TRI-AD Toyota Research Institute Advanced Development, Inc.

TRI-AD drives successful creation of HD maps for automated driving on surface roads
~Ongoing partner collaboration to drive further accuracy~

Toyota Research Institute-Advanced Development, Inc. (“TRI-AD”), Toyota’s automated driving software development company, has successfully completed proof of concepts (“PoC”) demonstrating high definition (“HD”) map building for surface roads with relative accuracy of less than 50 centimeters, a good level that is required for automated driving.

In these PoCs, TRI-AD verified that both following methods are effective for HD map building:

1. Building map information for automated driving via map data derived from the cameras of ordinary vehicles as well as satellite imagery, without the use of conventional means of collecting data such as survey vehicles.
2. Applying vehicle data from TRI-AD’s Automated Mapping Platform (“AMP”) to other companies’ platforms by converting data formats and applying correcting algorithms.

By utilizing the results of these PoCs, it is expected that the delay in updating HD maps for automated driving can be shortened, areas of HD map coverage can be expanded quickly, and costs to build and maintain the HD maps can be substantially reduced.

Each PoC results are below:

Maxar Technologies (“Maxar”), a trusted partner and innovator in Earth Intelligence and Space Infrastructure, Japan’s leading IT services provider NTT DATA Corporation (“NTT DATA”), and TRI-AD are collaborating on a proof of concept to build automated HD maps for automated vehicles using the highest-resolution commercial satellite imagery since April 25th, 2019. The PoC demonstrates it is possible to automatically extract the required map information by analyzing and eliminating automobiles and the shadow and inclination of buildings in satellite imagery. On this occasion, maps with a relative accuracy of 25 centimeters*1 were created within the 23 wards in Tokyo, as well as 6 cities globally, and were verified to be useful for automated driving. (Refer to Image 1,2 and 3.)

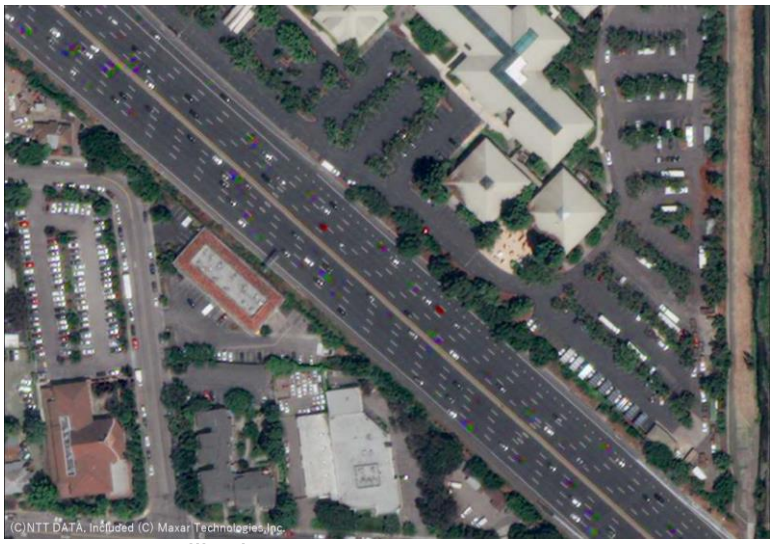

Image 1. Satellite imagery

Image 2. Automobiles elimination

Image 3. Map information extraction

TRI-AD and leading road intelligence platform, CARMERA Inc. (“CARMERA”), have successfully conducted a camera-based HD mapping initiative. As part of their global partnership, the collaboration used “dashcam” drive recorders to detect and place key road features - such as lane markings, traffic signals and signs - within the 23 wards in Tokyo and 2 cities in the United States. The project achieved a relative accuracy of 40 centimeters*1 for key navigation features - a major advance in camera-only detection. TRI-AD’s work with CARMERA used the same hardware-agnostic computer vision and processing technology as CARMERA’s Real-Time Events and Change Management engine, which detects, validates and delivers navigation-critical updates to CARMERA’s regenerative HD mapping system in minutes rather than months. By using consumer-grade vehicle cameras that are common around the world, TRI-AD and CARMERA showcased a scalable approach to next-generation map making.

