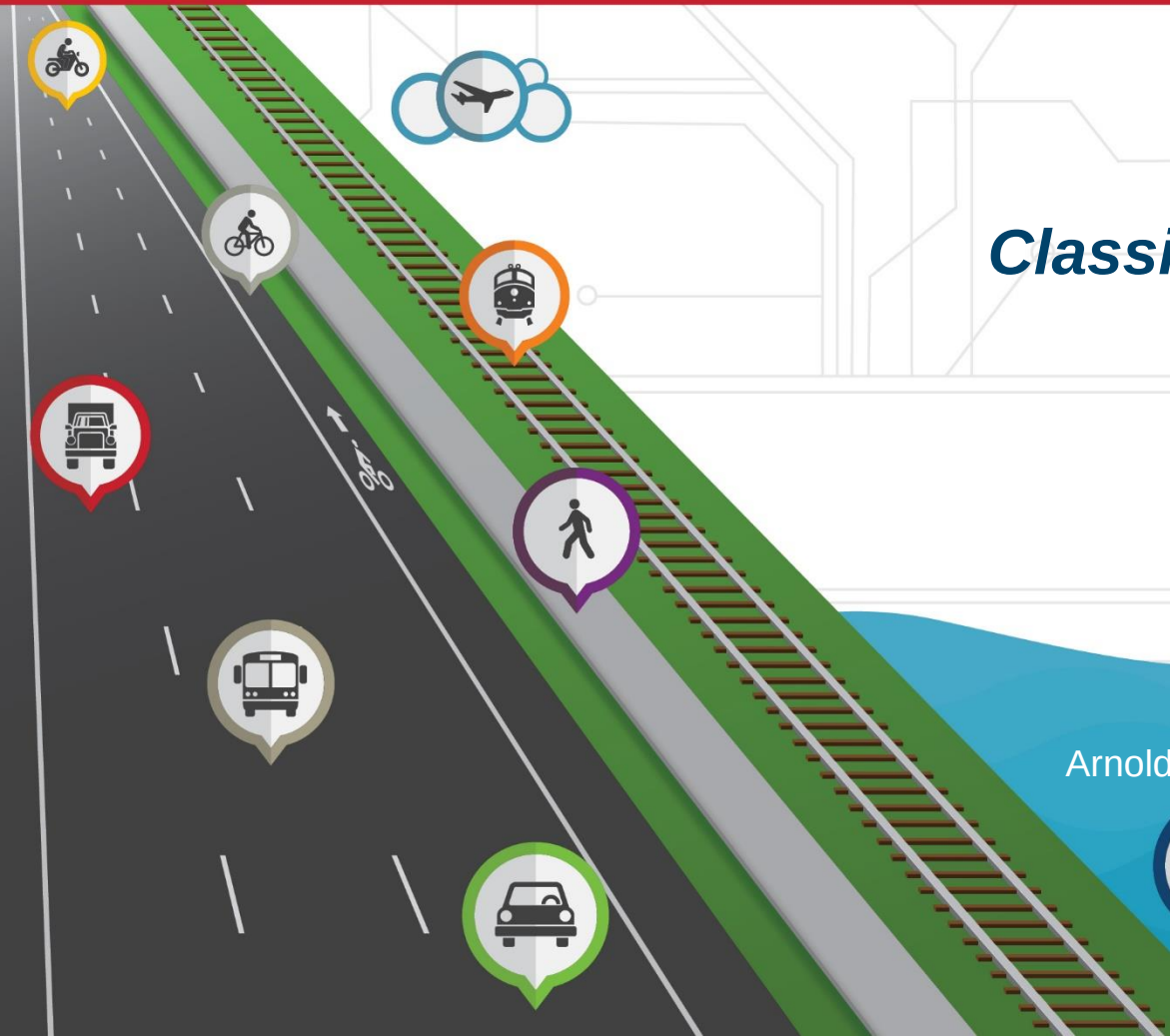


Truck Taxonomy

Classification and Commodity via Machine Learning

Innovations in Freight Data Workshop

Arnold and Mabel Beckman Conference Center

April 10, 2019

FDOT

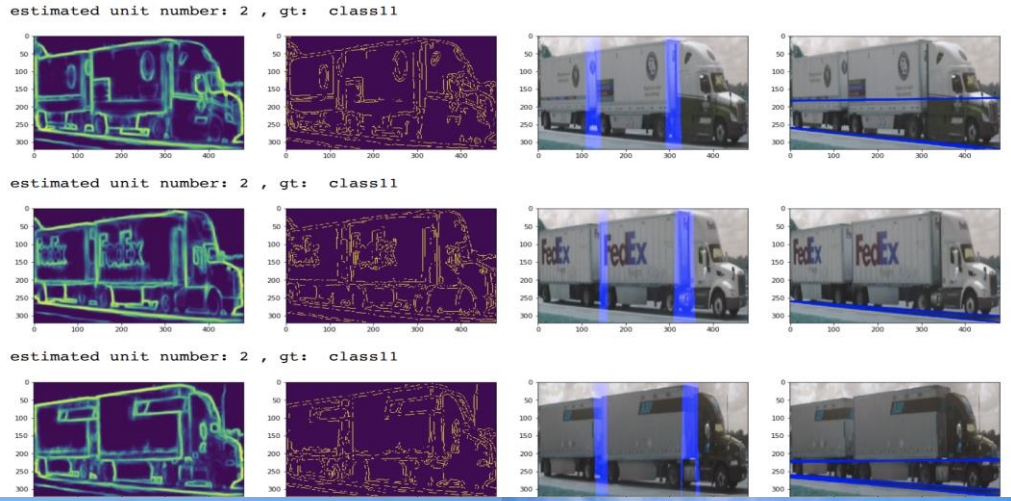
Overview

» Background

» Project Concept

» Research Progress

» Timeline & Next Steps

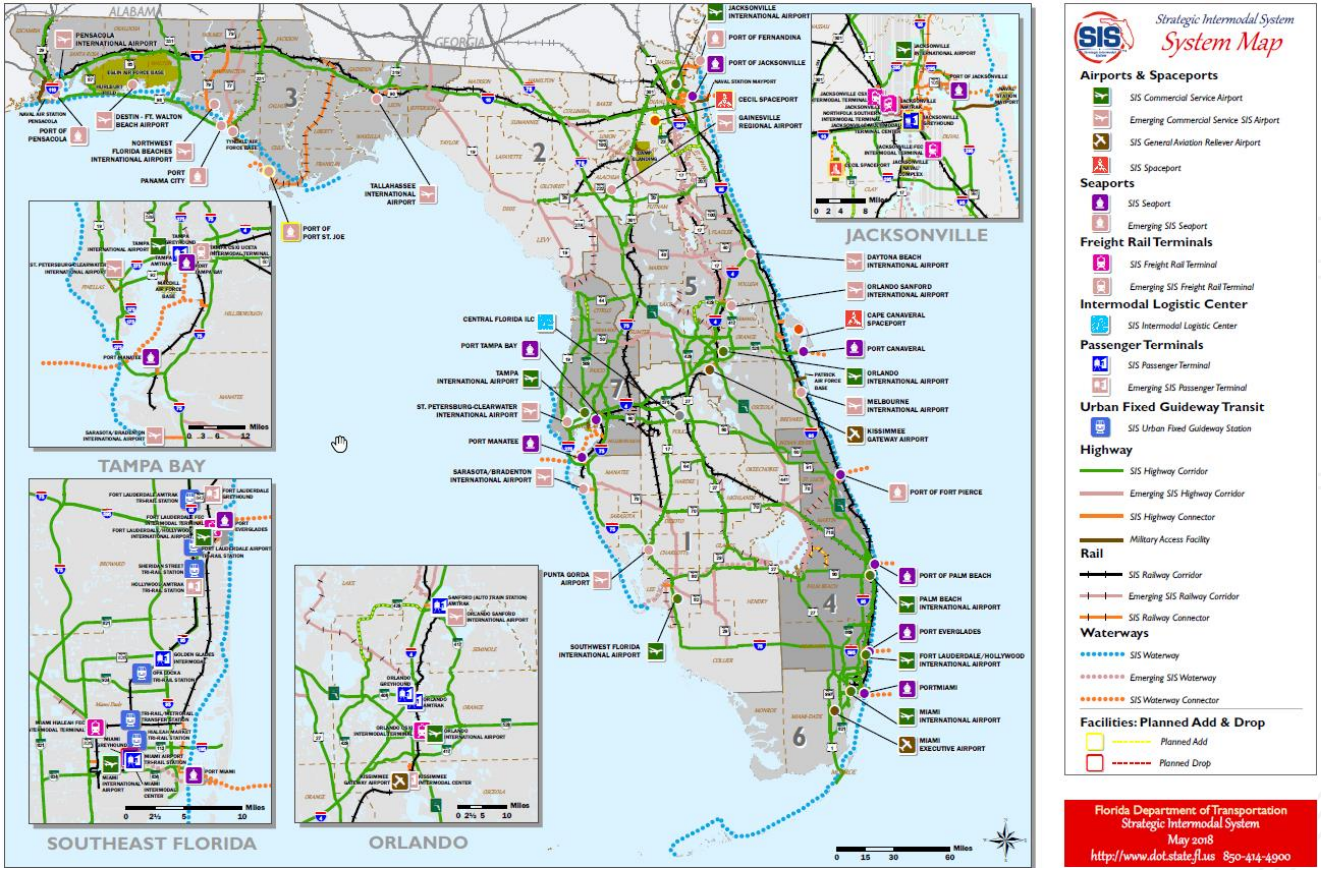


Project Background

Freight Planning in Florida factors

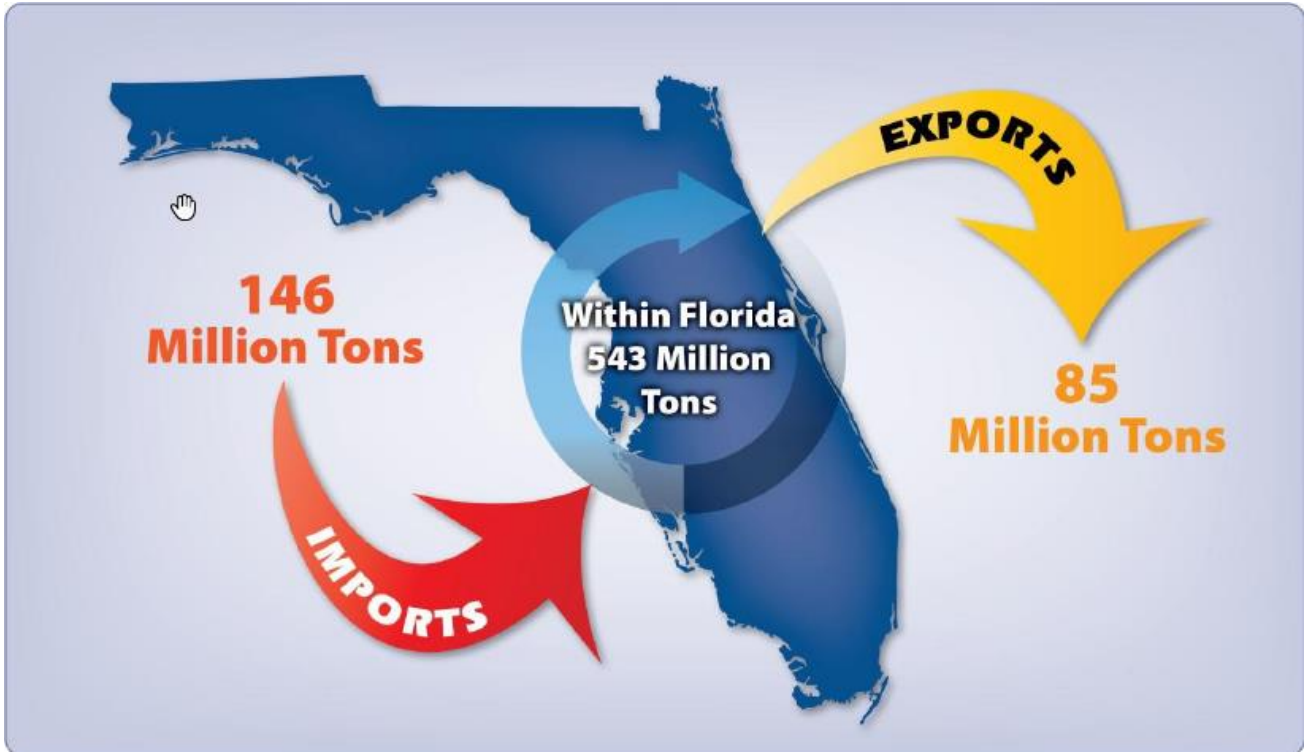
Geographical Facts

- 3rd most populous state in the nation (21M+)
- Geography – peninsula, not a regional hub
- Visitors (3M+ per day)
- Service sector economy – lack of manufacturing



Freight Planning in Florida factors

Freight and Logistics factors:



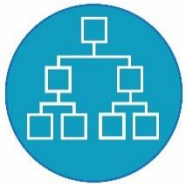
Source: Freight Analysis Framework

Project Concept

Conceptualization

Weigh in Motion (WIM) Data

+



Taxonomy

+

Commodity

+

Video

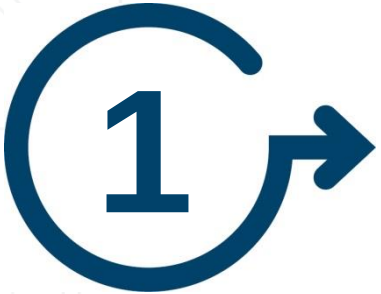
+

Machine Learning

=

Truck and Commodity Data Collection System

