Introduction to Dr. Ma Changjie

• **Chief software Architect** of high-precision map of intelligent automobile department of **Baidu, Inc.**;

• **Ph.D.** of China University of Geosciences (Wuhan);

• **Research interests**: Geographical Information Science, Autonomous Driving, Navigation & HD Map;
Baidu Apollo HD Map

Dr. Ma Changjie
Nov. 2018
Open Capability  
Shared Resources  
Accelerated Innovation  
Sustained Mutual Benefit
Apollo is Accelerating Innovation for Autonomous Driving

- **2017.4** Hello Apollo
  - Apollo Platform Announced

- **2017.7** Apollo 1.0
  - Closed Venue Tracking
  - Autonomous Driving

- **2017.9** Apollo 1.5
  - Fixed Lane
  - Autonomous Driving

- **2018.1** Apollo 2.0
  - Autonomous Driving
  - for Simple Urban Road Conditions

- **2018.4** Apollo 2.5
  - Vision-based Highway
  - Autonomous Driving in Limited Area

- **2018.7** Apollo 3.0
  - Upgraded Architecture

- **131** Partners
- **11,000 +** Developers
- **230,000 +** Lines of code
Apollo Pilot: Making Driving Safer

**Multi-Driving Scenarios**
- Highway/Ring Road Cruising
- Obstacle Evasion
- Auto Lane-changing
- Traffic Jam
- ETC and ramps
- Automatic Valet Parking
- Valet Parking/Summoning
- Traffic Jam Pilot
- Stop & Go Supported
- Station Parking/Obstacle Evasion

**Multi-Vehicle Types**
- **Passenger Vehicle**
  - Private Car
  - Shared Car
- **Commercial Vehicle**
  - Freight
  - Bus
  - Mid-size
  - Mini-size

Apollo Pilot: Making Driving Safer
Apollo HD Map

- One Road Network Architecture
- Full-Scenario Features
- AI Driven Technology
One Road Network Architecture

### HD Map
- AD Assisted Driving Data (e.g. Speed up, Slow down, etc.)
- Dynamic Data (RTTI, Traffic Events etc.)
  - Sensor Feature
  - Parking Facility
  - Lane Topology
  - Traffic Signs
  - Data Adapter/Cross-reference

### SD Map
- Lane-Level Navigation Data
- Road-Level Navigation Data
  - BMD
  - POI
  - Routing
  - Names
  - Road Network
One Road Network Architecture
Full-Scenario Features: Highway & Expressway

<table>
<thead>
<tr>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane Marking Geometry</td>
</tr>
<tr>
<td>Lane Marking Color</td>
</tr>
<tr>
<td>Lane Marking Style</td>
</tr>
<tr>
<td>Lane Marking Material</td>
</tr>
<tr>
<td>Lane Marking Width</td>
</tr>
<tr>
<td>Lane Construction State</td>
</tr>
<tr>
<td>Lane Number</td>
</tr>
<tr>
<td>Lane Width/Type</td>
</tr>
<tr>
<td>Lane Centerline</td>
</tr>
<tr>
<td>Lane Topology</td>
</tr>
<tr>
<td>Max/Min Speed Limit</td>
</tr>
<tr>
<td>Junction</td>
</tr>
<tr>
<td>Overpass</td>
</tr>
<tr>
<td>Guardrail/Curb</td>
</tr>
<tr>
<td>Arrows/Words</td>
</tr>
<tr>
<td>...</td>
</tr>
</tbody>
</table>

Beijing

Shanghai

Lane Centerline
Lane Marking Geometry
Lane Marking Style
Lane Marking Color
Guardrail
Curb

