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The Impact of HD Maps for Autonomous Vehicles on the Evolution of Cartography

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Abstract:

We are currently witnessing rapid advancements in the development of products that convey spatial information in various forms, ranging from traditional 2D maps to sophisticated 4D models, often referred to as digital twins. Within the realm of maps for autonomous vehicles, distinctions can be made between Digital Maps, Enhanced Digital Maps, and High Definition Maps (HD Maps), as noted by Elghazaly et al. (2023). HD Maps, the most advanced and complex type, have been under development for several years and stand apart from traditional cartographic concepts. These maps are critical components in autonomous driving systems, offering detailed and precise representations of road environments. They play a key role in localization, detection, prediction, and planning for autonomous vehicles (Tsushima et al., 2020).

HD Maps are highly detailed digital representations of road environments, designed primarily for autonomous vehicles and Advanced Driver Assistance Systems (ADAS). They diverge significantly from traditional maps in several key aspects:

1. **Centimeter-Level Accuracy**: These maps provide highly detailed terrain data, enabling precise navigation in 3D space. They include features such as road shapes, lane markings, traffic signs, curbs, obstacles, and barriers (Vardhan, 2017).
2. **Integration with Sensor Systems**: HD Maps interact with technologies like lidar, radar, cameras, IMU, GNSS, and IoT, ensuring accurate positioning and ongoing updates.
3. **Dynamic Updates**: They account for real-time changes in the environment, such as road construction or weather conditions.
4. **Vehicle Control**: They support direct vehicle control sometimes without human involvement, requiring high reliability and data formatted for computer processing rather than human interpretation.

Elghazaly et al. (2023) describe HD Maps as "virtual sensors" because they provide autonomous vehicles with a rich understanding of their surroundings, often surpassing the capabilities of onboard physical sensors.

The creation of HD Maps highlights shifts in cartographic processes. Manual map development is becoming increasingly rare, replaced by automated systems, including vehicles themselves, that process massive datasets in the cloud using AI algorithms. These changes raise critical questions about the nature of maps and their impact on cartography:

- How do these products redefine the concept of a map?
- Where is the boundary between a map and map data?

According to the authors, the emergence of HD Maps can profoundly influence the traditional concept of maps and cartography. It will necessitate a reevaluation of map definitions and the cartographer's role in map development. The following hypotheses are explored:

1. Map production will rely more on automation and artificial intelligence than human effort.
2. Maps will increasingly cater to machine audiences, such as autonomous vehicles and robots.
3. Maps will evolve from tools for spatial representation to active participants in decision-making.
4. The field of cartography must address legal and ethical challenges, including privacy, property, cybersecurity, and safety, which were less relevant for traditional maps.

HD Maps expand the understanding of maps from static visual tools to dynamic systems of precise spatial information, designed for both humans and machines. This shift emphasizes automation, large-scale data processing, interactivity, real-time updates, and integration with IoT and AI technologies. Such advancements mark a fundamental transformation in the field of cartography.

This article reviews existing literature on the relationship between cartography and HD Map creation, comparing traditional maps to HD Maps. Despite the growing body of research on HD Maps, little attention has been given to their cartographic aspects. The term "cartography" is rarely mentioned, underscoring the need to evaluate the potential impact of HD Maps on cartographic practices, including data processing, modeling, presentation, and the redefinition of maps and map classifications.

Cartography faces increasing challenges, including automated 3D and big data generalization, 3D object representation, efficient updates, and semantic link optimization. These challenges have been analyzed and discussed with experienced practitioners actively involved in the creation of HD Maps. The article also explores alternative uses of HD Maps for other cartographic products and builds upon on previous research by Gotlib, Gartner, and Olszewski (2021).

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