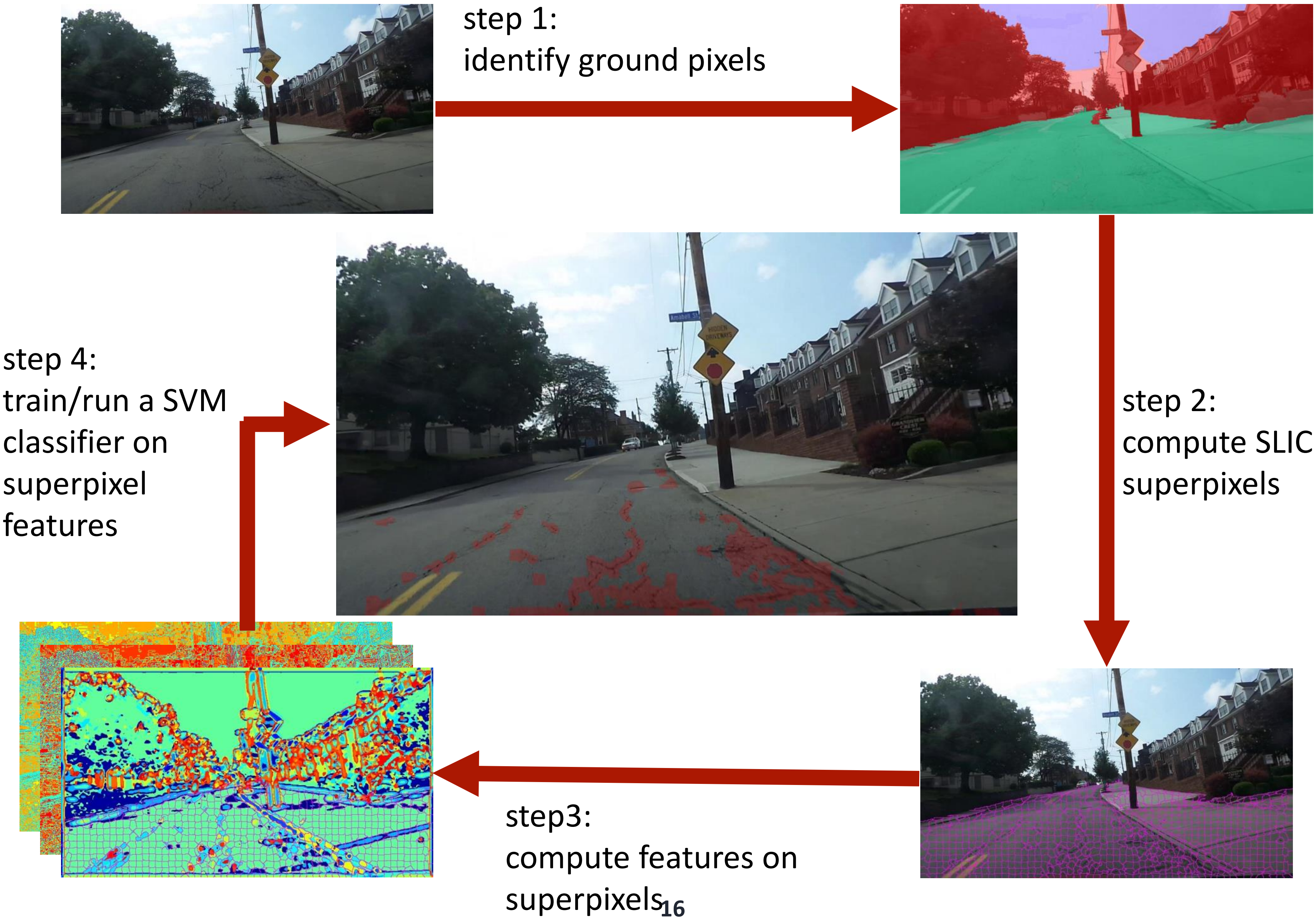


- Day latest
- Day all
- Night latest
- Night all
- Dawn/dusk latest
- Dawn/dusk all

Display raw images



Automatic Road Damage Detection


step 1:
identify ground pixels
step 2:
compute SLIC
superpixels
step3:
compute features on
superpixels
step 4:
train/run a SVM
classifier on
superpixel
features

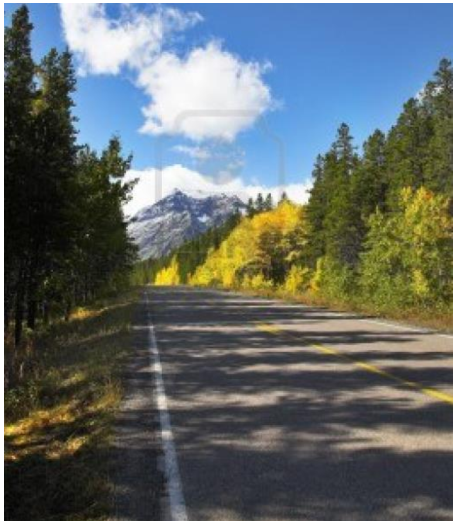

Amabell St
HIDDEN
DRIVEWAYS

Final Result

no damage some damage lots of damage

Computer Vision is difficult!

- Rule of thumb:
  - 80% detection is doable
  - 95% detection is very hard
  - ~~99% is almost impossible~~
  - 99% needs deep learning and lots of labeled examples (100K)



Advantage of lots of data

- Select data during the day when it was overcast (good illumination, no rain, no shadow)
- Select data during spring and summer (no snow, no leaves)
- Score the same road many times

Some human interaction needed

- Check periodically to ensure quality.
- System should flag borderline cases.
- System should flag things that don’t make sense
  - Sudden changes from one collection to another
  - Things that have not been seen before