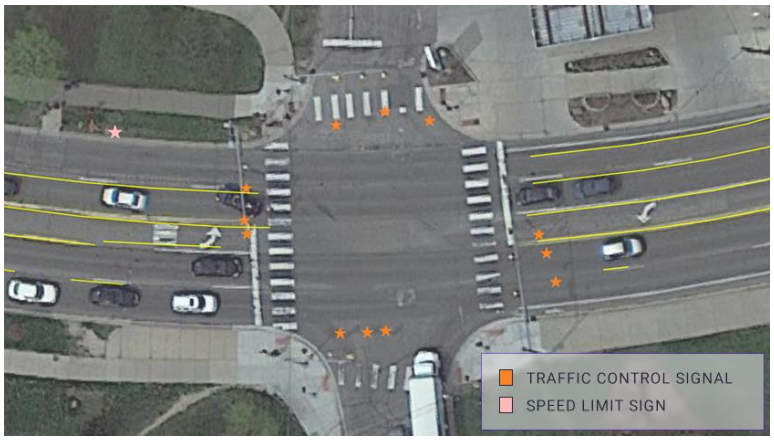

Image 4. Suburban road feature placement

Image 5. Urban street-level object detection

TRI-AD also collaborated on a PoC with TomTom International BV. (“TomTom”), a leading independent location technology specialist. Together, the companies showed that lower-class roads (urban roads), including lane markings necessary for automated driving, could be successfully created or updated in near real-time on TomTom’s HD map. The solution was achieved by verifying the reliability of the vehicle data collected by TRI-AD’s AMP, and then converting it for input into TomTom’s cloud-based transactional mapmaking platform.

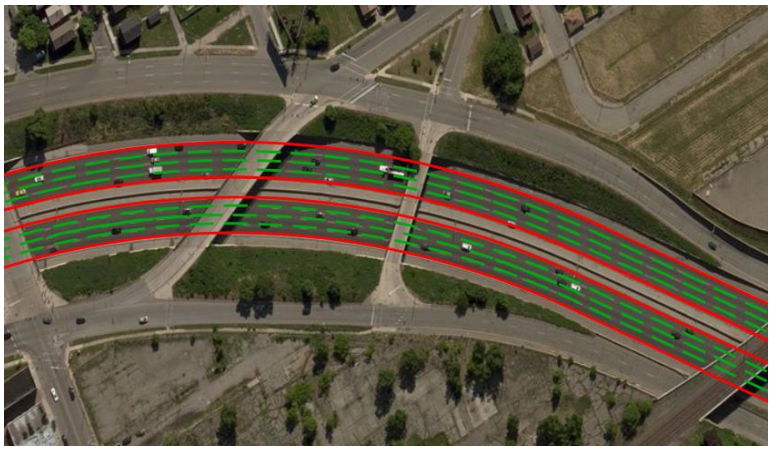
Image 6. Highly accurate HD Map lane markings

TRI-AD has collaborated with a world’s leading location data and technology platform, HERE Technologies (“HERE”) for this PoC. Correcting the positional errors in the vehicle data collected by TRI-AD, HERE was able to automatically create surface road maps using HERE’s advanced “Self-Healing” technology. By using only vehicle sensor data, HERE ingested the data into its platform and automatically generated HD maps including lane level information required for automated driving. HERE’s HD Live Map has already been selected to power some of the world’s most prestigious OEM’s Level 3 automated vehicle programs.