Project Data Requirements

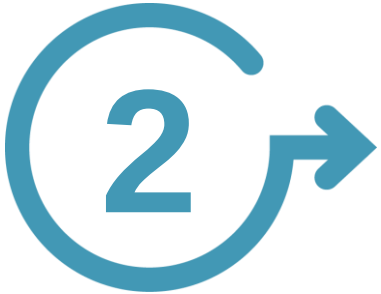


Traffic Data

Weigh-In-Motion (WIM)

» Per Vehicle Record (PVR)

Vehicle Weights Uses – Federal reporting & transportation planning / decision making



Commodity

Commodity data is not associated with WIM data

Alternatives – FAF, IHS Transearch

Limitations – Local data granularity, five-year dataset releases

Technology

Video Capture of physical attributes road sensors do not obtain

Machine Learning – Artificial Intelligence, Transfer Learning

Image Library

Truck Taxonomy

Truck and Commodity dataset created for FDOT business needs

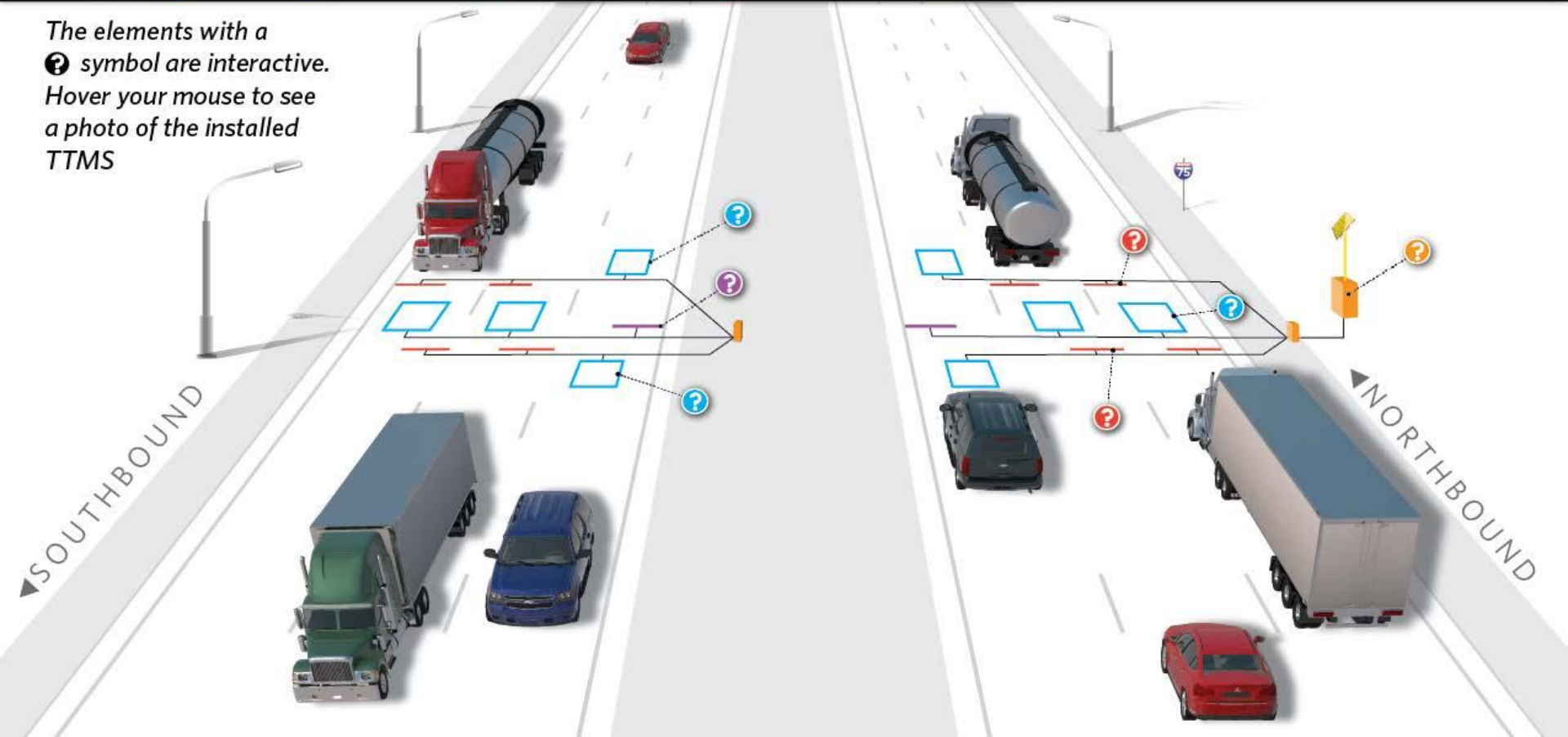
» Freight Planning
» Commercial Vehicle Operations and ITS
» Strategic Intermodal System
» Roadway Design
» Maintenance
» External Partners

TELEMETERED TRAFFIC MONITORING STATION (TTMS 9956)

I-75 AT WHITE SPRINGS
Installed 2016

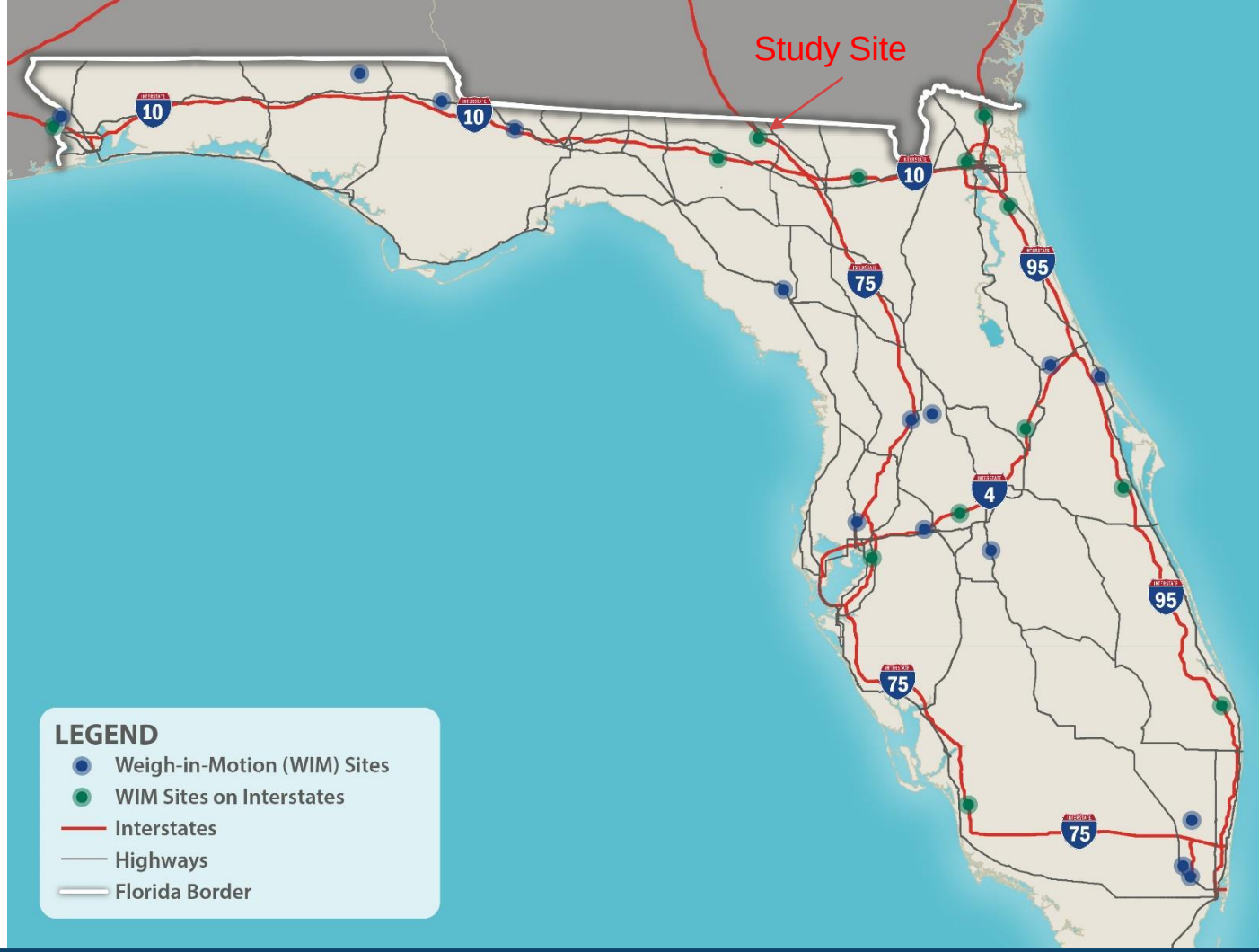
Legend: Cabinet | Solar Array | Inductive Loops | Kistler Sensor | BL Piezo Sensor