Arrow

Overpass
**Full-Scenario Features: Urban Road & Close Area**

<table>
<thead>
<tr>
<th>Features</th>
</tr>
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<tbody>
<tr>
<td>Lane Marking Geometry</td>
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<tr>
<td>Lane Marking Width</td>
</tr>
<tr>
<td>Lane Construction State</td>
</tr>
<tr>
<td>Virtual Lane Connectivity of Intersection</td>
</tr>
<tr>
<td>Intersection Boundary</td>
</tr>
<tr>
<td>Traffic Light</td>
</tr>
<tr>
<td>Stop Line</td>
</tr>
<tr>
<td>Speed Bump</td>
</tr>
<tr>
<td>Zebra Line</td>
</tr>
<tr>
<td>Overpass</td>
</tr>
<tr>
<td>Traffic Sign</td>
</tr>
<tr>
<td>No Parking Area</td>
</tr>
<tr>
<td>...</td>
</tr>
</tbody>
</table>
Full-Scenario Features: Parking Facility

<table>
<thead>
<tr>
<th>Features</th>
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</thead>
<tbody>
<tr>
<td>Parking Facility Region</td>
</tr>
<tr>
<td>Parking Space ID</td>
</tr>
<tr>
<td>Parking Space Geometry</td>
</tr>
<tr>
<td>Parking Wheel Marker</td>
</tr>
<tr>
<td>Parking Lane Marking</td>
</tr>
<tr>
<td>Pole</td>
</tr>
<tr>
<td>Drivable Area</td>
</tr>
<tr>
<td>Connection to Road</td>
</tr>
<tr>
<td>Handover Zone</td>
</tr>
<tr>
<td>Arrow</td>
</tr>
<tr>
<td>No Parking Area</td>
</tr>
<tr>
<td>Zebra Line</td>
</tr>
<tr>
<td>Curvature</td>
</tr>
<tr>
<td>Traffic Sign</td>
</tr>
<tr>
<td>Ramp Area</td>
</tr>
<tr>
<td>...</td>
</tr>
</tbody>
</table>

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- **Parking Facility Region**
- **Parking Space ID & wheel marker**
- **Lane Marking & traffic sign**
AI Driven Technology: HD Map Production Pipeline

Data Sourcing
- GPS
- IMU
- LiDAR
- Camera

Backend Automation
- Point Cloud Fusion & Recognition
- Fusion
- Pole
- Curb
- Guardrail
- Arrow
- Signboard

Map making & Validation
- Mapmaker
- Map production management

Map Compile & Release
- NDS Release
AI Driven Technology: Point Clouds & Images  Automated Processing

PCF&PCR
- Motion Compensation
- 3D Modeling
- Feature extraction
- Point Cloud Fusion
- Point Cloud Recognition

TSR
- Image Recognition

MSF
- 3D->2D Mapping
- Element track
- cluster
- Filter & fill-up

Deep Learning Neural Network (CNN/RCNN/RNN)
AI Driven Technology: Point Clouds & Images  Automated Recognition

Chinese standard traffic sign list above, 200 types or so.

Lane marking and Guardrail in China about 50 types

<table>
<thead>
<tr>
<th>Feature</th>
<th>Accuracy rate</th>
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</thead>
<tbody>
<tr>
<td>Lane Marking</td>
<td>96.6%</td>
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<tr>
<td>Guardrail</td>
<td>99.1%</td>
</tr>
<tr>
<td>Curb</td>
<td>99.1%</td>
</tr>
<tr>
<td>Sign</td>
<td>95.4%</td>
</tr>
<tr>
<td>Pole</td>
<td>95.5%</td>
</tr>
</tbody>
</table>
AI Driven Technology: Intelligent Map Ecosystem

Smartphone Crowd-Sourcing

In-Car Smart Device

Intelligent Connected Car

Autonomous Driving Car

Data

DC

Data

DC

Data

DC

Data

DC

Data

DC

Intelligent Map Platform

Baidu Survey Fleet
Open Road testing with BMW/Bosch/Cherry

BMW AD road testing on Open road 2016

Bosch AD road testing on SuZhou Highway 2017

Cherry AD road testing on Wuhu Highway 2018
OEM Partners Testing Reports & Nomination
Thanks