AV: CONTROL/DATA WORLDS COLLIDING

AUTOMOTIVE CONTROLS

FULL AUTONOMY

ARTIFICIAL INTELLIGENCE

LOW-LEVEL
SIMPLE BY DESIGN
NARROW SCOPE FOR CONTROL

LARGE SCALEABLE IT SOFTWARE

ABSTRACT/PROBABILISTIC-LEVEL
HIGHEST COMPLEXITY AND VALUE
VERY DIFFICULT TO VERIFY AND PROVE RELIABILITY

HIGHER-LEVEL
SCALABLE COMPLEXITY FOR ADVANCED DATA PROCESSING
RELIABILITY VIA PARALLELISM, DIVERSITY
PRI VISION: SIMPLIFY AV, ROBOTICS

**FOCUS** TIME SPENT ON REUSABLE SOLUTION LOGIC/UI

**MAX** = GENERIC ROBOT PLATFORM

- **MOBILE**
- **AUTONOMOUS**
- **X = ANYTHING**

- **PORTABLE**
- **SERVICES**
- **PLUG & PLAY**
- **ANYTHING**

**HIGH-LEVEL APPLICATION LOGIC**

**Sensors**

**Actuators**

**Devices**
**Actions/Maneuvers**

**Perception, Fusion**

**POSE**

**Inertial Navigation**

**Map Data, Communications**

**WORLD EVENTS**

**SENSORS**

**VEHICLE MOVEMENT**

**PATH PLANNING**

**VEHICLE CONTEXT**

**ROUTE PLANNING**

**TRULY COMPLETE STACK – DEV & RUNTIME**

**MAX**

**An Ddion Planning Executive**

**Controls**

**Actuators**
PERCEPTION AND CONTEXT SERVICES

SENSOR EVENTS
- LiDAR
- Radar
- Camera

VEHICLE MOVEMENT
- GPS
- IMU
- Speed Sensor

CONTEXT
- Map Data

VEHICLE MAX
- Parse data (lidar)
- (Radar)
- (camera)
- Perception (lidar)
- (Radar)
- (camera)
- Fusion
- Parse Data (gps)
- (imu)
- (speed)
- Pose
- Route planning
- Action Planning
- Actions/Maneuvers

Maps interface
FLEXIBLE, EXTENSIBLE MANEUVER MODEL

Fusion

Action planning (Action/Maneuver arbitration by priority and design)

Path Planning

Controls

Actuators

Steering
Shift
Brake
Throttle

Subscriptions to Events

Actions/Maneuvers

TURN R/L
COMMUNICATE ANALYSIS
PASS VEHICLE
AVOID OBSTACLE...

WORLD EVENTS

ANALYZE IMAGE FOR TRAFFIC LIGHTS, DETERMINE STATE

NEURAL NET / AI

OTHER LOGIC

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HIGHLY CONFIGURABLE

TASK: MONITOR CAMPUS WITH SEVERAL BUILDINGS

- **VEHICLE 1:** STANDARD TRUCK
  - ACKERMAN STEERING
  - FULL SIZE, COMMS, SENSORS

- **VEHICLE 2:** SECURITY BOT
  - SKID STEERING
  - TRACK-DRIVEN, FEWER SENSORS, COMMS

- BOTH CAN RUN EXACT SAME MISSION:
  - JUST CHANGE CONFIG
  - NO CODE CHANGES
**WHAT CHANGES BETWEEN PLATFORMS?**

**APPLICATION UI/LOGIC**

**CHANGE AS NEEDED — THIN LAYER**

**CORE PLATFORM, CORE AUTONOMY: UNCHANGED**

**SENSORS, BEHAVIORS, ACTIONS ARE MANAGED WITH CONFIGURATION TEXT FILES (E.G. ACKERMAN VS. SKID STEERING)**

**SMALL AMOUNTS OF CODE MAY BE REQUIRED FOR UNUSUAL SENSORS**
SIMPLE CASE: “FOLLOW ME”

- SENSORS NORMALLY DETECT AND AVOID PEOPLE, THINGS
- IN THIS MODE, VEHICLE STILL DETECTS PEOPLE, BUT SEEKS TO KEEP PERSON IN FRONT OF VEHICLE
- SO AS PERSON MOVES, VEHICLE “FOLLOWS”
- TAKE FROM VEHICLE TO VEHICLE USING DIFFERENT SENSORS – WITHOUT CHANGES!
## MAX Reuse Across Platforms/Solutions