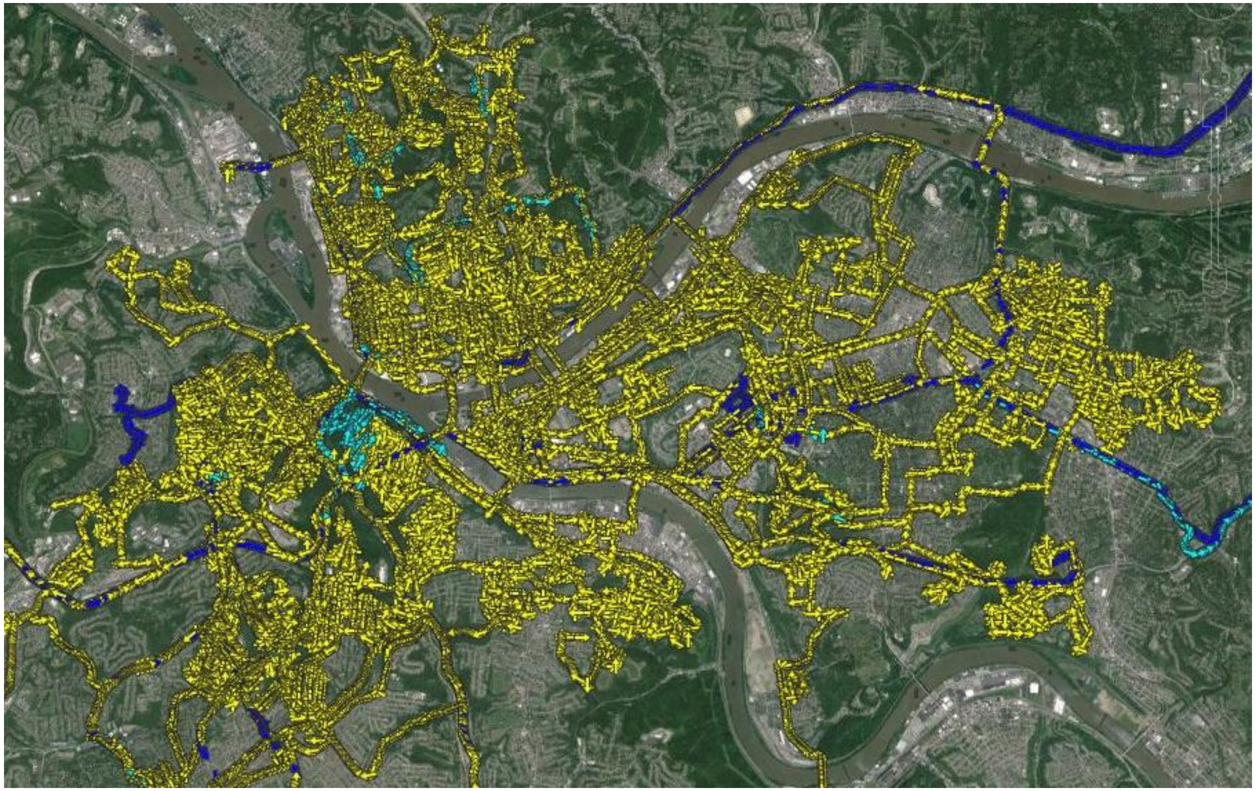
On the other hand…

- In some things computers are much better:
  - Human: judging crack vs. good road vs. shadow
  - Computer: Measuring areas

General lesson: Don’t just trust the computer, work with it!

Pilot Test in Pittsburgh

- Mounted data collection system on 3 Pittsburgh vehicle
- Implement road assessment into their infrastructure management system.