The elements with a ? symbol are interactive. Hover your mouse to see a photo of the installed TTMS



Weigh in Motions Sites

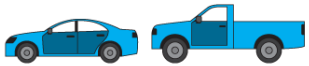
- » 29 Statewide locations
- » 13 on Interstates
- » Per Vehicle Records w/ Time Stamp
- » Initial Study Site – ‘9956’ on I-75 near FL/GA border



FHWA Vehicle Classifications

1. Motorcycles
2 axles, 2 or 3 tires

2. Passenger Cars
2 axles, can have 1- or 2-axle trailers



3. Pickups, Panels, Vans
2 axles, 4-tire single units
Can have 1 or 2 axle trailers

4. Buses
2 or 3 axles, full length

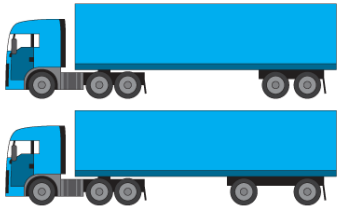
5. Single Unit 2-Axle Trucks
2 axles, 6 tires (dual rear tires), single-unit

6. Single Unit 3-Axle Trucks
3 axles, single unit

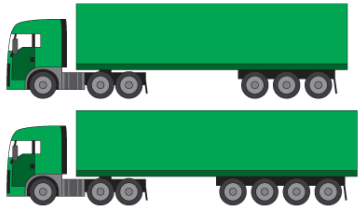
7. Single Unit 4 or More-Axle Trucks
4 or more axles, single unit

8. Single Trailer 3- or 4-Axle Trucks
3 or 4 axles, single trailer

9. Single Trailer 5-Axle Trucks
5 axles, single trailer



10. Single Trailer 6 or More-Axle Trucks
6 or more axles, single trailer



11. Multi-Trailer 5 or Less-Axle Trucks
5 or less axles, multiple trailers

12. Multi-Trailer 6-Axle Trucks
6 axles, multiple trailers

13. Multi-Trailer 7 or More-Axle Trucks
7 or more axles, multiple trailers

FAF4 STCG Assignments

FAF Code	Commodity Description
1	Animals and Fish (live)
2	Cereal Grains (includes seed)
3	Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)
4	Animal Feed, Eggs, Honey, and Other Products of Animal Origin
5	Meat, Poultry, Fish, Seafood, and Their Preparations
6	Milled Grain Products and Preparations, and Bakery Products
7	Other Prepared Foodstuffs, Fats and Oils
8	Alcoholic Beverages and Denatured Alcohol
9	Tobacco Products
10	Monumental or Building Stone
11	Natural Sands
12	Gravel and Crushed Stone (excludes Dolomite and Slate)
13	Other Non-Metallic Minerals not elsewhere classified
14	Metallic Ores and Concentrates
15	Coal
16	Crude Petroleum
17	Gasoline, Aviation Turbine Fuel, and Ethanol (includes Kerosene, and Fuel Alcohols)
18	Fuel Oils (includes Diesel, Bunker C, and Biodiesel)
19	Other Coal and Petroleum Products, not elsewhere classified
20	Basic Chemicals
21	Pharmaceutical Products
22	Fertilizers
23	Other Chemical Products and Preparations
24	Plastics and Rubber
25	Logs and Other Wood in the Rough
26	Wood Products
27	Pulp, Newsprint, Paper, and Paperboard
28	Paper or Paperboard Articles
29	Printed Products
30	Textiles, Leather, and Articles of Textiles or Leather
31	Non-Metallic Mineral Products
32	Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes
33	Articles of Base Metal
34	Machinery
35	Electronic and Other Electrical Equipment and Components, and Office Equipment
36	Motorized and Other Vehicles (includes parts)
37	Transportation Equipment, not elsewhere classified
38	Precision Instruments and Apparatus
39	Furniture, Mattresses and Mattress Supports, Lamps, Lighting Fittings, and Illuminated Signs
40	Miscellaneous Manufactured Products
41	Waste and Scrap (excludes of agriculture or food, see 041xx)
43	Mixed Freight
99	Commodity unknown

Conceptualization

- » Intimate knowledge of WIM data ✓
- » Roadside cameras ✓
- » Advanced knowledge of trucks/trailers ✓
- » Concept of Truck Taxonomy ✓
- » Basic knowledge of Transfer Learning ✓
- » Identify experts of Transfer Learning and Application Development ✓

Research Progress Update

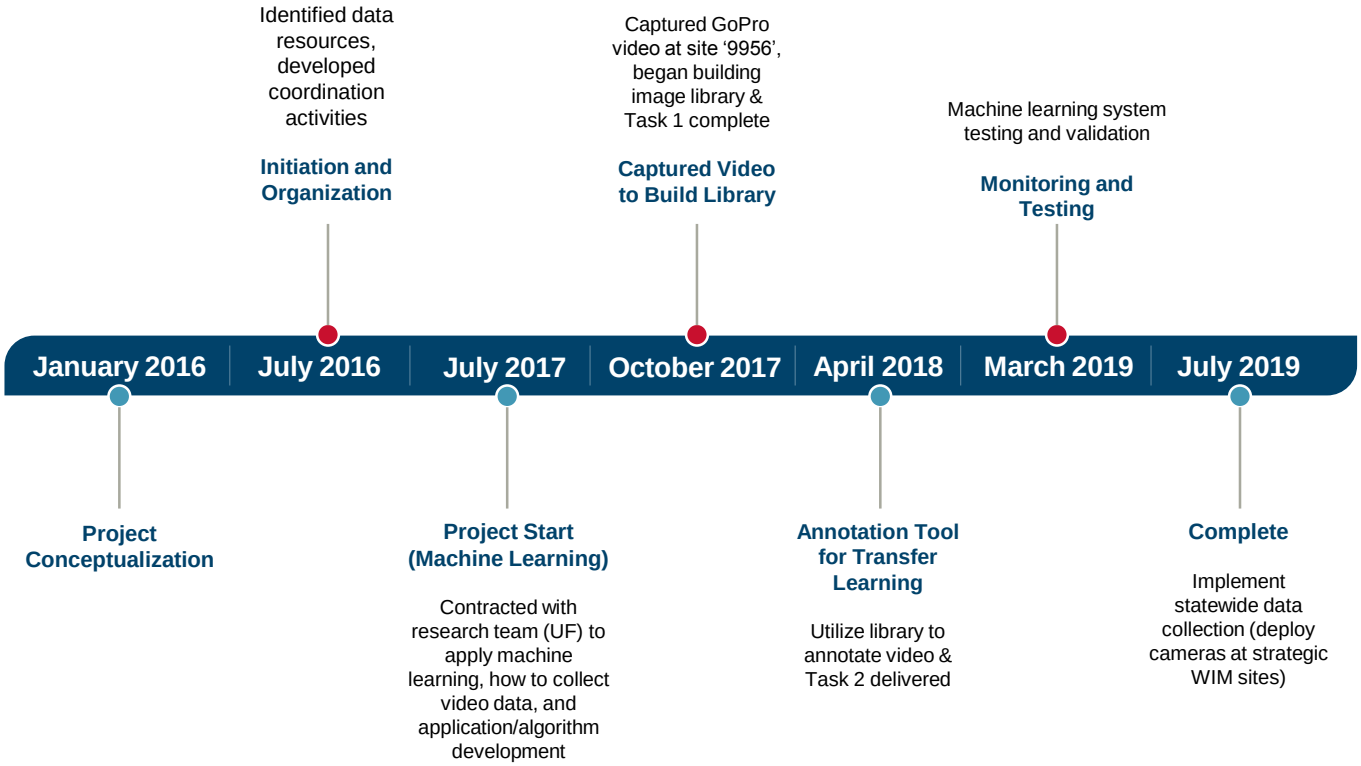
Project Team and Objectives

- University of Florida Transportation Institute
  - Principal Investigator – Sanjay Ranka

- FDOT TDA (project sponsor)
  - Project Manager(s) – Jerry Scott, Ed Hutchinson, Eric Griffin

- **Project Start** – July 2017 - **Project End** – July 2019
  - Task 1 – Investigate approach for truck classification based on video and weight
  - Task 2 – Develop classification algorithms for automatic classification of trucks
  - Task 3 – Develop classification algorithms for commodity classification
  - Task 4 – Final Report

Research Project Timeline



Coding Languages and Hardware

Libraries: Pytorch, OpenCV, Dlib, Tkiner, ffmpeg
GPU Cards: 3 NVIDIA TITAN X Pascal Graphics Card ($1,200 ea.)
1 NVIDIA TITAN V Graphics Card ($2,999 ea.)
Programming Language: Python
Operating System: Ubuntu 16.04

