Programmable Test Track for AVs

Aviral Shrivastava

Arizona State University

With inputs and support from:
Lina Karam, Georgios Fainekos, Heni Ben Amor, Rida Bazzi, Ram Pendyala, Sethuraman Panchanathan (faculty @ ASU)
Edward Andert, Mohammad Khayatin (my students @ ASU)
Marissa Walker, Kevin Biesty, Matt Clark (state of Arizona)
Greg Leeming (Intel), Jack Weast (Intel), Jeffrey Wishart (Exponent), Nils Hoffman (Local Motors)

CML

About myself

- Computer Scientist by training
  - IIT Delhi, and UC Irvine
- Professor of CSE @ Arizona State University

- NSF, NIST, Industry projects on
  - Scaling real-time compute-power of processors
  - Tick-talk: Timing API for distributed CPS
  - Testing the timing of CPS

- AV-related research
  - Help build some AVs
  - Design of algorithms for traffic intersections of AVs [DAC 2017][RTSS 2018]

Software correctness is hard!!

```
bool flag[2] = {false, false};
int turn;
```

```
flag[0] = true;
turn = 1;

while (flag[1] == true && turn == 1)
{
    // busy wait
}

// critical section
...
// end of critical section

flag[0] = false;
```

```
flag[1] = true;
turn = 0;

while (flag[0] == true && turn == 0)
{
    // busy wait
}

// critical section
...
// end of critical section

flag[1] = false;
```

Peterson's algorithm for mutual exclusion of two threads

Software correctness is hard!!

The Ariane 501 crash

- Start.
- 37 seconds of flight.
- KaBOOM!
- 10 years and 7 billion dollars are turning into dust.

Why visibility matters—the Ariane 5 crash

- Velocity was represented as a 64-bit float
- A conversion into a 16-bit signed integer caused an overflow
- The current velocity of Ariane 5 was too high to be represented as a 16-bit integer
- Error handling was suppressed for performance reasons

*Source: http://moscova.inria.fr/~levy/talks/10enslongo/enslongo.pdf

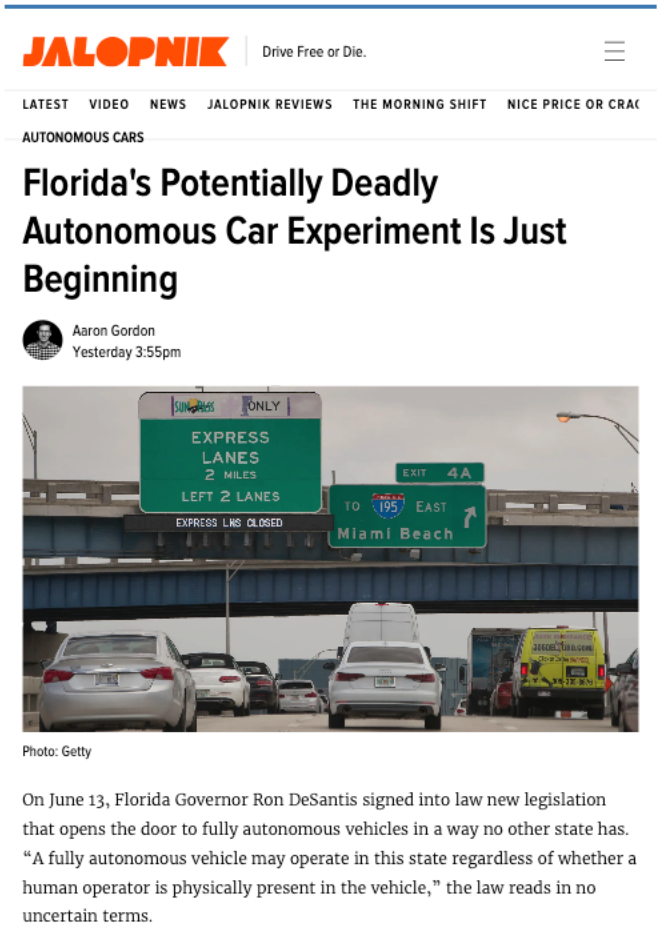
```
-- Vertical velocity bias as measured by sensor
L_M_BV_32 :=
   TBD.T_ENTIER_32S ((1.0/C_M_LSB_BV) *
   G_M_INFO_DERIVE(T_ALG.E_BV));
-- Check, if measured vertical velocity bias ban be
-- converted to a 16 bit int. If so, then convert
if L_M_BV_32 > 32767 then
   P_M_DERIVE(T_ALG.E_BV) := 16#7FFF#;
elsif L_M_BV_32 < -32768 then
   P_M_DERIVE(T_ALG.E_BV) := 16#8000#;
else
   P_M_DERIVE(T_ALG.E_BV) :=
         UC_16S_EN_16NS(TDB.T_ENTIER_16S(L_M_BV_32));
end if;
-- Horizontal velocity bias as measured by sensor
-- is converted to a 16 bit  int without checking
P_M_DERIVE(T_ALG.E_BH) :=
   UC_16S_EN_16NS (TDB.T_ENTIER_16S ((1.0/C_M_LSB_BH) *
   G_M_INFO_DERIVE(T_ALG.E_BH)));
```

Consensus-driven testing of AVs

- No test can prove the safety of a CAV
  - Confidence building measure

- Measurable target for the developers
- Clear definition of due diligence
- Confidence building

- AV developer/manufacturer independent/agnostic



JALOPNIK Drive Free or Die.