Road Condition Reporting

Clear

Significant snow cover

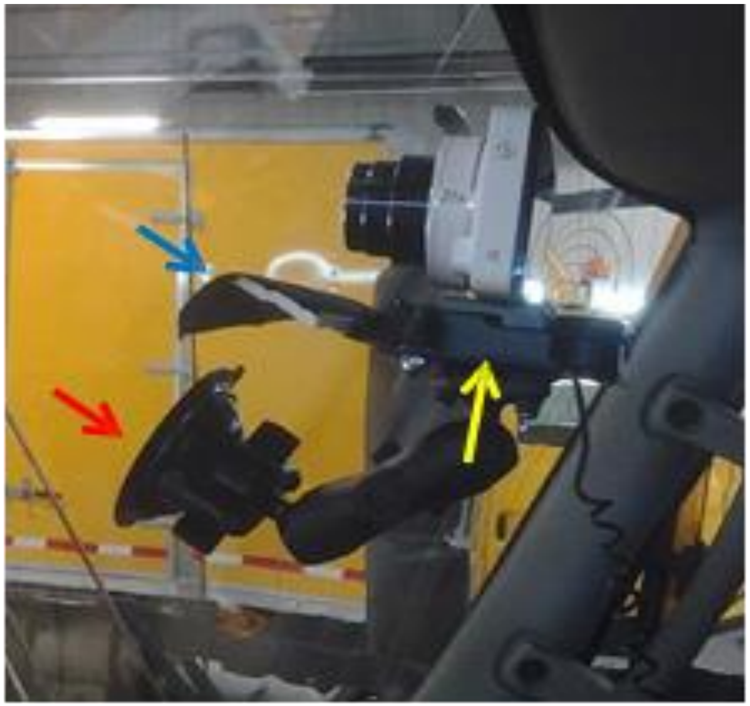
Wet with freezing conditions

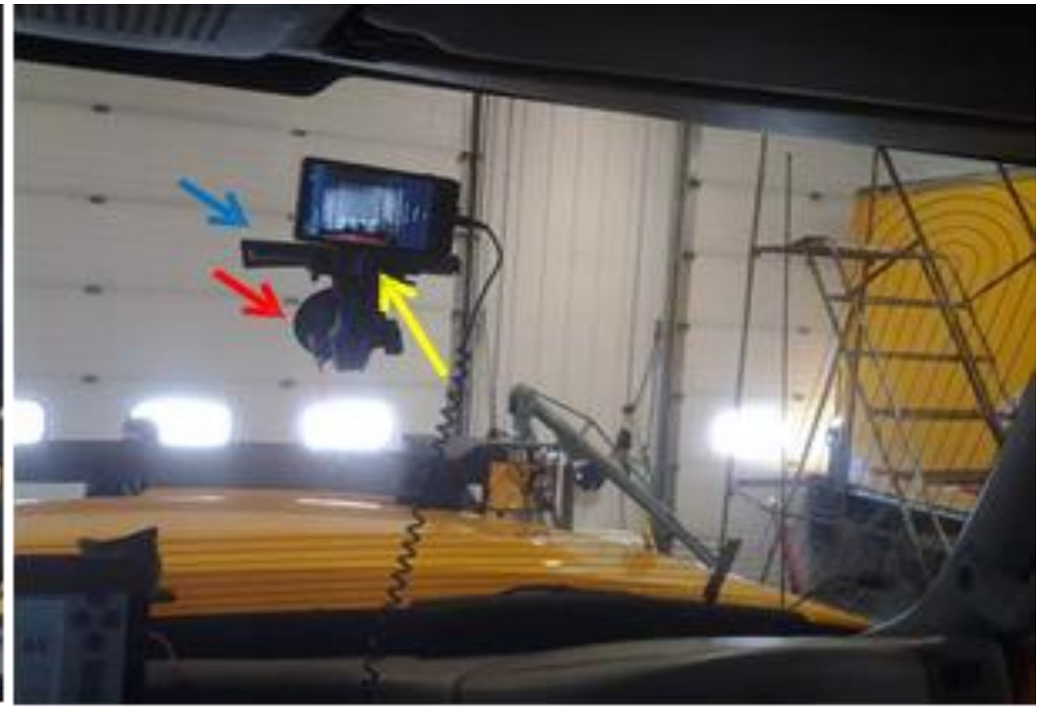
Icy

Snow and/or slush covered

impassable

Camera Mount





Suction Cup
Quick release
Black Felt Shield

Data Collected

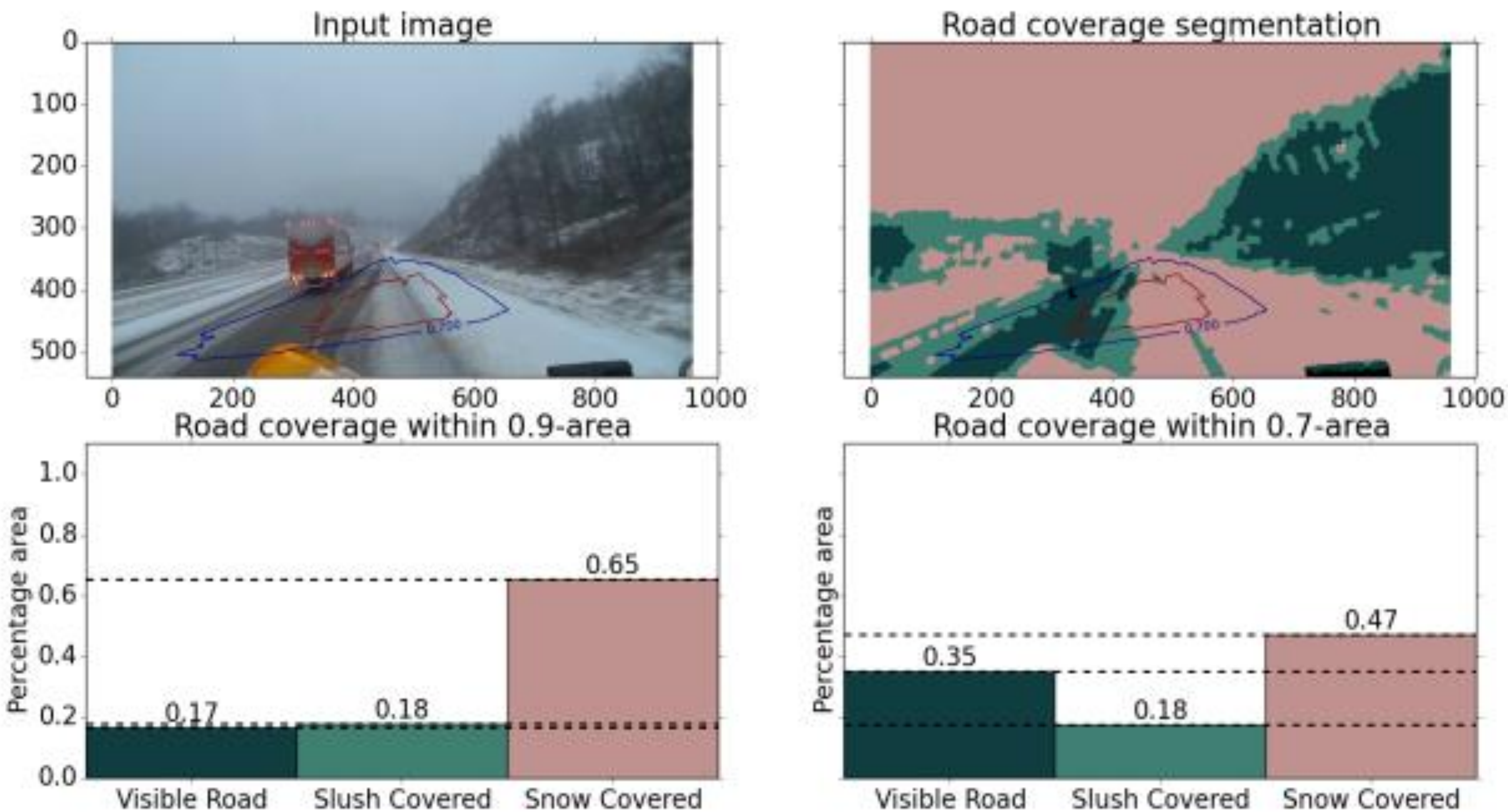
- Almost 40 hours of data
- 23 shifts (some are a few minutes, others several hours)
- Two snow plows in two districts (D-4 and D-9)

