OTONOM SÜRÜŞ: DÜNDEN BUGÜNE, OTONOM KAMYONLAR

BYÖYÖ 2020

2 TEMMUZ, 2020

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ANATOMY OF AN AUTONOMOUS VEHICLE

Sense
- Object detection (vehicles, pedestrians, traffic signs)
- Road detection (lane markings, road surface,...)
- Intent prediction (e.g., what will this car do in two seconds?)
- Self-localization (where am I?)

Plan
- Mission planner
- Path planner (think Google Maps)
- Trajectory planner
- Vehicle control
  - Lateral
  - Longitudinal

Act
- Steering position/torque control
- Speed control (brake, acceleration)
- Behaviors (headlights, vipers,...)
DARPA GRAND CHALLENGES

- Urban Challenge (2007)
- Talent pool
- Public awareness

Caveat: set the ultimate problem as the first frontier
SELF-DRIVING GENEALOGY
A SINGLE PLAYBOOK

- Focus on a geofenced area and think it simplifies complexity
- Build HD maps
- Use maps for localization + obstacle detection
- Build a large test fleet and continuously collect test data and update maps
- Heavily rely on supervised learning + deep learning
  - Starting to change
- Rinse and repeat
SELF-DRIVING 2020: RECTIFIED EXPECTATIONS

- **2016**
  - **Quartz**
    - Ford (F) will have a self-driving car with no steering wheels or pedals in 2021
      - At an event in Silicon Valley, Ford CEO Mark Fields announced that in five years’ time, the company intends to have a fully autonomous vehicle on the road.
      - Aug 16, 2016
  - **Bloomberg**
    - Uber's First Self-Driving Fleet Arrives in Pittsburgh This Month
      - Sebastian Thrun, the creator of Google's self-driving car project, spent seven years researching autonomous robots at CMU, and the project's former director, ...
      - Highly Cited: Aug 18, 2016
  - **Los Angeles Times**
    - Look, Ma, no hands: Google to test 200 self-driving cars
      - Look, Ma, no hands: Google to test 200 self-driving cars ... space for your belongings, buttons to start and stop, and a screen showing where the car is going.
      - May 28, 2014

- **2015**
  - **Wired**
    - The World's First Self-Driving Semi-Truck Hits the Road
      - (An autonomous truck could exit the interstate near the end of its journey, park in a designated lot, and wait for a human to come drive it on surface streets to its ...)
      - In-Depth: May 5, 2015

- **2014**
  - **Bloomberg**
    - Alphabet exec says self-driving cars have gone through a lot of hype, but Google helped drive that hype
      - Waymo executives think people have taken its promises of self-driving cars too seriously. The Alphabet subsidiary went “through a lot of hype that was sort of ...”
      - Oct 23, 2019

- **2018**
  - **Bloomberg**
    - Shaken by hype, self-driving leaders adopt new strategy: Shutting up
      - PALO ALTO, Calif. — Three former executives at Google, Tesla and Uber who once raced to be the first to develop self-driving cars have adopted a new ...
      - Oct 18, 2018

- **2019**
  - **Bloomberg**
    - Ford CEO Tamps Down Expectations for First Autonomous Vehicles
      - Too much hype has built up about how soon self-driving cars will hit the road, but they will ultimately change the world, Ford Motor Co.'s chief executive officer ...
      - Apr 9, 2019
  - **VentureBeat**
    - Uber expects a long wait before self-driving cars dominate
      - Urtasun’s comments fall in line with the rest of the self-driving industry, which after much hype and bold promises has tempered expectations and pushed out ...
      - Apr 8, 2019

WHY AUTONOMOUS DRIVING IS HARD?

• Easy to demonstrate, hard to turn into a robust product
• Uncertainty in the real world is very difficult for robots to model and cope with
  • Humans cause most of the uncertainty
  • Humans are very good at interpreting and coping with each other
IT IS MORE THAN JUST DETECTING OBJECTS

Maybe careless?

Distracted driver

Not a cone, not a stop sign!

Why did the chicken cross the road?

Have a fighter jet in training data?

Is half a pick-up still a pick-up?
EXAMPLE: PROBABILITY OF JAYWALKING
ISSUES WITH ML BASED SYSTEMS

- Lack of robustness against adversarial perturbations
- Lack of introspection and formal frameworks to provide bounded performance guarantees
- Real world continuous data from robots violating the i.i.d. assumption
PROGRESS HAS STALLED / SLOWED DOWN

• Open ended definition of full autonomy
• Linearly probing an exponentially large state space
• Negative unit economics limit test fleet size
THE LOCOMATION APPROACH TO AUTONOMY

Distillation of vast “know-how” and “know-how-not-to”

• Embrace the long path ahead for full autonomy, start with a tangible scope
• Build a robust, safe hardware and the software autonomy stack at the core (L4 / L5 capable)
• Build a true minimum viable product and start adding significant value now, then iterate quickly
• Make sure there is a viable business with positive unit economics at every iteration
• Incrementally validate the system for increasingly complex applications / domains
SELF-DRIVING TRUCKS: DIFFERENCES

• Safety
  • A fully loaded truck is a 80,000 pound projectile going at 70mph
    • ~30m/s displacement
  • Highways are more structured, but semi-trucks pose higher safety risks
    • Zero room for any mishap
    • All it takes is one bad accident
    • Edge cases are less frequent but equally rich

• Autonomy technology
  • Motion planning / vehicle control
    • Different trailers, changing tire, brake, etc. performance
  • Sensing
    • Moving cab, hard to correlate what a sensor sees with where the vehicle is

“If you think safety is expensive, try having an accident.”
SAFETY - VALIDATION

• Functional safety – ISO26262, etc.