<table>
<thead>
<tr>
<th>Function</th>
<th>Automotive</th>
<th>Industrial</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obstacle detection and avoidance</td>
<td>Developed here</td>
<td>Reuse without change, add negative ODA if needed</td>
<td>Reuse without change</td>
</tr>
<tr>
<td>V2X Communication</td>
<td>Reuse/Adapt, but use DSRC</td>
<td>Developed here – DDS</td>
<td>Reuse/Adapt, but use wifi</td>
</tr>
<tr>
<td>Parking Maneuver</td>
<td>Developed here</td>
<td>Reuse for loading (dump truck); add dynamic siting</td>
<td>Reuse for charging station</td>
</tr>
<tr>
<td>Intersection handling</td>
<td>Developed here</td>
<td>Reuse without change</td>
<td>Reuse without change</td>
</tr>
<tr>
<td>Dynamic course/mission changes</td>
<td>Add to existing re-routing</td>
<td>Developed here</td>
<td>Reuse without change</td>
</tr>
<tr>
<td>Indoors navigation</td>
<td>Reuse without change</td>
<td>Reuse without change</td>
<td>Developed here</td>
</tr>
</tbody>
</table>
FLEXIBLE ARCHITECTURE

- SCALE UP/DOWN AS TASK REQUIRES
- LEVERAGE REAL-TIME VM FOR HW/OS FLEXIBILITY
- SPECIALIZED ALGORITHMS RUN ON TUNED HW ARCH
- DISTRIBUTED PROCESSING MORE FAULT-TOLERANT

KEY:
- Strong HW and SW PLATFORM approach – IT like
- Abstraction of HW/OS enables maximum code reuse
WE HAVE DONE IT BEFORE

FIRST ROBOT

2003

FIRST FULLY AUTONOMOUS VEHICLES
(HISTORIC DARPA GRAND CHALLENGES)

2004-2007

COMMERCIAL & SHOWCASE DEPLOYMENTS
(PA TURNPIKE, AUTONOMY KITS, NEIL YOUNG, HARVESTER, ETC.)

2008-2015

INTEL CAPITAL INVESTMENT
GROWTH & TEST TRACK FACILITY

2016-2017

2017-2018

STRATEGIC CUSTOMERS

Premium Brand Automotive OEM

Tier 1 Auto Supplier

Multinational PC Manufacturer

LIEBHERR

WIND AN INTEL COMPANY

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LOCATED IN CROZET, VIRGINIA
SOLUTIONS IN MANY AREAS
MAXIMUM VALUE

- **A TRULY FLEXIBLE PLATFORM, PROVEN OVER MANY IMPLEMENTATIONS**
  - Unique combination of configurability, hardware/communications flexibility
  - Algorithm modularity, Full stack-suite of app services

- **MIGRATE SEAMLESSLY ACROSS PROJECTS TODAY**
  - Leverage inherent network effect from MAX platform model

- **IP: PLATFORM PATENTED IN 2006**
  - With extension (continuance in part) this Spring

- **PATH TO PRODUCTION/CERTIFICATION**
  - MAX built with production in mind - not just R&D, but actual deployment
  - Beginning work on 61508 certification (SIL 2 to start)
THANK YOU!

QUESTIONS?

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FLEXIBLE AUTONOMY

DISTRIBUTED PROCESSING, LAYER ON AI, ACCELERATION AS NEEDED

• GPS IS PRIMARY LOCALIZATION
• ADD LANE-KEEPING WHEN GPS IS POOR
• ADD SENSOR DATA TO MANAGE OBSTACLES
• USE SMALLER, DISTRIBUTED AND FLEXIBLE PROCESSORS
  • LOW POWER, LOW HEAT
• USE MORE WHEN NEEDED

EVENTS

Data processing in distributed Nodes

OBSTACLES

Fusion and movement planner

SIGNALS/SIGNS

LOCATION

LiDAR
Radar
IMU
Camera
FUSION IN TIME AND SPACE

- Sensor (S)
- Noise Filter (NF)
- Perception (P)
- Fused - Time (F_T)
- Fused - Space (F_S)
- Physical Objects (PO)
- Sensation Perspective (SP)

The diagram illustrates the fusion process, where data from sensors and noise filters are processed through perception modules to produce fused representations in both time and space.
MULTI-SENSOR FUSION APPROACH

SENSOR DIVERSITY FOR SAFETY, RELIABILITY IN AUTOMOTIVE

• GPS FOR CORE LOCALIZATION
• CAMERA FOR ADVANCED DETECTION, LOCALIZATION (AI-BASED)
• 16-BEAM LIDARS
  • USE 1-4+ AS NEEDED FOR OBSTACLE IDENTIFICATION
• RADARS FOR LONG-RANGE OBSTACLE DETECTION
**MULTI-SENSOR FUSION APPROACH - II**

HAUL TRUCK: VERY SIMILAR TO AUTOMOBILE - SAME PLATFORM, JUST RECONFIG

- GPS FOR CORE LOCALIZATION
- CAMERA FOR ADVANCED DETECTION (AI-BASED)
- RADARS FOR LONG-RANGE OBSTACLE DETECTION
- 8-BEAM LIDARS FOR SMALLER OBSTACLE DETECTION