Sample Images -day




Sample Images - night

Determining road/slush/snow using computer vision



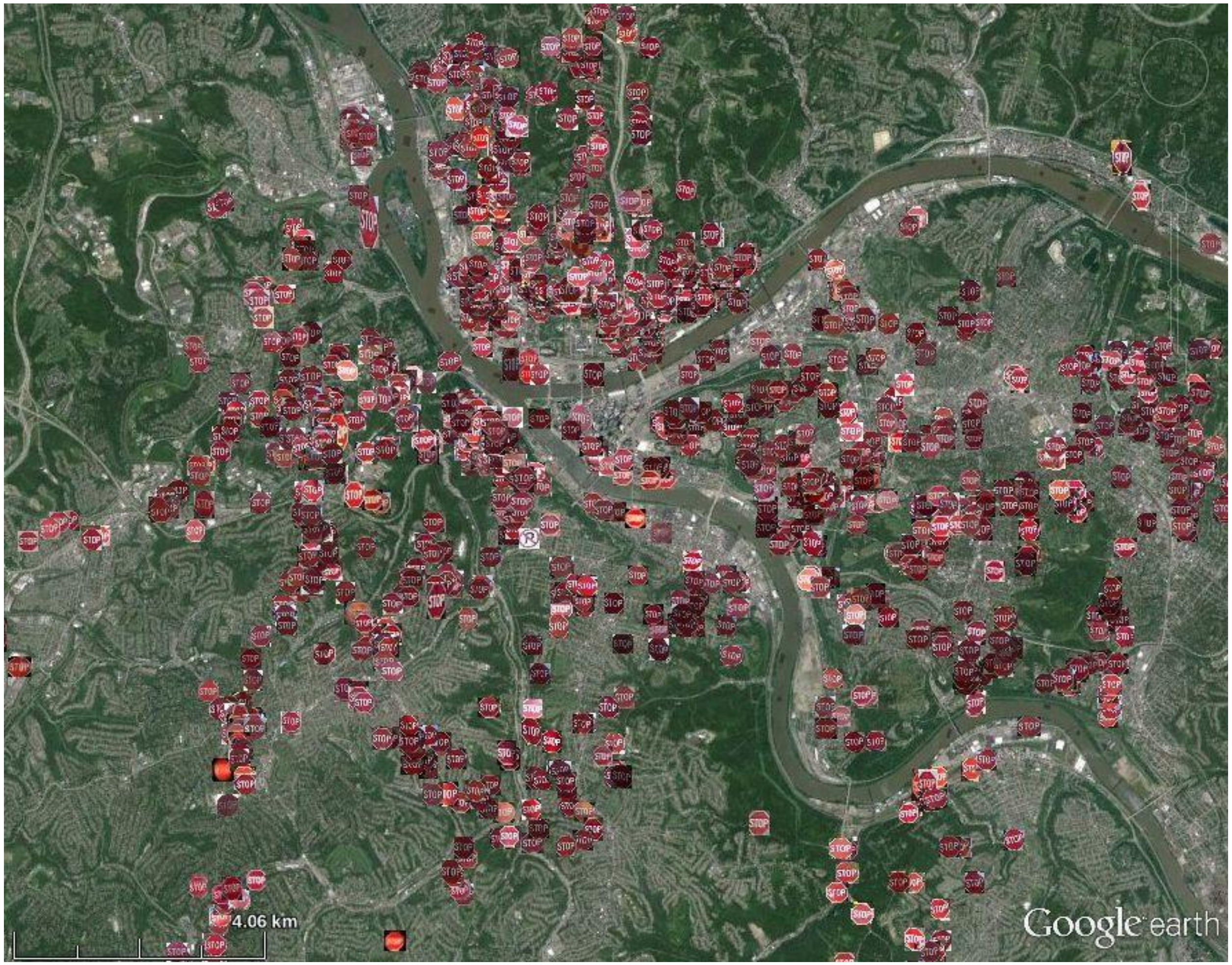
Road directly in front of snow plow

Road including adjacent lanes

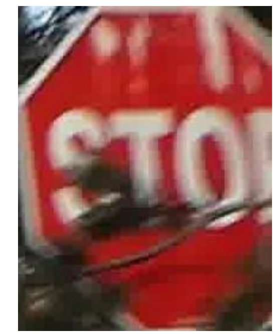
Sign detection

Stop Sign Detection

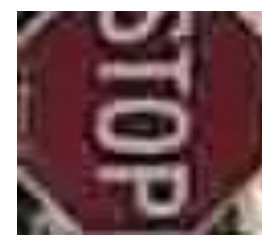
- Inventory of stop signs
- Detect problems



