

# Semi-Automated Synthesis of Driving Rules

Diego Ortiz Barbosa

Leilani Gilpin

Alvaro A. Cardenas

**UC SANTA CRUZ**

VehicleSec

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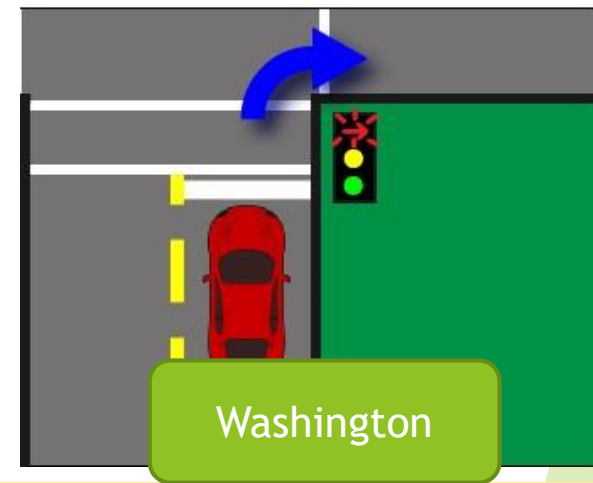
# Driving is More Than Safety: Societal, Regulatory, and Cultural Expectations of Driving Behavior

Driving expectations vary by region:  
How should you react to a red arrow?



## Right Turn Against a Red Arrow

You may not turn right if you are stopped at a red arrow light. Wait until the light changes to green before making your turn.



on. If you are turning right, you may turn after coming to a full stop if it is safe and if there is no sign prohibiting the turn on a red arrow. You may also turn left onto a one-way street

# How can we automatically find and encode regional driving rules?

Answer: Regional Driving Manuals

- Best driving practices by state or territory
- Guides and specification of certain behaviors
- Recommendations depending on location
- Additional information regarding specific equipment that might be in the vehicle



# Translating Natural Language Rules to Formal Rules that Can be Used by Computers

- Stop behind the limit line (white lines on the road that show you where to stop). If there is no limit line, stop before you enter the crosswalk. If there is no crosswalk, stop before you enter the intersection.
- Look both ways and turn when it is safe. Do not turn wide into another lane.
- Complete your turn in the right lane.

Keep reading for more information about turning right in specific situations.

#### Right Turn Against a Red Light

You may turn right at a red light unless there is a "No turn on red" sign. Follow the same steps as a normal right turn.

#### Right Turn Against a Red Arrow

You may not turn right if you are stopped at a red arrow light. Wait until the light changes to green before making your turn.

#### Right Turn at a Public Transit Bus Lane

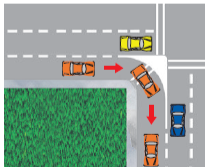
It is illegal to drive, stop, park, or leave a vehicle in an area designated for public transit buses. Signs will be posted to indicate the lanes are for "bus only" use. However, you may cross a bus lane to make a right turn.

#### Right Turn onto a Road with a Dedicated Lane

A dedicated right turn lane does not merge into another lane and allows you to make a "free right turn" without stopping first. You may make your turn even if there is a red light for vehicles going straight through the intersection.

If there is a traffic light or sign on the right curb of the right turn lane, you must obey that light or sign. Always yield to pedestrians in a crosswalk when turning.

If free right turns are not allowed, there will be a sign saying so.



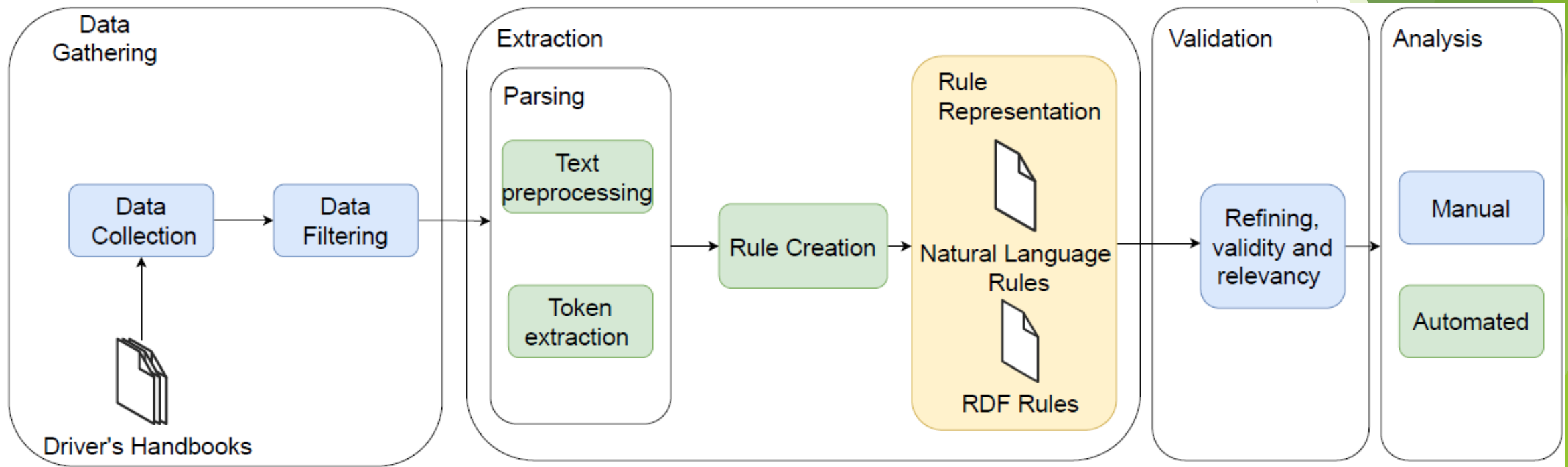
- Stop behind the limit line (white lines on the road that show you where to stop). If there is no limit line, stop before you enter the crosswalk. If there is no crosswalk, stop before you enter the intersection.