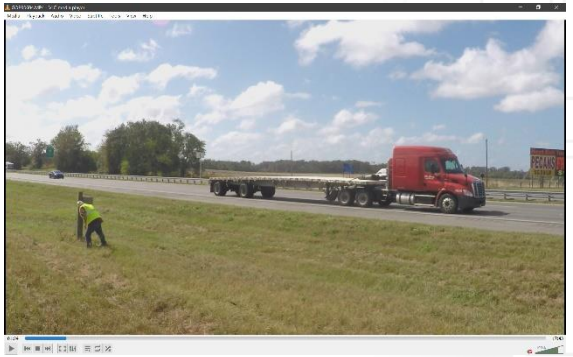
Truck Taxonomy Library Development

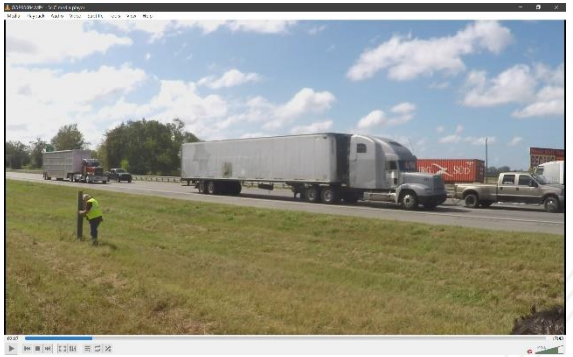
» FHWA Scheme F Classifications

» Truck Trailer Type Combinations

» GoPro Video Imagery taken at WIM Site 9956

» FAF4 STCG Commodities





				Tier I	Tier II(a)	Tier II(b)		Tier III	Tier IV	TIER V	TIER VI
Video/Time	Time	Lane	Image	FHWA Class	Vehicle Type	Trailer / RV / Service Type	Trailer SubType	Company	NAICS Codes	NAICS - Second Tier	NAICS - Third Tier
GP0604	0:00:25	1	2	3	RV	Class_B_Campervan	2 axle				
~	0:00:26	2	3	10	Sleeper	Flatbed	Step/Drop Deck		Transportation_and_Other		
3027 starting point	0:00:28	2	4	12	Sleeper	Enclosed	Dry_Van	ACT	Unknown Commodity		
	0:00:31	1	5	9	Sleeper	Enclosed	Reefer	Witte Bros	Unknown Commodity		
	0:00:42	1	7	9	Sleeper	Enclosed	Dry_Van	RBI	Unknown Commodity		
	0:00:50	2	8	9	Sleeper	Enclosed	Dry_Van		Unknown Commodity		
~	0:01:19	1	11	9	Sleeper	Chassis			Empty		
~	0:01:24	1	12	9	Sleeper	Flatbed			Empty		
	0:01:31	1	14	9	Sleeper	Enclosed	Dry_Van	Dollar General	Retail_Ready_Finished_Goods	Other Miscellaneous Store Retailers	
	0:01:36	1	15	9	Sleeper	Enclosed	Dry_Van	RBI	Unknown Commodity		
	0:01:50	1	18	9	Sleeper	Enclosed	Conestoga		Unknown Commodity		
	0:02:05	1	20	12	Sleeper	Enclosed	Dry_Van	FedEx	Postal_Service_and_Parcels		
	0:02:09	1	21	9	Sleeper	Enclosed	Dry_Van		Unknown Commodity		
	0:02:17	1	23	9	Sleeper	Enclosed	Reefer		Unknown Commodity		
	0:02:18	1	24	9	Day_Cab	Specialty	Livestock		Unknown Commodity		
	0:02:33	2	25	3	PickupTruck_or_Van	one_axle	Box		Unknown Commodity		
	0:02:34	1	26	9	Sleeper	Enclosed	Dry_Van	SouthernAG	Unknown Commodity		
	0:02:35	2	27	9	Sleeper	Enclosed	Reefer		Unknown Commodity		
	0:02:40	1	28	9	Sleeper	Enclosed	Dry_Van	Stoughton	Unknown Commodity		
	0:02:42	2	29	9	Sleeper	Enclosed	Dry_Van		Unknown Commodity		
~	0:02:51	3	31	3	PickupTruck_or_Van	one_axle	Boat/other		Transportation_and_Other		
~	0:03:04	1	32	9	Sleeper	Tank	Food Grade Tank		Unknown Commodity		
	0:03:40	1	33	9	Sleeper	Enclosed	Dry_Van		Unknown Commodity		
~	0:03:43	2	34	5	RV	Class_A_Motorcoach					
	0:03:44	2	35	10	Day_Cab	Specialty	Dump		Unknown Commodity		
	0:03:52	2	36	9	Sleeper	Specialty	Car Hauler		Transportation_and_Other		
	0:04:18	1	39	9	Sleeper	Enclosed	Dry_Van	Ashley Furniture Industries	Retail_Ready_Finished_Goods	Furniture	

Truck Taxonomy Library Development

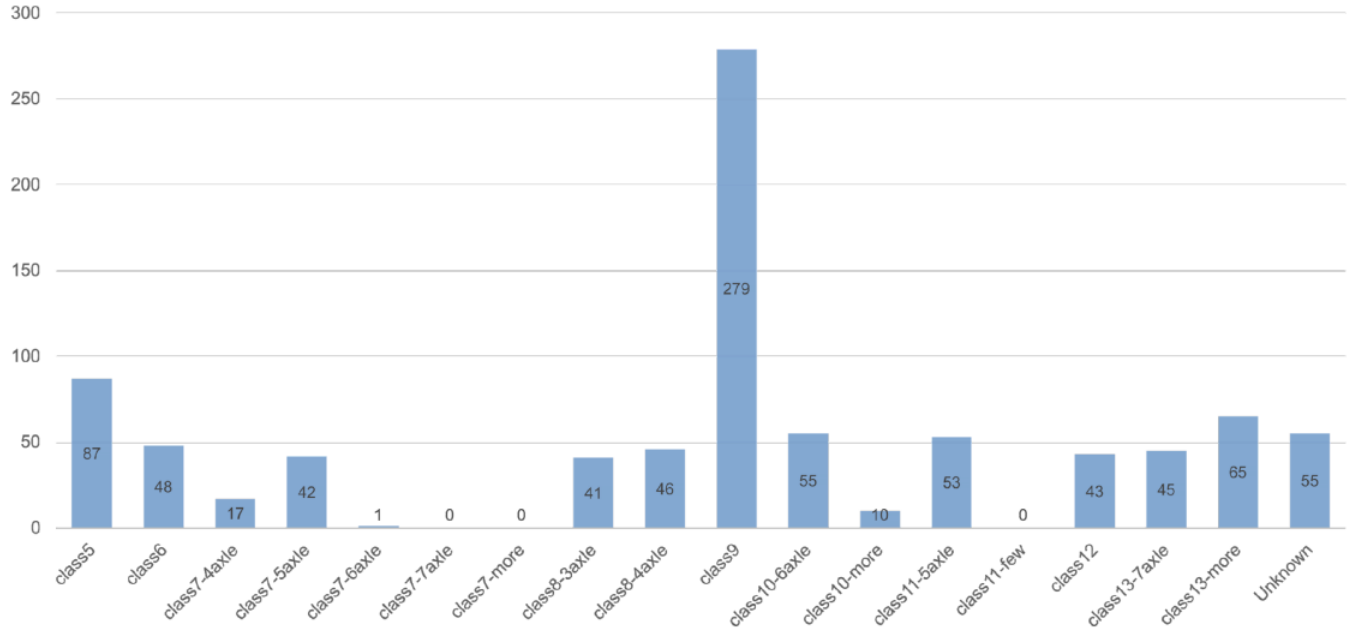


Figure 5: Imbalance truck class distribution of our training dataset. In reality, Florida has 60-70% of Class 9 trucks. In this case, when we collect the training dataset, attentions should be paid to the minor classes (collecting more minor class samples to ensure a balanced distribution).