sticker


occluded

graffiti


displaced

Lane Marker

- Find lane markers
- Determine quality

good

damaged

Inspection Possibilities

Algorithm developed

Pilot Phase

Wires: Tree overgrowth

weather

Vegetation overgrowth

Signs: Damage, fading, graffiti

Building: Graffiti, code violation

Sidewalk: Damage, accessibility

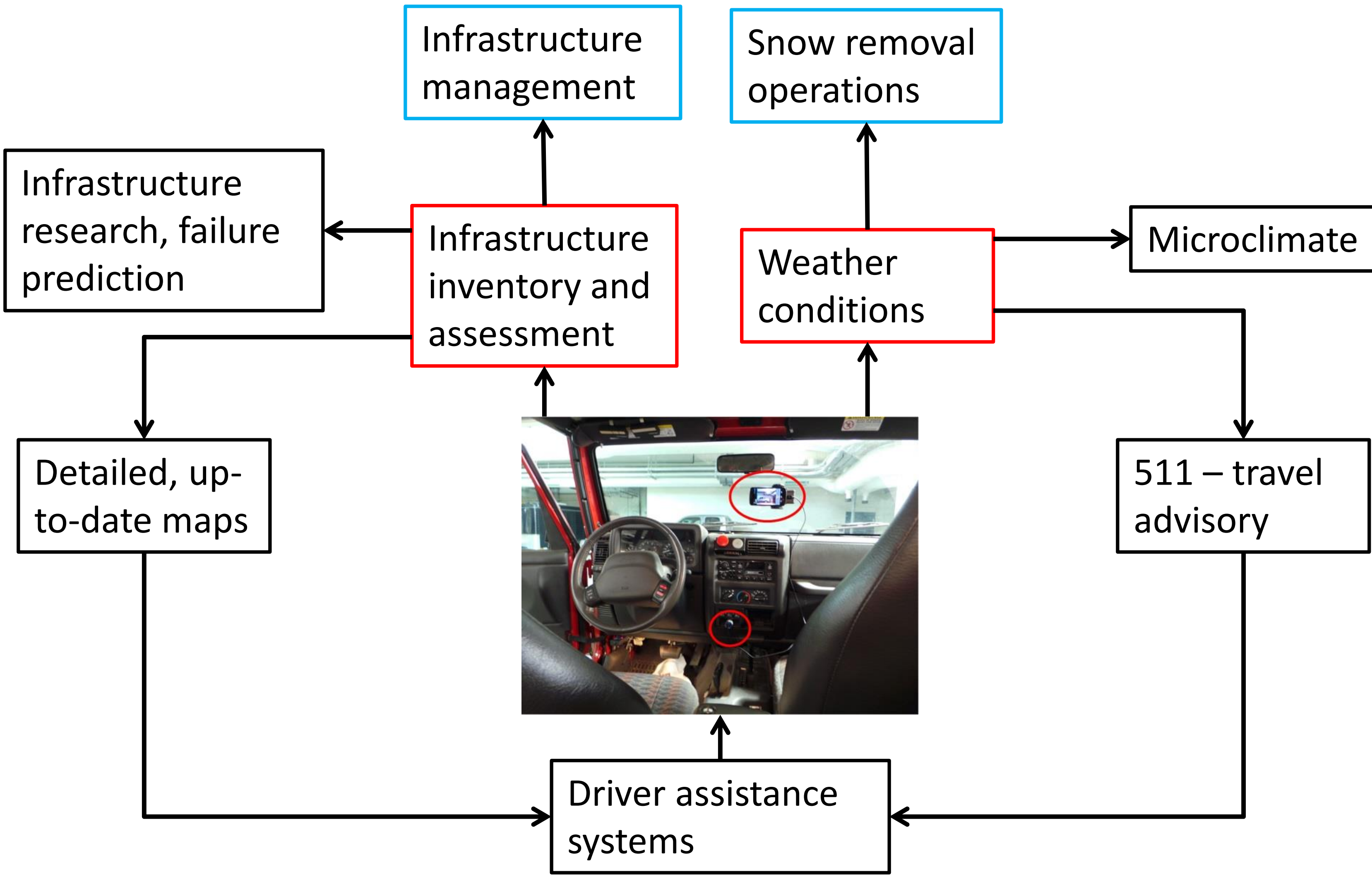
Drainage

Lane markers: Damage, fading