Natural Language  
Extraction of Rules

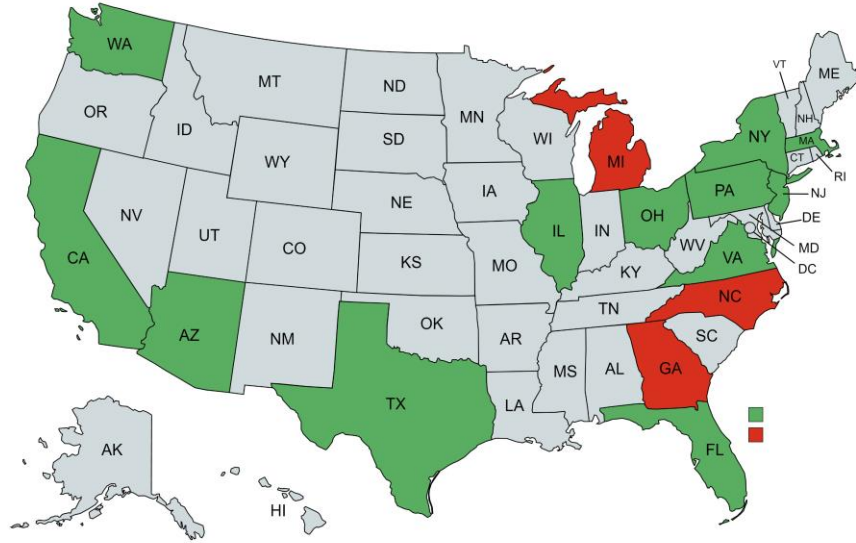
IF NOT (crosswalk,  
has, limit line), THEN  
(stop, before,  
crosswalk)

Encoding  
RDF formal  
language

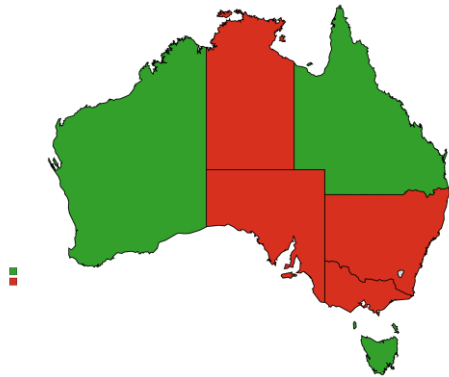
# Framework to Extract and Encode Rules of the Road to Autonomous Vehicles



# Data Gathering



Created with mapchart.net



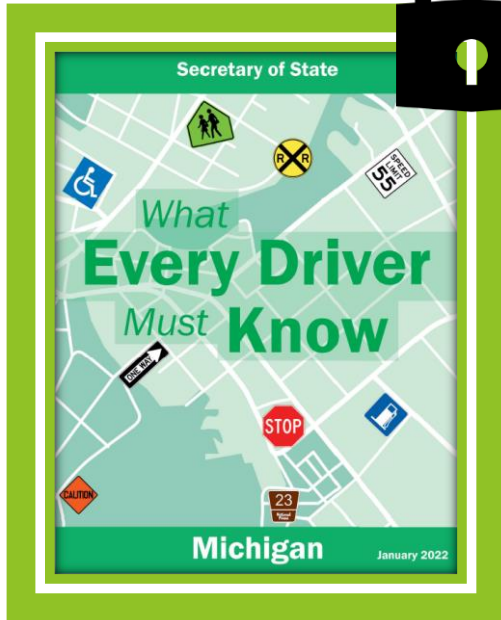
Created with mapchart.net

- ▶ Manuals of the 15 most populated states
- ▶ To further demonstrate our adaptability, we decided to try it in another country, such as Australia
  - ▶ Different signs
  - ▶ Opposite driving side
  - ▶ Use of metric system
- ▶ **Red territories** indicate that we were not able to process those manuals