• Graceful degradation (lizard brain)

• MTBFs - Hardware redundancy

• Top down (e.g., Functional Hazard Analysis, Fault Trees)

• Bottom up (e.g., field testing)

• Safety at the system architecture level
LOCOMATION TECHNOLOGY READINESS ROADMAP

Mainly long-haul / over-the-road

AUTONOMOUS RELAY CONVOY (ARC™)
(pilot: 2019 – commercial: 2021)

Initially short-haul, expand the range over time

HIGHWAY FULL AUTONOMY
(pilot: 2021 – commercial: 2024)

+ Short-haul, dedicated linehaul / relays

AUTONOMOUS DRONE FOLLOWER, 3 TRUCK CONVOYS
(pilot: 2020 – commercial: 2023)

Initially short-haul, expand the range over time

HUB-TO-HUB FULL AUTONOMY
(pilot: 2022 – commercial: 2025+)
LOCOMATION STACK

- Autonomy retrofit kit
  - OEM installation in the future

- Compatible with major truck makes/models
  - ~70% of all trucks, >90% of large fleets in US

- Robust, safe, future compatible design
  - Full L4 self-driving capable

- Rapid deployment/scaling on new routes
  - No reliance on infrastructure or HD maps

- Integration with the fleet management systems
  - Optimization/scheduling for convoy dispatching
DRIVE-BY-WIRE KIT

Locomation B-Kit
- Steering Control
- Brake Control
- Throttle Control

Locomation A-Kit
- Hardware
  - Sensors, Computing
- Software
  - Autonomy Stack
SENSING

- Custom software to optimize sensor configuration
- MirrorPod sensing unit
  - Easy to install – similar to a mirror replacement
  - “Hammerhead effect” to see through traffic on the sides
  - Adequate coverage around the vehicle with minimal blind spots
  - Easy to “factory calibrate”
  - Patent pending
- INS
  - Low cost: VectorNav
  - Ground truth: NovAtel Span

Optimal sensor coverage
Note: very simplified block diagram due to confidentiality of the full design.
Tight following distance requires impeccable motion planning

Accurate system identification (braking distance, mass distribution)

Formation control
PERCEPTION

- Core elements implemented using geometric vision algorithms
  - Contrast and continuity based lane detector & tracker
  - Shape and template based leader truck detector & tracker
  - Multi-modal pre and post detection sensor fusion
  - White box, verifiable
  - Lightweight, does not require a GPU farm to run
- Future expansions will use ML "doers" with verifiable "checkers" as the safety net for complex semantic understanding and prediction
PERCEPTION – LEADER TRACKING - CAMERA
PERCEPTION – LEADER TRACKING - LIDAR
PERCEPTION – LEADER TRACKING – 3-WAY FUSION
- Model Predictive Control (MPC)
- Inverse dynamics based trajectory planning
  - Nominal (in-lane) lateral control
  - Lane change
  - Accel and decel profiles
- Evasive planning
  - Plan next actions for not just the benign expectations, but also for a list of abnormalities
  - Full stop, swerve, pull to side, etc.
- System identification for braking, CG, tire-terrain interaction, etc.
  - Characterize what the vehicle can (and will) do
  - Comprehensive initial calibration
  - Continuous online calibration
INV. DYNAMICS BASED TRAJECTORY PLANNING

Generate motions consistent with
• vehicle dynamics
• road surface conditions
• rules of road (lanes).

Options and Analysis
Continuum Search – not convex
Command Space Sampling – too hard to meet constraints
Workspace Sampling – hard but doable
SIMULATION

Custom in-house simulator for photorealistic perception development/testing

Ultimate one-stop-shop simulation environment

Commercial vehicle dynamics simulator
DEVELOPMENT AND V&V FOR SAFETY

- Rapid development vs. rigorous engineering
- Agile is good for quick prototyping
- Proven concepts need “hardening”
- Even prototype needs to be safe
- No “Go fast and break things”

Tested and verified components
TEAM

✓ 100+ years founder experience, 50+ AV systems deployed
✓ Multiple trucking products launched, thousands of units sold
✓ Deep expertise in freight analysis and optimization
✓ 22 headcount, average engineer AV experience: 14 years
SELECT RELEVANT PAST WORK
WRAP UP

• Humans are lousy drivers but replacing them with machines is still an open science question

• The industry had been suffering from the “Innovator’s Dilemma”

• A more efficient, “first principles” approach is viable

• Selecting a domain and application is important from sustenance point of view

• Locomation takes a very strong “last mover” position, filters every assumption through the “know-how” and “know how not to” filters

• Autonomy will first come to freight transportation, and incrementally
Teşekkürler!

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