LATEST VIDEO NEWS JALOPNIK REVIEWS THE MORNING SHIFT NICE PRICE OR CRAC

AUTONOMOUS CARS

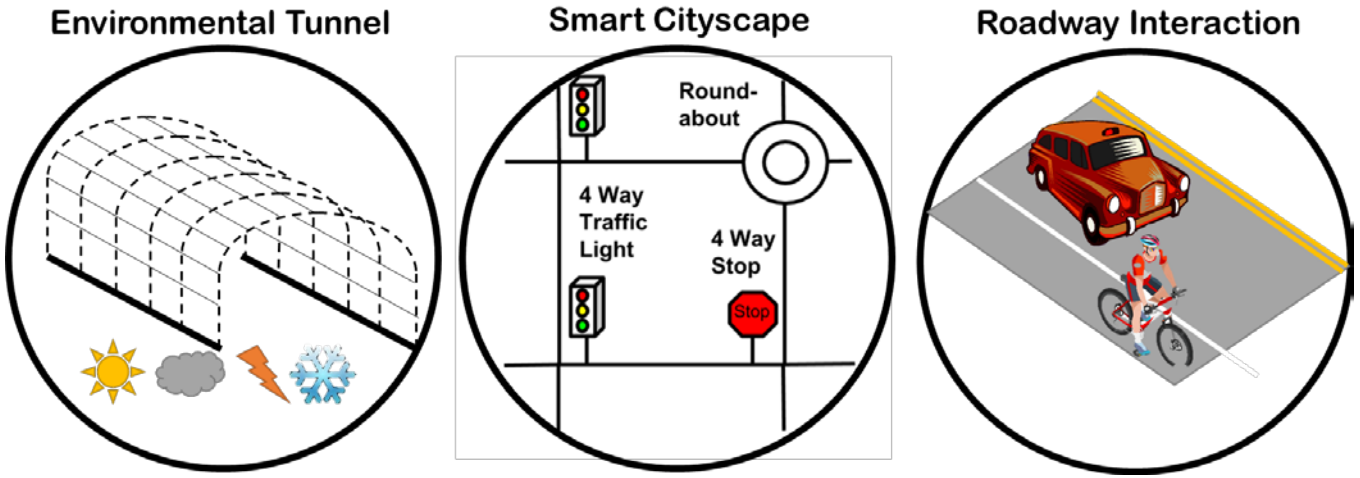
Florida's Potentially Deadly Autonomous Car Experiment Is Just Beginning

Aaron Gordon
Yesterday 3:55pm

Photo: Getty

On June 13, Florida Governor Ron DeSantis signed into law new legislation that opens the door to fully autonomous vehicles in a way no other state has. "A fully autonomous vehicle may operate in this state regardless of whether a human operator is physically present in the vehicle," the law reads in no uncertain terms.

Programmable test track



- Environmental Tunnel
  - Wind, snow, rain
- Cityscape
  - Intersections, stop signs
- Roadway interactions
  - Bicyclists, other vehicles, deer on a highway

- Program the timing of the events and interactions
- Can be set using a script

How to create the tests?

- Choose commonly occurring scenarios
- Choose among the known NHTSA crash scenarios
- Driving scenarios to test sensor and sensor-fusion weak points
  - Sudden start/stop of rain, light
- Driving scenarios to test ML vulnerabilities
  - Adversarial attacks
- Driving scenarios to test software vulnerabilities
  - Module interaction and reuse, exceptions handlers
- Driving scenarios to test TIM situations
  - How does the AV behave in an acident
- Driving scenarios to test AV-driver interface
  - Is there enough time for a driver to be alerted and that they can meaningfully intervene
- Driving scenarios to test basic security vulnerabilities
  - Jeep attack

Varying illumination and obstacle types

Runtime safety monitor

- Mutually agreed-to safe driving rules (e.g. RSS)
- Safety monitor that will test whether the vehicle is driving safely at all times
  - Needs only coarse-level information, like the speed of the vehicle, position, acceleration of the vehicle

- Useful for internal testing for a manufacturer/developer
- Conflict resolution
- If non-tamperable (encrypted), the collected data will be compelling evidence to defend the actions of your vehicle

- Fundamental tension of using own sensors/using vehicle data
  - Use low-level information – will be useful to validate software's decisions

Conclusion

- **Software correctness is hard!!!**

- Before deployment - Need Mutually agreed-to test for AVs
- After deployment - Need runtime safety monitors

- Exciting times are ahead