Development started

Pavement: Damage

Long Term Outlook: Part of I/O devices in a car



3D reconstruction from images

3D accident reconstruction from images

- There is very little time to record an accident scene.
- Laser scanners are very expensive.
- Currently 3D reconstruction is only done for fatal accidents:

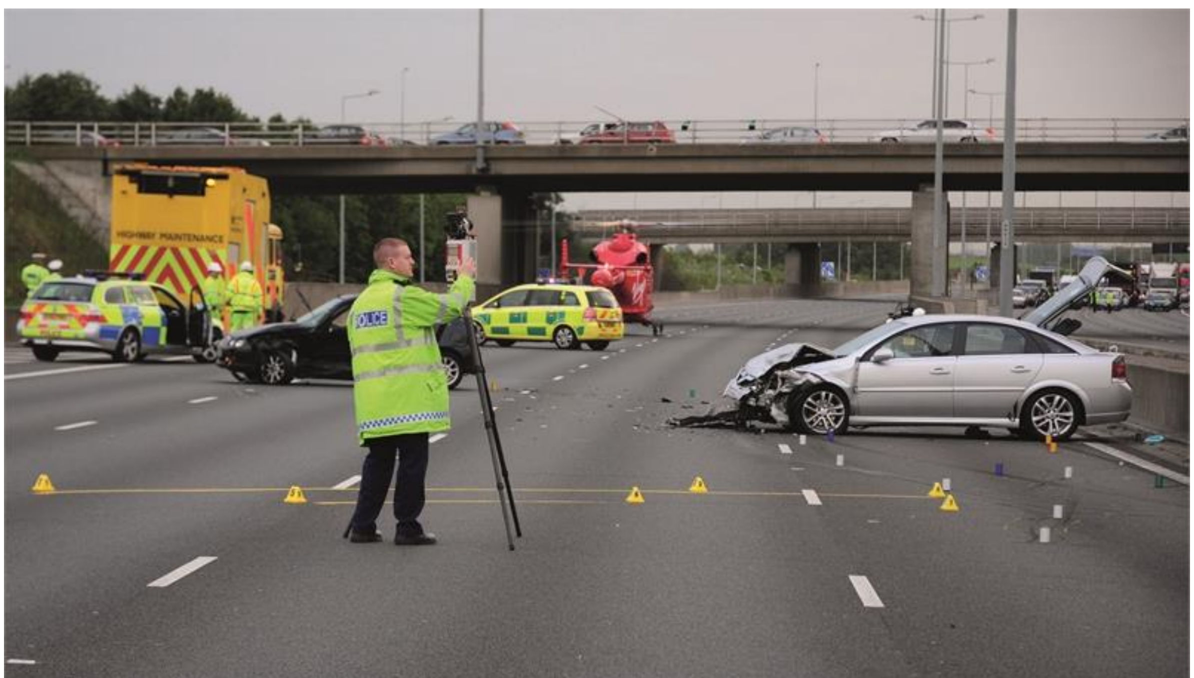
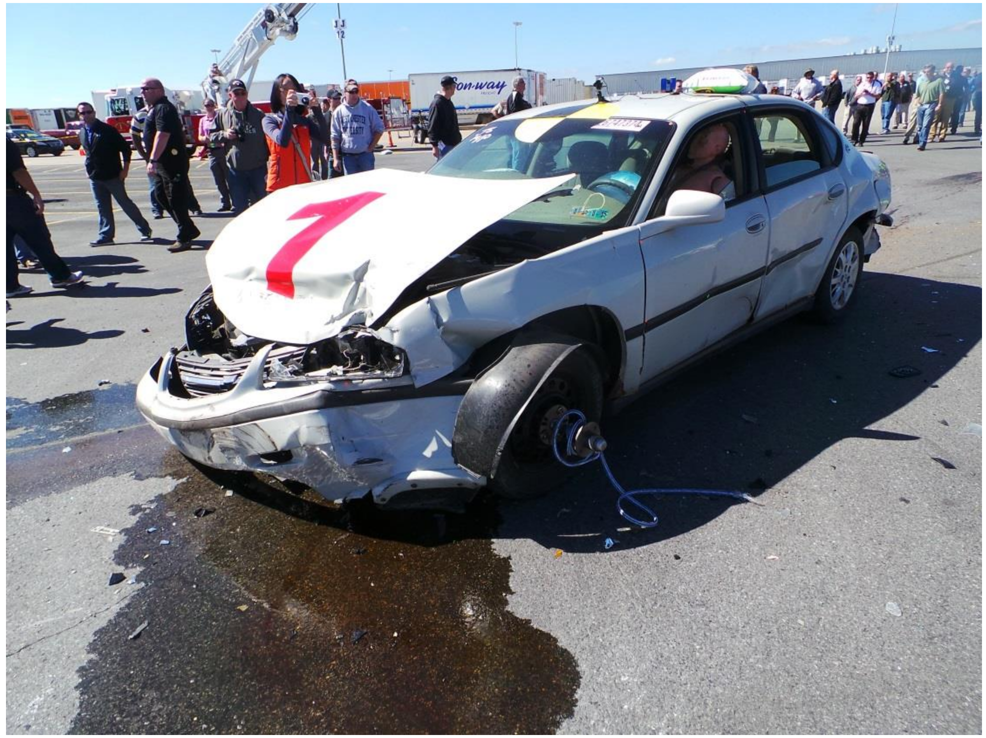