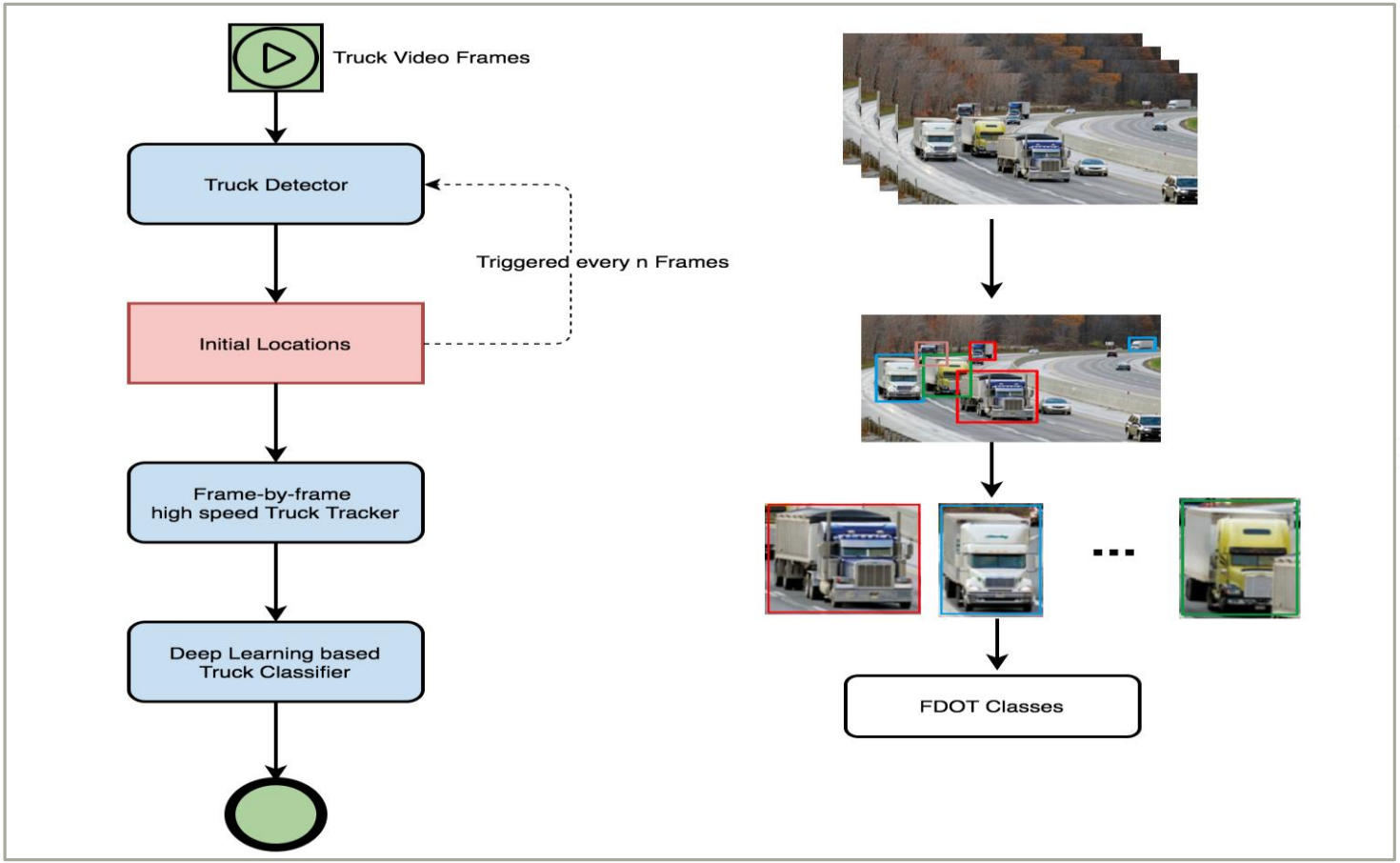
Initial Algorithm Training

Image-Net Model, Researchers Image Database

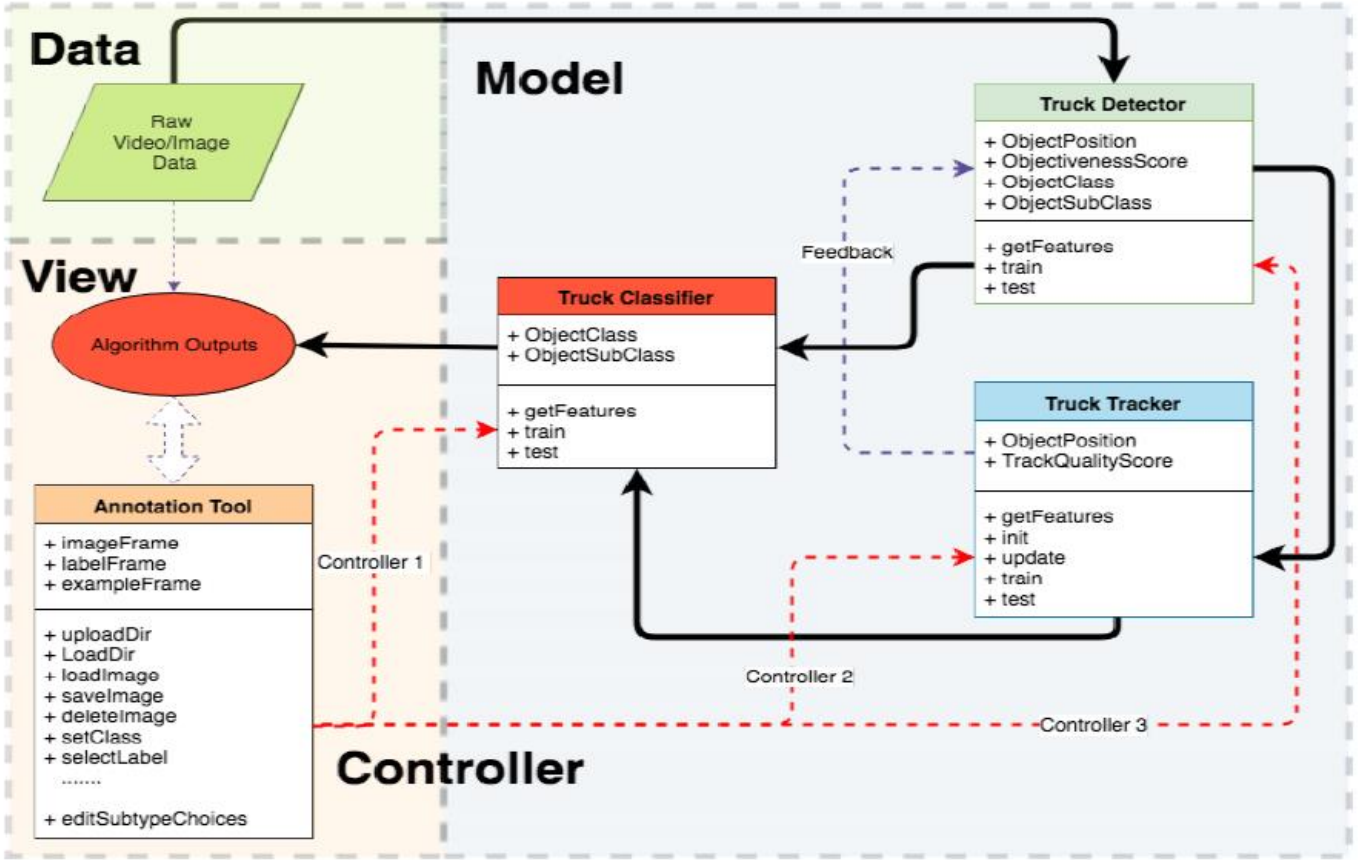
- Over 15M labeled high resolution images
- Roughly 22k categories
  - This imagery is used to train the machine algorithm. Actual field collected imagery is used to test the trained machine algorithm.