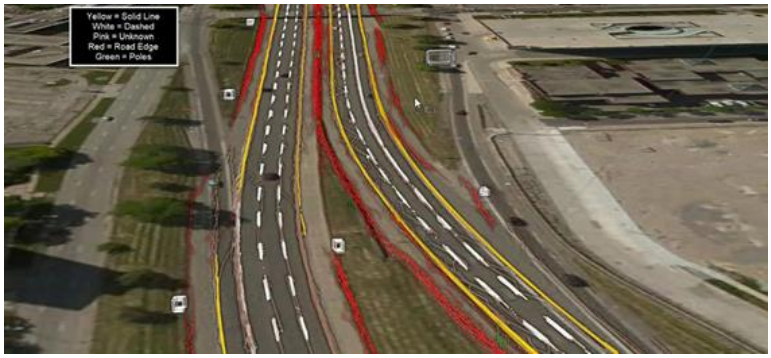

Image 7. Automatic generation of lane level HD map

Mandali Khalesi, Vice President of Automated Driving Strategy and Mapping at TRI-AD, said:
"I'm very pleased to announce the results of the PoCs with Maxar and NTT DATA , and CARMERA, and also the results of our new demonstration partners, TomTom and HERE. We got a step closer to a future where automated driving becomes a safer and more accessible technology for all. We will continue to cooperate with partners as we further refine our accuracy."

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About TRI-AD
Toyota Research Institute-Advanced Development, Inc. (TRI-AD), located in Tokyo, Japan, was founded in March 2018 for the purpose of developing innovative products that will enable Toyota's vision, "Mobility for All." TRI-AD's mission is to create new technology and advanced safety systems for the world. TRI-AD also oversees Toyota's newly announced Woven City, that will serve as an incubator for smart city design, connected mobility, and robotics technology from Toyota and its partners.
For more information about TRI-AD, please visit: www.tri-ad.global.

About Maxar Technologies
Maxar is a trusted partner and innovator in Earth intelligence and space infrastructure. We deliver disruptive value to government and commercial customers to help them monitor, understand and navigate our changing planet; deliver global broadband communications; and explore and advance the use of space. Our unique approach combines decades of deep mission understanding and a proven commercial and defense foundation to deploy solutions and deliver insights with unrivaled speed, scale and cost effectiveness. Maxar's 5,800 team members in 30 global locations are inspired to harness the potential of space to help our customers create a better world. Maxar trades on the New York Stock Exchange and Toronto Stock Exchange as MAXR. For more information, visit www.maxar.com

About NTT DATA Corporation
NTT DATA is a leading IT services provider and global innovation partner headquartered in Tokyo, with business operations in over 50 countries. Our emphasis is on long-term commitment, combining global reach with local intimacy to provide premier professional

services varying from consulting and systems development to outsourcing. For more information, visit www.nttdata.com.
NTT DATA have been fully engaged in the satellite-imaging business for 20 years, providing our AW3D-branded 3D maps on a global short-delivery basis. NTT DATA's AI and enhanced image-processing expertise to expand the coverage of high-definition maps on a fast, scalable and cost-effective basis. For more information, please visit www.aw3d.jp/en/ (AW3D).

About CARMERA
CARMERA is the leading road intelligence company building fully regenerative, production HD maps—via 100x cheaper, crowdsourced, camera-only updates—to deliver safe autonomy for all. Working with top automotive OEMs and mobility-as-a-service companies across North America, EMEA and Asia, CARMERA supports Level 2 (human-first) through Level 4 (machine-first) autonomy utilizing its sensor- and format-agnostic approach, and modular map creation and map maintenance offering. With a team hailing from the world's leading mapping, machine vision and AI institutions, and most recent venture backing led by GV (Google Ventures), CARMERA is headquartered in New York City and Seattle, with satellites in San Francisco, London, Detroit, Seoul and Tokyo. Learn more at carmera.com.

About TomTom
TomTom is the leading independent location technology specialist, shaping mobility with highly accurate maps, navigation software, real-time traffic information and services.
To achieve our vision of a safer world, free of congestion and emissions, we create innovative technologies that keep the world moving. By combining our extensive experience with leading business and technology partners, we power connected vehicles, smart mobility and, ultimately, autonomous driving.
Headquartered in Amsterdam with offices in 30 countries, TomTom's technologies are trusted by hundreds of millions of people worldwide.
www.tomtom.com

About HERE
HERE, a location data and technology platform, moves people, businesses and cities forward by harnessing the power of location. By leveraging our open platform, we empower our customers to achieve better outcomes - from helping a city manage its infrastructure or a business optimize its assets to guiding drivers to their destination safely. To learn more about HERE, please visit www.here.com and http://360.here.com.

Notes
*1 Reference values in some environments with good data accuracy in the target areas of these PoCs.

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