Image from http://www.hendonpub.com/law_and_order/articles/2014/06/3d_laser_scanning

Staged Crash




20140923_125653.JPG
20140923_125656.JPG
20140923_125658.JPG
20140923_125703.JPG
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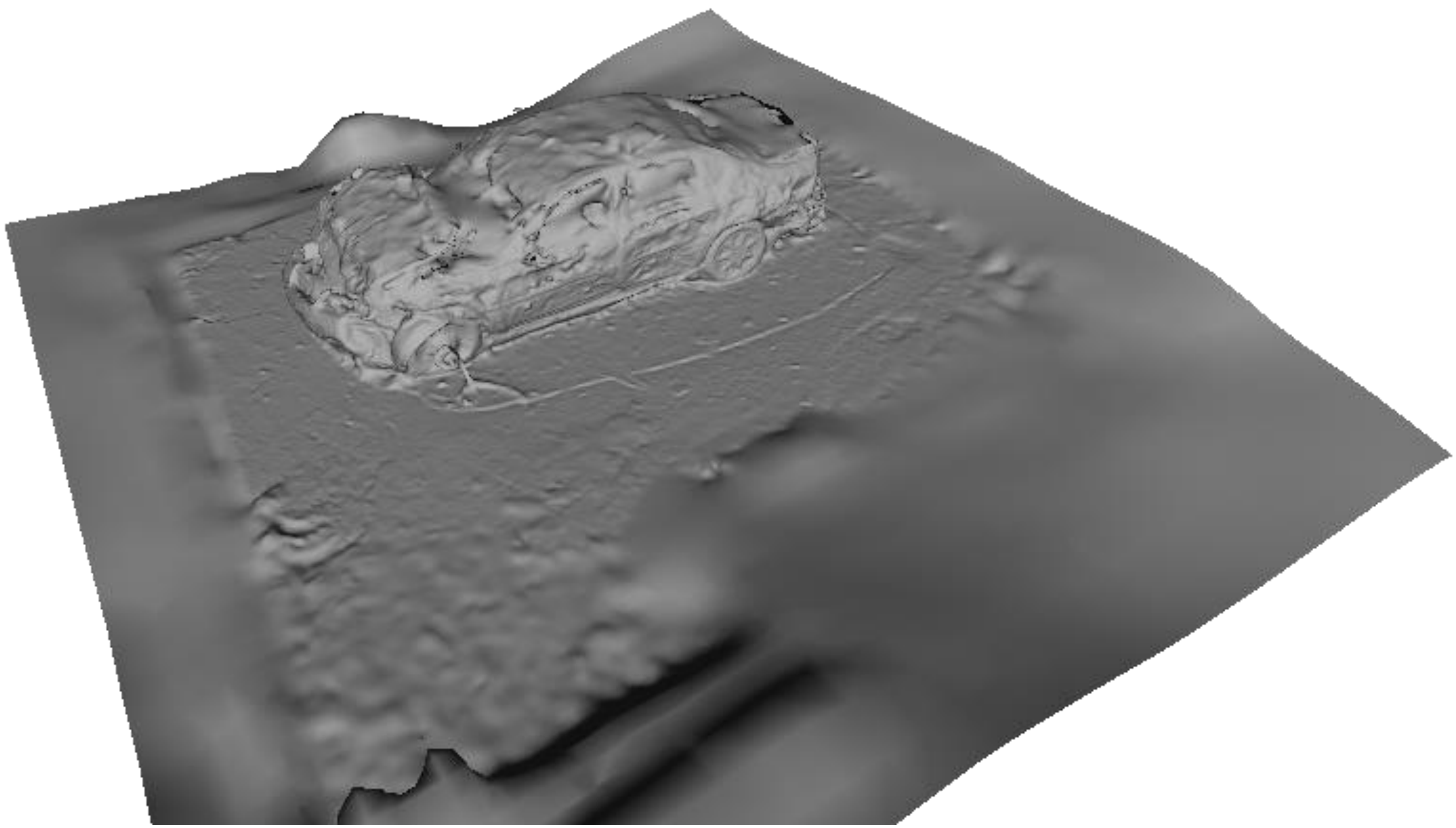
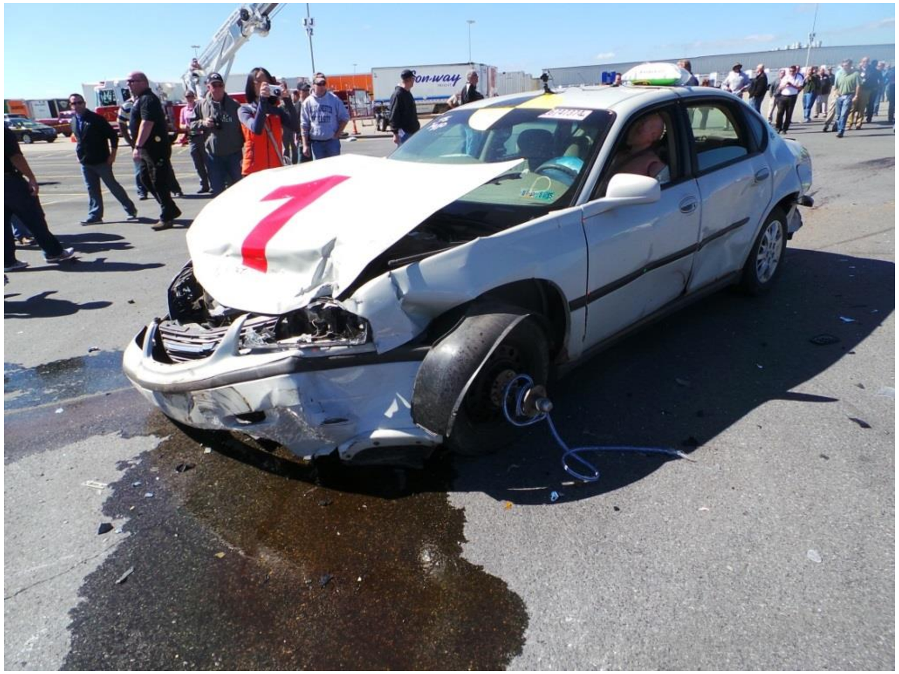
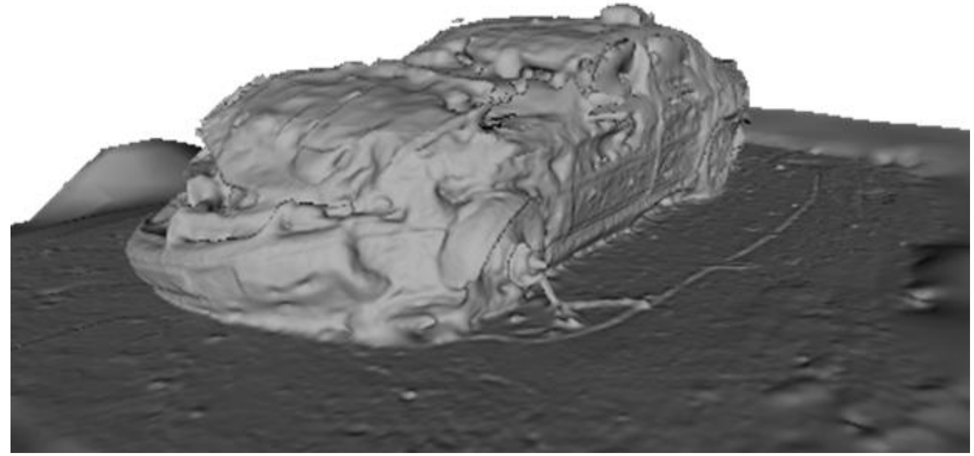
3D Model