Source: http://image-net.org/

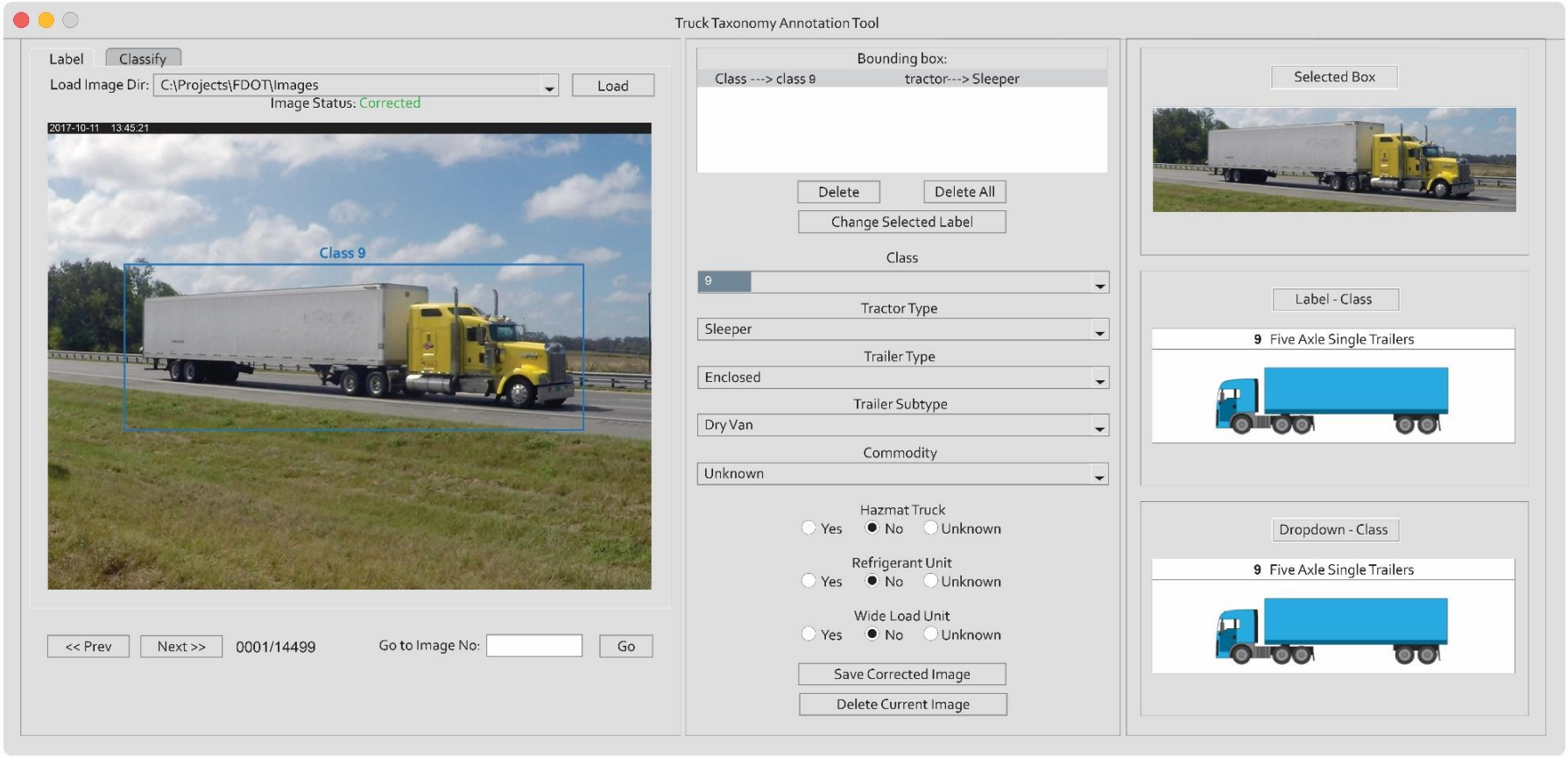
Truck Classification Architecture



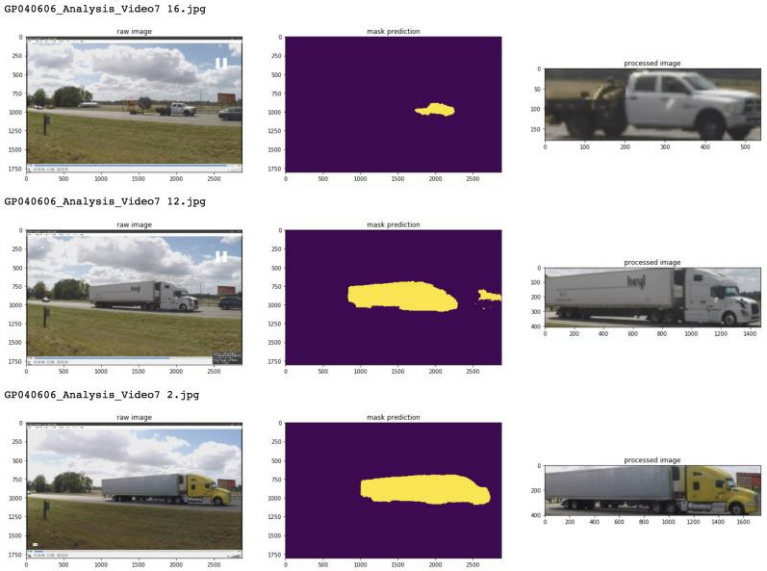
Truck Model Overview



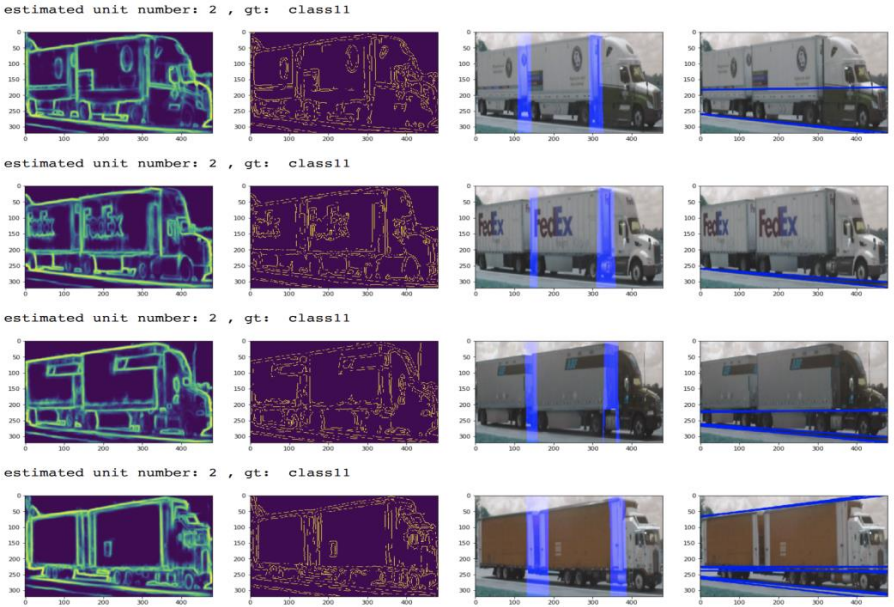
YOLO Annotation Tool – Transfer Learning



Geometric Features for Classification



Size and Aspect Ratio



Number of Trailers

Geometric Features for Classification

Number of wheels (proxy for number of axles)

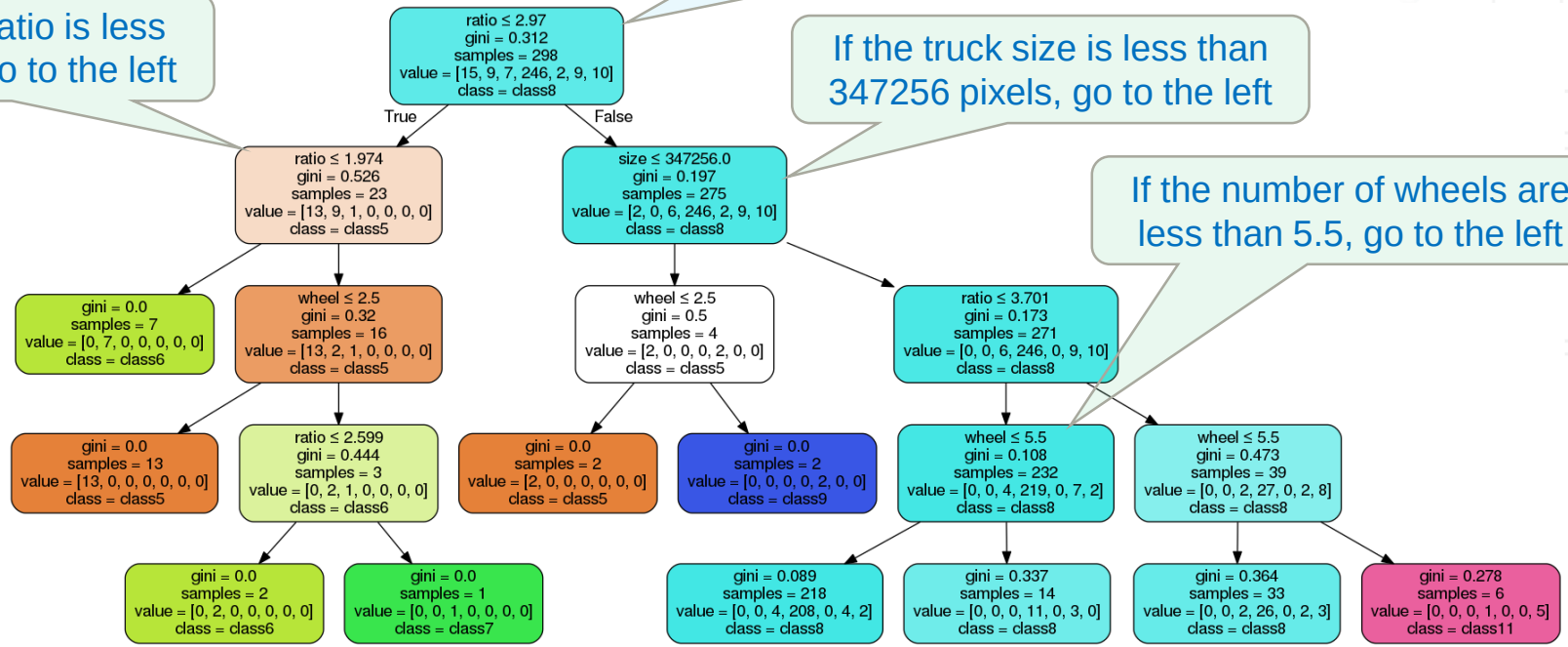
Example of decisioning based on geometrics features

If the aspect ratio is less than 2.97, go to the left

If the aspect ratio is less than 1.9740, go to the left

If the truck size is less than 347256 pixels, go to the left

If the number of wheels are less than 5.5, go to the left



Training Sample Results Summary

Truck Classification:

Training Accuracy	Validation Accuracy
100%	88%

Truck Tractor Classification:

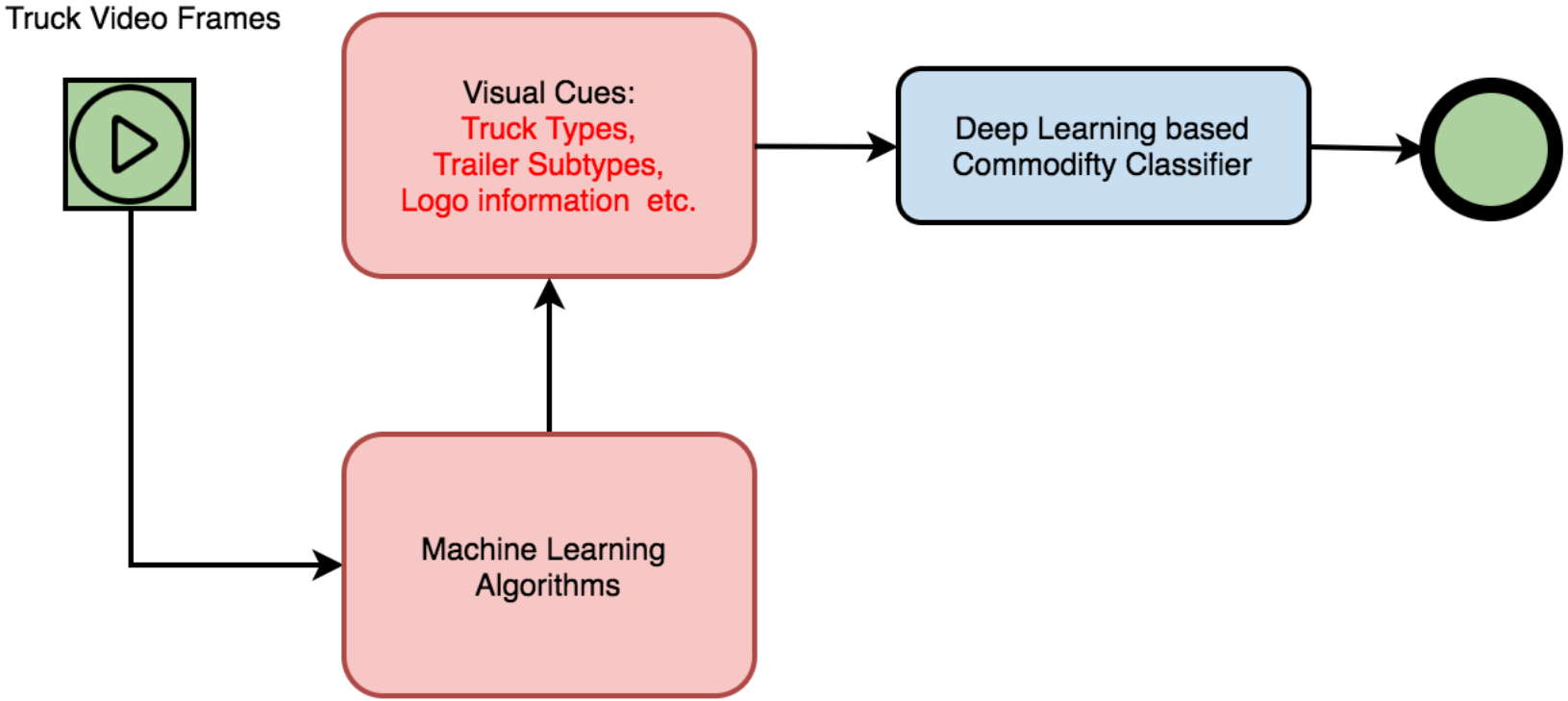
Training Accuracy	Validation Accuracy	Top-3 Validation Accuracy
99.7%	91.6%	99.7%

Truck Trailer Classification:

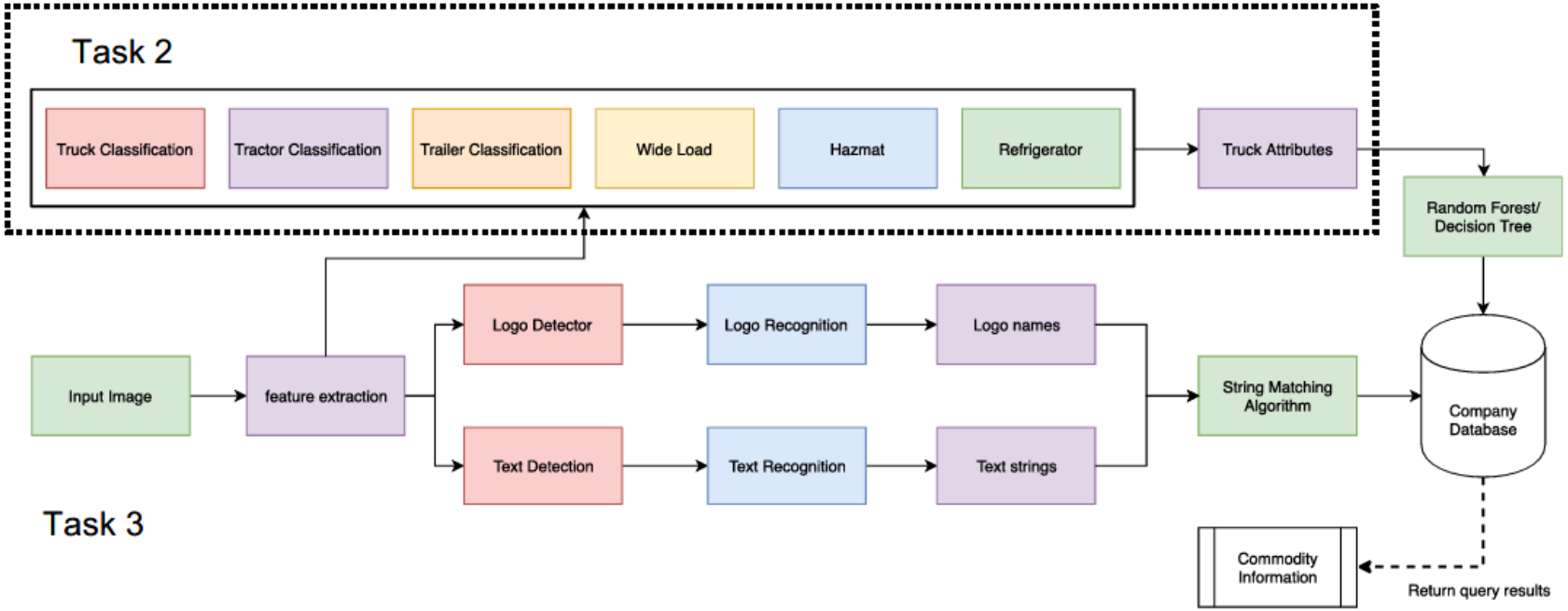
Training Accuracy	Validation Accuracy	Top-3 Validation Accuracy
100%	85.8%	91.9%

Attributes	Training Accuracy	Validation Accuracy
Hazmat	100%	86.4%
Wide load	100%	89.4%
Refrigerator unit	100%	83.1%

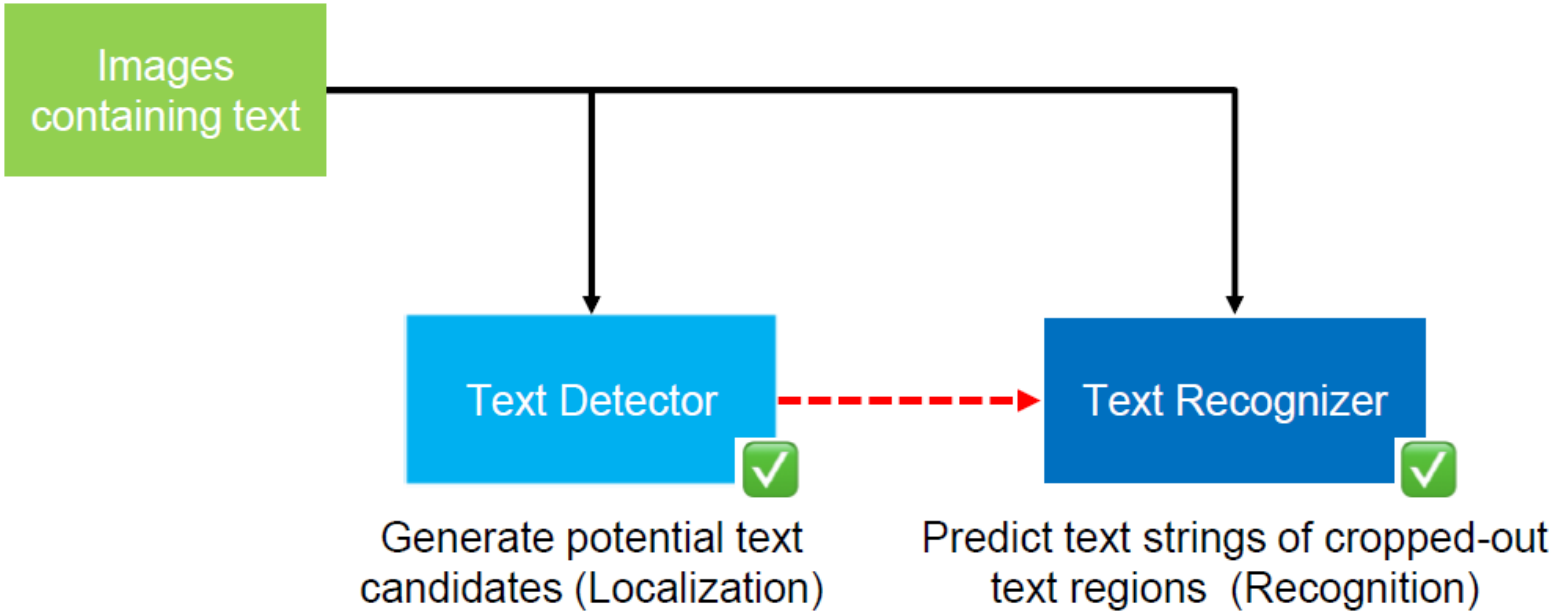
Commodity Monitoring Architecture



Commodity Monitoring Architecture



Text Recognition – Two Key Components

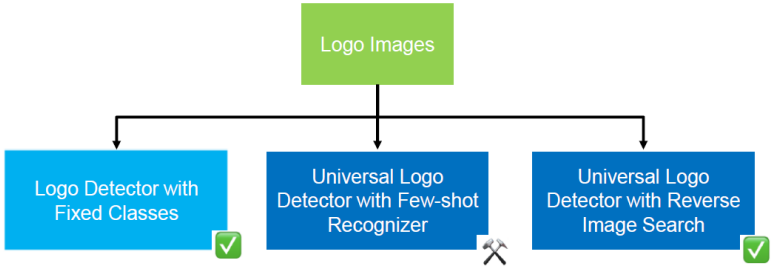


✅ Finished ⚒ On-going

Logo Recognition – Text Detection

The developed algorithms can achieve a high recall with a competitive recognition accuracy.

Logo Recognition Solutions



1. **Logo Detector with Fixed Classes** – Collect many training samples of the same logo in different angles and train the detector for this certain logo class.

   Advantage: Simple model design. Great if users already know logos/brands and intentionally ignore others.
   Disadvantage: Model cannot localize and recognize unseen logo images not belonging to a predefined class. Need to retrain the model when new logo classes are discovered/added.

2. **Universal Logo Detector (with k-nearest neighbors)** – Adds bounding boxes to suspected logos within image samples. Crops bounding logos and runs them through ULD, with the finalization through KNN to get the best search results.

   Advantage: Is a generic logo detector that can detect any potential logo imagery.
   Disadvantage: Need to manually annotate samples for each class. Limited training samples yield unsatisfactory results.

3. **Universal Logo Detector (with Reverse Image Search)** – Reverse image search is a content-based image retrieval query technique where a sample image is used to search related concepts about this image. It allows users to search for related images just by uploading an image or image URL.

   Advantage: It can return reasonable results with richer meta data related to the logo imagery.
   Disadvantage: Maintenance costs associated with HTML Parser API changes based on Google hosting.

Logo Recognition – Selected Solution

Project team settled on combining the cropping feature in Solution 2 with the Reverse Image look-up from Solution 3.

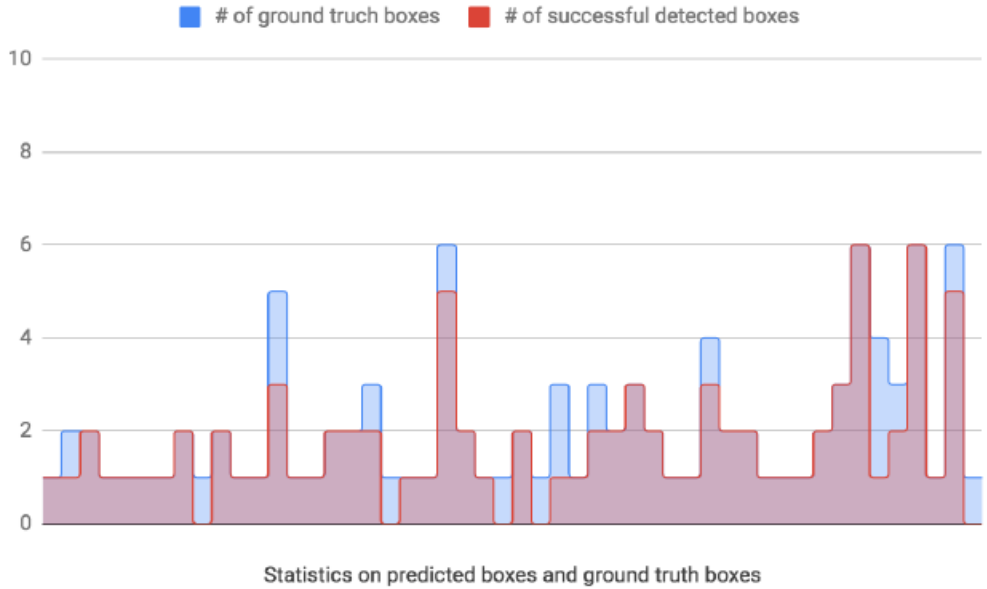
Once truck images were input into their Universal Logo Detector, they are able to estimate the location for each potential logo within each image. The cropped out logo regions enable the model to focus on pure logo content information and ignores non-relevant background noise/distraction information.