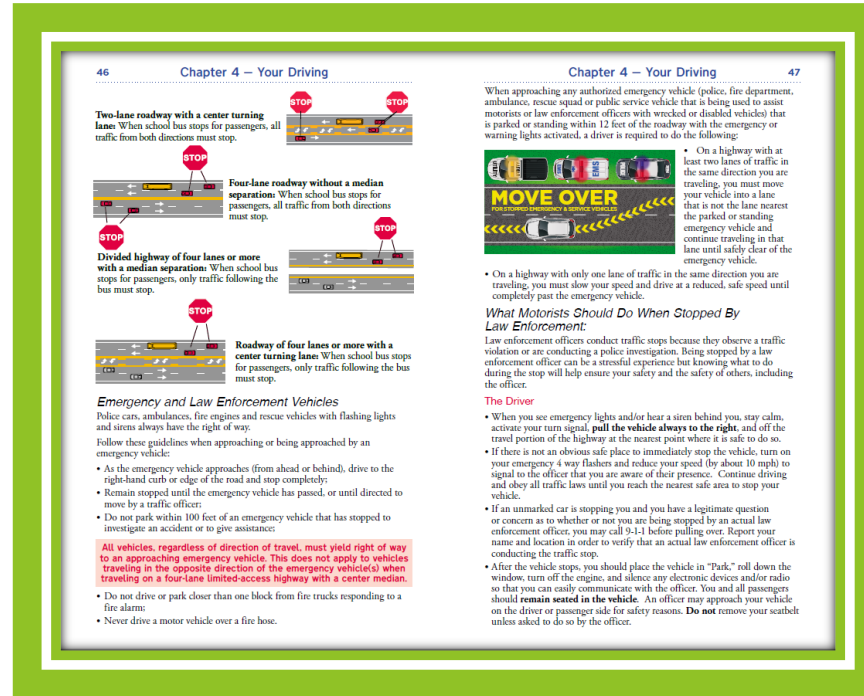


# Challenges

With Manuals...



Portrait mode



Figures and columns



With rules...

- Irrelevance of certain extracted rules
  - Non-driving rules (motorcycles, bicycles, pedestrian)
- Some rules had issues like spelling mistakes or misplaced words due to:
- Dashes
  - Page Jumps
  - Lists

# Rule Extraction and Encoding from Driving Manuals

makes sense to drive more slowly. If your vehicle begins to lose traction, decrease your speed even more. Good tires with deep tread help to

Each sentence processed individually



Identify Keywords: **“IF”, “THEN”, “BECAUSE”**  
Turn sentence into IF(phrase) THEN(phrase)

Triple structure generation

Search for conjunctions: **“and”, “that”, “not”, “or”** to separate clauses

Using a part-of-speech tagger we generate the rule using the structure (subject,verb,object)



*IF (vehicle, begins, lose traction), THEN (self, decrease, speed)*



# Results

67 automatically extracted rules

212 that needed small refinements

## Examples:

- if you miss your exit take the next one

*IF(self, miss, exit), THEN (self, take, one) → IF (self, miss, exit), THEN (self, take, next one)*

- if you are the driver entering the highway you must yield to the exiting driver

*IF(self, isA, driver), THEN (self, yield, exiting) → IF (self, isA, entering), THEN (self, yield, exiting)*

# Rules can Identify Conditions that AVs must Identify & Adapt to

*IF (self, encounter, duststorm), THEN (self, Reduce, speed)*

If you encounter a severe dust storm reduce your speed immediately

**AVs can get weather reports and correlate to camera feed & then adapt driving behavior**



*IF (self, has, trailer), THEN (currents, cause, jackknife)*

if you are pulling a trailer wind currents can cause your vehicle to jackknife

**AVs can attempt to identify if they are pulling a trailer or not so they can drive accordingly**



# Contribution and Future Work

- ▶ We extracted 200+ rules from the manuals available online



The screenshot shows a code editor interface with a dark theme. At the top, it displays '529 lines (529 sloc) | 96.7 KB' and buttons for 'Raw' and 'Blame'. Below is a search bar with the text 'Search this file...'. The main content is a table with four rows, each representing a rule and its semantic text.

Line	Rule	Semantic text
1	<b>Rule</b>	<b>Semantic text</b>
2	IF (self, miss, turn), THEN (driving, until, turn)	if you miss a turn keep driving until you can safely and legally turn around
3	IF (self, block, intersection), THEN (self, get, ticket)	you may get a ticket if you block the intersection
4	IF (self, miss, exit), THEN (continue, around, exit)	if you miss your exit continue around until you return to your exit

- ▶ Improve the extraction to get the most relevant and mandatory rules from each state
- ▶ Identify deviations from each state
- ▶ Structure selected rules as Linear Temporal Logic for simulation in CARLA using Scenic
- ▶ Use these rules in an anomaly detection system to determine compliance

- ▶ You can check the rules at:

<https://github.com/RollingBeatle/rule-analyzer/tree/main/results>

- ▶ Special thanks to seed funding initiative from UCSC for making this possible