Colorized 3D model



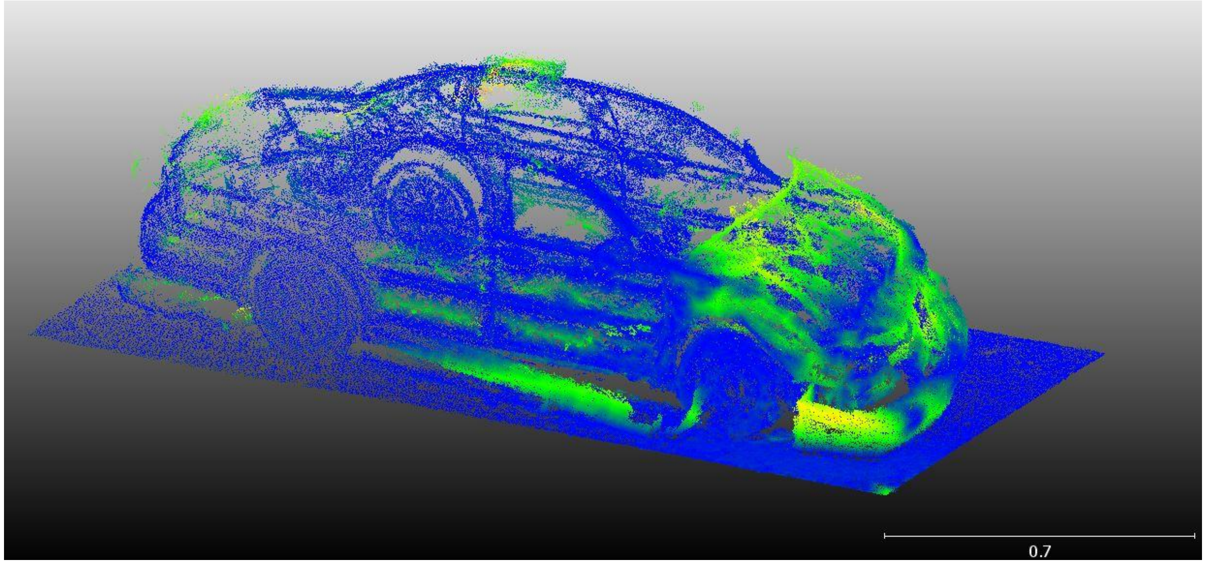


Before and after crash comparison

Photo before crash

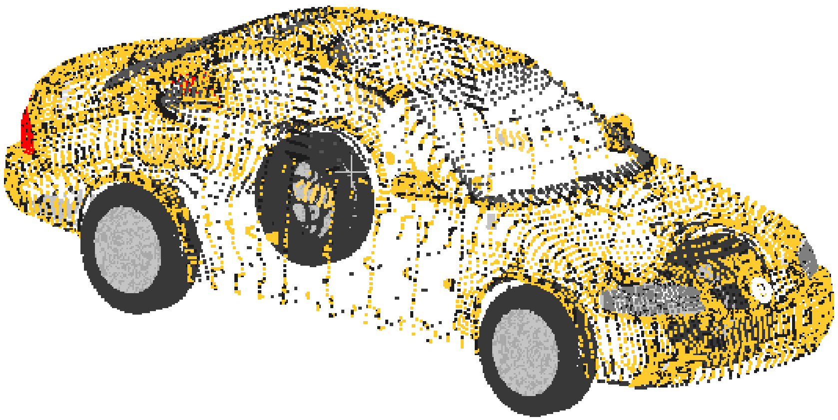
Photo after crash

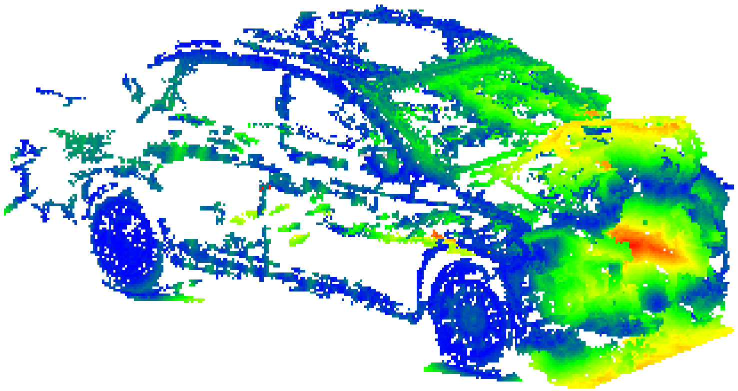
The 3D models of before and after the crash are aligned and compared. The differences in the models are highlighted.



⇒ **Accident investigation**
⇒ **Crashworthiness research**

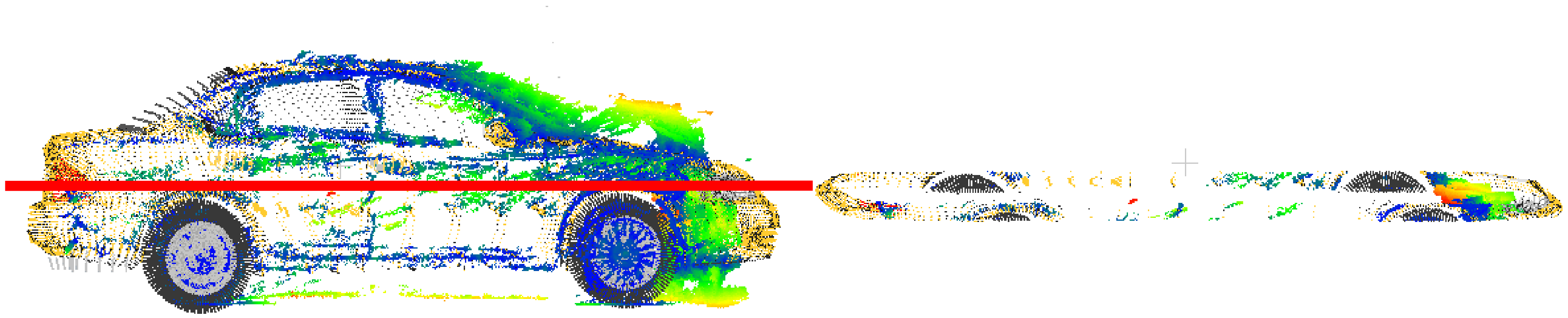
Compare crashed vs. new

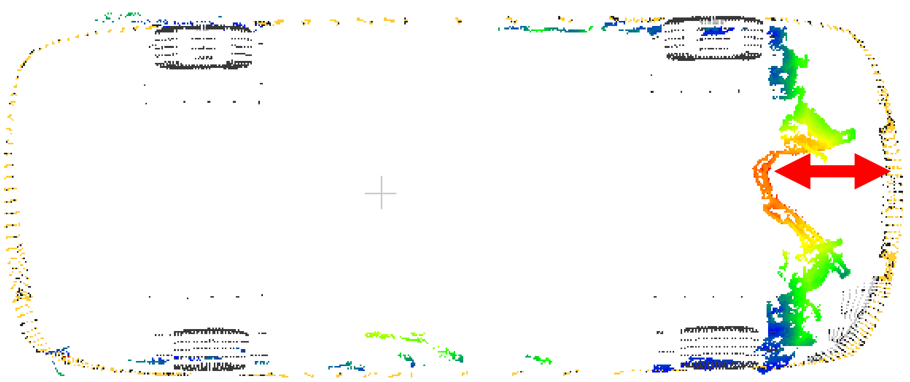




Color indicates the distance of the point from the crashed car to the new car

Top-down view after aligning two models

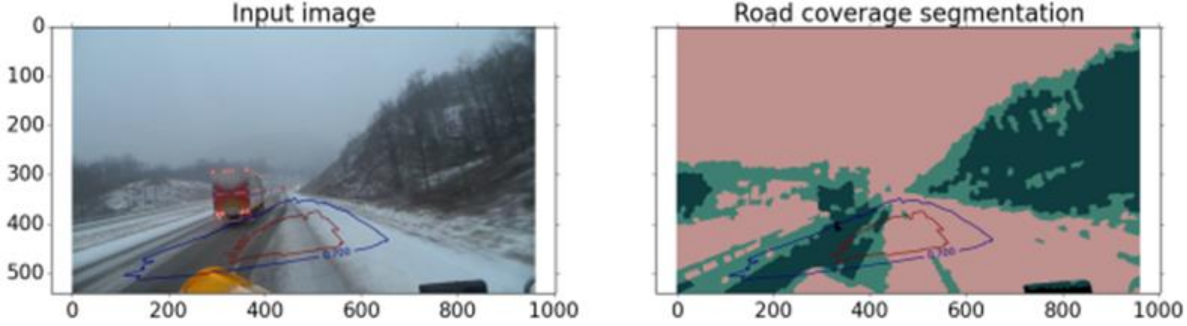




Solid model: motorcycle crash

Inside & outside of a crushed car

Many other possible application besides accident reconstruction


Input image
Road coverage segmentation
0
100
200
300
400
500
0
200
400
600
800
1000


Not match
STOP
Match

Thank you!