	CompanyName	First Name	Last Name	Job Title	Phone	Fax	Address	City	State	Zip Code	County	FullAddress	Website URL	Employees	Annual Sales	Industry	SIC Code	SIC CodeDescription	NAICS
2	3Oaks.com	Frederick	Grindle	Owner	Not Available In	Not Available In	5718 6th St	Zephyrhills	FL	33542	PASCO	5718 6th St Zephyrhills FL 33542	3oaks.com	1	2000000	Computer & Office Machir	7378	Computer Maintenance and Repa	811212
3	Aerosabb Inc	Demetrio	Saab	Owner	Not Available In	Not Available In	PO Box 237	Zellwood	FL	32798	ORANGE	PO Box 237 Zellwood FL 32798	aerosabb.com	1	2000000	Other Support Activities-/	4581	Airports, Flying Fields, and Airpor	488190
4	1st Bank Yuma	Alicia	Lugo	Operations Officer	Not Available In	Not Available In	2799 S 4th Ave	Yuma	AZ	85364	YUMA	2799 S 4th Ave Yuma AZ 85364		38	7935000		602200	State Commercial Banks	522110 - Commercial Banking
5	1 800 Plumbing	Alan	Cline	Owner	Not Available In	Not Available In	12600 N 113th Ave	Youngtown	AZ	85363	MARICOPA	12600 N 113th Ave Youngtown AZ	800plumbing.com	4	4000000	Plumbing & Hvac Contrs	1711	Plumbing, Heating, and Air-Condit	238220
6	Safeway	Carmie	Alfan	Manager	Not Available In	Not Available In	29834 N Cave Creek Rd	Cave Creek	AZ	85331	MARICOPA	29834 N Cave Creek Rd Cave Creek safeway.com		5	7000000	Supermarkets & Other Gr	5411	Grocery Stores	445110
7	Cross Tool & Manufacturing; Inc	Kaminski	Aaron	Chief Executive	Not Available In	Not Available In	1000 East Butler Avenue; S	WOODRUFF	AZ	85942	NAVAJO	1000 East Butler Avenue; Suite 102	machinedpartsquote	0	0		3999	Manufacturing Industries, NEC	332212
8	419 Metal & Auto Recycling Ctr	Bart	Philips	Owner	Not Available In	Not Available In	600 Old Sanford Oviedo Rd	Winter Spring	FL	32708	SEMINOLE	600 Old Sanford Oviedo Rd Winter	419metals.com	4	6000000	Iron & Steel Mills	3312	Steel Works, Blast Furnaces	331111
9	A LA Carte Languages	Elena	Green	Owner	Not Available In	Not Available In	1555 Howell Branch Rd # 2	Winter Park	FL	32789	ORANGE	1555 Howell Branch Rd # 206C Wint	alacartelanguages.cc	1	0	Language Schools	8299	Schools and Educational Services,	611630
10	Blockbuster Video	Kritsina	Blancao	Manager	Not Available In	Not Available In	5580 Cypress Gardens Blvd	Winter Haven	FL	33884	POLK	5580 Cypress Gardens Blvd Winter	blockbuster.com	3	3000000	Video Tape & Disc Rental	7841	Video Tape Rental	532230

Experimental Results

- Randomly sample 50 truck images containing texts

# of successful detected boxes	# of ground truth boxes	Average Recall
86	105	81.90%



Statistics on predicted boxes and ground truth boxes

Next Steps

Project Challenges

1. Efforts to capture commercial vehicle configurations will be labor intensive.
2. Determine technical requirements along with hardware requirements early.
3. Implementation opportunities are still undetermined.
4. Public perspective of the system will be challenge.
5. Data management and governance considerations – Is the Department willing to develop and maintain a policy on this system?

Future Steps

1. Collect and annotate more data to increase potential for more successful results.

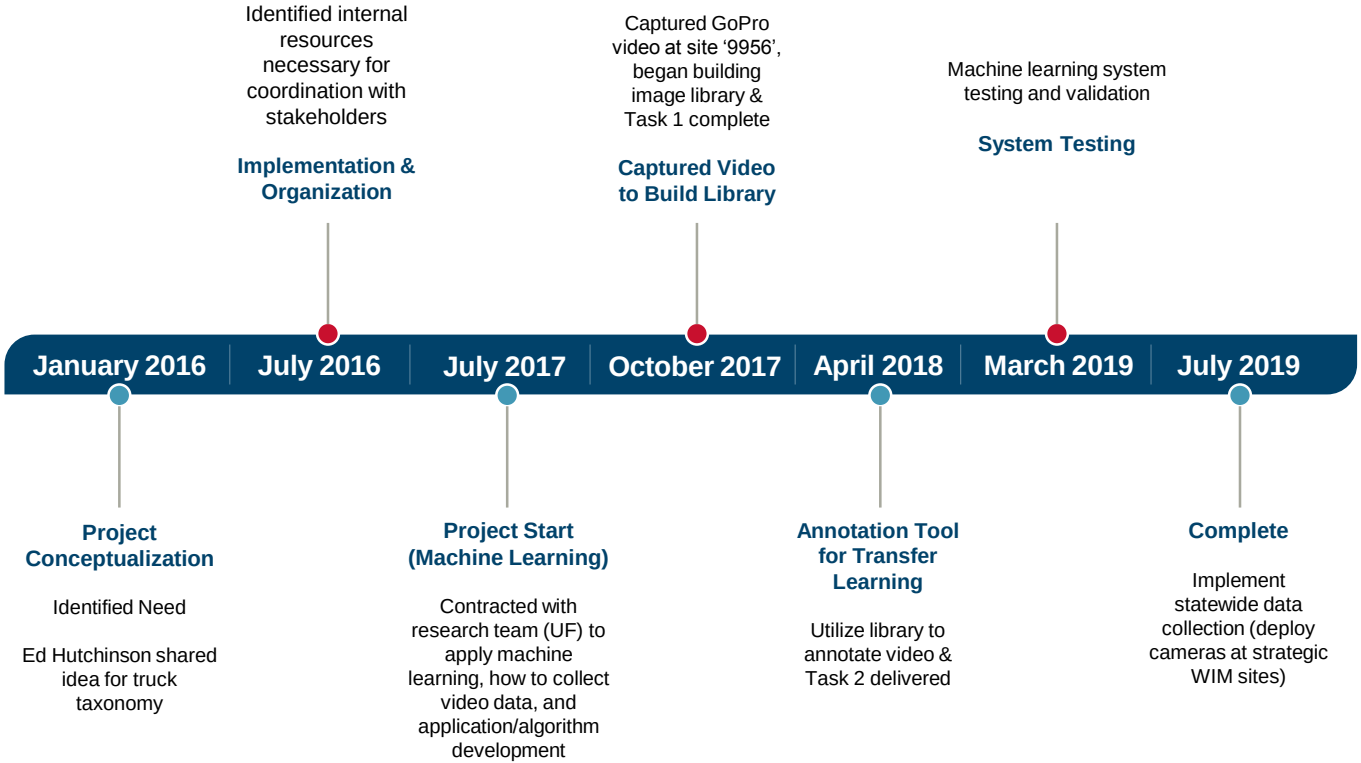
2. Purchase and install video equipment at WIM stations statewide (20+ locations), in order to acquire more location specific data.

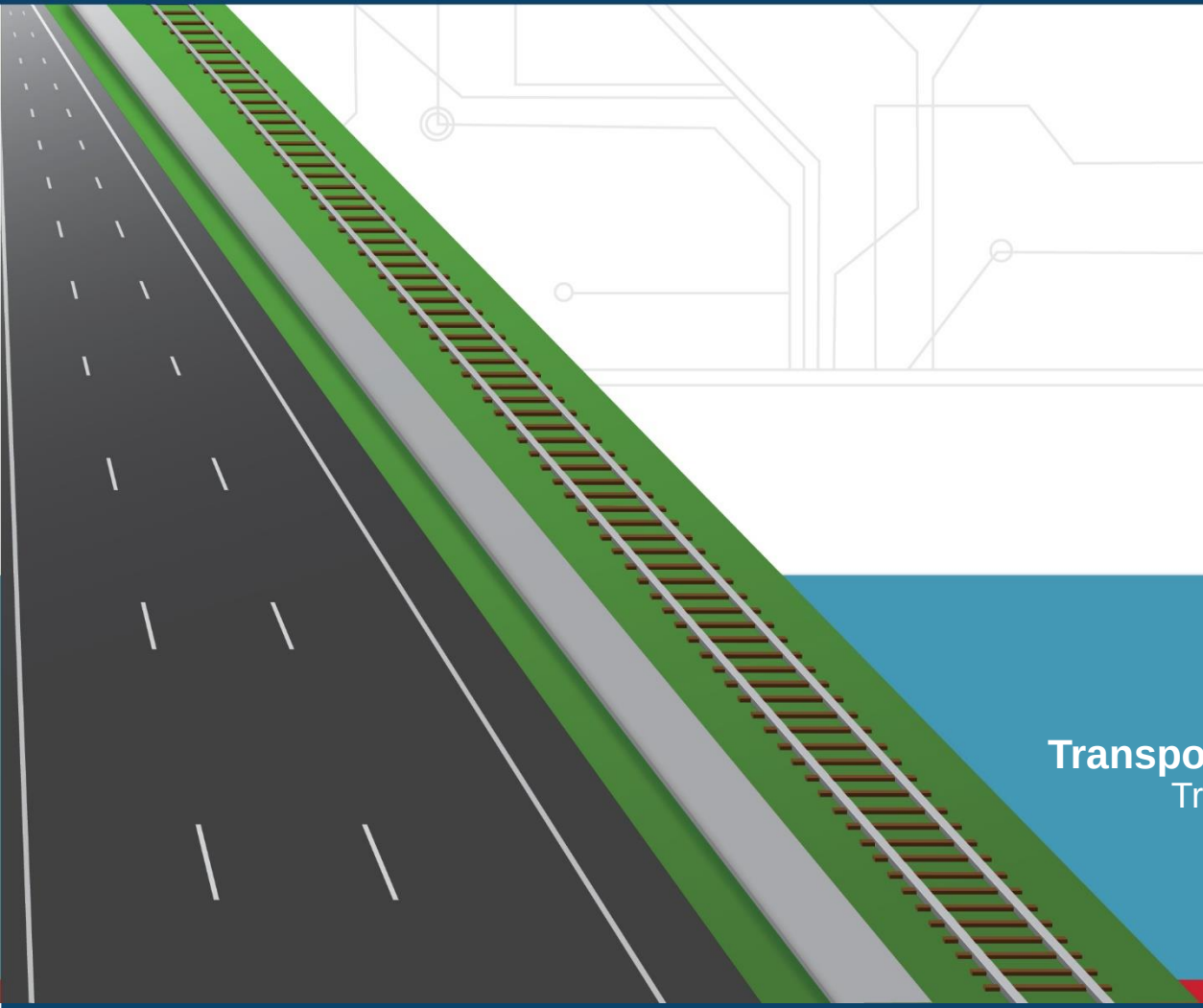
3. Build a database that incorporates crosswalks with other commodity code systems *(North American Industry Classification System (NAICS)/Standard Industrial Classification (SIC)*

4. Integrate existing algorithms into the YOLO annotation tool.

5. Solicit support of private sector capabilities and systems.

Research Project Timeline





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