

# Breadcrumb Augmented Autonomous Driving System (BAADS) Patent Application

## Title

Breadcrumb Augmented Autonomous Driving System

## Abstract

A system and method for enhancing autonomous vehicle navigation by integrating breadcrumb data from multiple positioning sources into a distinct, universal virtual driving path, termed the "driveline." The Breadcrumb Augmented Autonomous Driving System (BAADS) collects positional breadcrumb data from numerous vehicles, periodically uploaded to a cloud-based global database, where it is aggregated to form a single, authoritative driveline database. Unlike comprehensive mapping or machine-learned models, this standalone driveline-derived from a minimal subset of the massive, publicly sourced breadcrumb data-complements existing sensor-driven autonomous systems, ensuring robust, precise navigation and confident autonomous turns in environments with irregular or absent road markings, even with partial or missing data.

## Background of the Invention

Modern automobile navigation systems often utilize electronic "breadcrumbs"-a sequence of recorded positional data points-to enable drivers to retrace previously traveled paths. This technology is particularly valuable in professional car racing, where drivers repeatedly navigate a fixed course. In racing, breadcrumbs assist in maintaining a chosen "line"-an optimal, virtual path through turns and straightaways, enhancing safety and performance. Racetracks typically lack extensive visible markings, making the driver's selected line a mental construct refined through repetition.

In contrast, human drivers on public roads intuitively select a "line" guided by visible features like lane lines, curbs, and signs. However, they must regenerate this path mentally for each trip, as current systems do not preserve or enhance it. While autonomous driving systems have advanced, relying on sensors, cameras, and

predefined data, they struggle in areas with faded, irregular, or absent road markings. Existing systems lack a mechanism to dynamically integrate collective path data with real-time autonomous control, limiting adaptability on less structured roadways.

The present invention addresses these limitations by combining breadcrumb-based navigation with autonomous driving technology, creating a system that learns, refines, and executes an optimal "driveline" from crowd-sourced data, complementing existing solutions and enabling navigation in challenging environments.

#### Prior Art

The following technologies and systems represent prior art relevant to autonomous vehicle navigation and crowd-sourcing, but none disclose the novel aspects of the Breadcrumb Augmented Autonomous Driving System (BAADS), particularly its use of crowd-sourced, periodically uploaded breadcrumb data to generate a universal, standalone driveline database based on weighted positional trails.

Waymo: Waymo, a leader in autonomous driving, employs a fleet of self-driving vehicles that collect extensive real-world driving data, processed through a cloud-based infrastructure to refine high-definition maps and navigation algorithms. Its system integrates real-time sensor data (e.g., LIDAR, cameras) with proprietary mapping to enable precise navigation, including in areas with poor markings, and has achieved commercial robotaxi operations by 2025. However, Waymo's approach relies on a closed-loop, fleet-specific dataset and detailed mapping, not a crowd-sourced, periodically uploaded breadcrumb database open to all vehicles. It does not disclose a universal driveline database derived solely from weighted positional breadcrumbs, distinguishing BAADS's novel method of creating a shared, optimized driving path from collective public input.

Tesla: Tesla's Full Self-Driving (FSD) system uses crowd-sourced driving data from its global fleet, uploaded periodically via cellular networks, to train neural

networks for autonomous navigation. By 2025, Tesla's vision-based approach, enhanced by AI, navigates unmarked areas using learned patterns from millions of vehicles, focusing on real-time adaptation and proprietary model refinement. While Tesla's system shares data across its fleet, it does not create a standalone, universal driveline database as a positional reference for all autonomous systems. Instead, it prioritizes machine learning over a simple, breadcrumb-derived path, leaving BAADS's crowd-sourced, weighted breadcrumb aggregation and universal driveline as a novel contribution absent from Tesla's claims.

**NVIDIA DRIVE:** NVIDIA's DRIVE Map, bolstered by its acquisition of DeepMap, offers a crowd-sourced, high-definition mapping solution for autonomous vehicles, updated via vehicle data uploads to a cloud system. By 2025, it supports navigation in inconsistent-marking areas by aggregating real-time road data from multiple vehicles, integrated with sensor fusion (e.g., cameras, LiDAR). While NVIDIA's system shares similarities with BAADS in crowd-sourcing and cloud processing, it focuses on building detailed, lane-level maps rather than a minimalist, breadcrumb-derived driveline database. BAADS's unique approach of using weighted positional trails to create a universal, non-mapping-based path represents a novel advancement not disclosed in NVIDIA's technology.

**Waze:** Waze, a crowd-sourced navigation app, collects GPS data from users to optimize real-time traffic routes, uploaded periodically to a central system for analysis. By 2025, it leverages collective driving behavior to suggest paths, focusing on human drivers rather than autonomous systems, and does not address navigation in unmarked areas beyond traffic avoidance. Waze lacks integration with autonomous sensors or the creation of a universal driveline database from weighted breadcrumbs. Its reliance on real-time routing for human guidance, rather than a persistent, crowd-sourced driving path for autonomous vehicles, distinguishes BAADS's innovation as a new claim not found in Waze's approach.

OpenStreetMap (OSM): OpenStreetMap, a community-driven mapping project, allows volunteers to contribute GPS traces to build a shared, open-access map, increasingly used in autonomous research by 2025. It aggregates positional data into a global database for navigation, particularly in less-mapped areas, but focuses on static map creation rather than dynamic, optimized driving lines. OSM does not disclose a periodically updated, crowd-sourced breadcrumb system generating a universal driveline database for autonomous vehicles, nor does it integrate real-time sensor data for unmarked environments, leaving BAADS's weighted breadcrumb method as a novel contribution.

Research Concepts (e.g., AADS, Cooperative V2I Systems): Academic and research efforts, such as the 2019 "AADS: Augmented Autonomous Driving Simulation" and 2024 surveys on cooperative vehicle-infrastructure systems, explore crowd-sourced data and autonomous navigation. These studies emphasize simulation or vehicle-to-infrastructure communication for path optimization, often using extensive datasets for mapping or AI-driven models. However, they do not describe a system that periodically collects and weights simple positional breadcrumbs from public vehicles to create a universal, standalone driveline database. BAADS's focus on a minimalist, crowd-sourced path for all autonomous systems, independent of complex infrastructure, marks a novel claim absent from these research efforts.

In summary, while the identified prior art includes crowd-sourcing, cloud-based data processing, and autonomous navigation, none disclose the specific combination of periodically uploading weighted breadcrumb data from numerous public vehicles to a global database, generating a universal, standalone driveline database as a positional reference for autonomous driving. This novel approach, central to BAADS, addresses the limitations of existing systems by providing a scalable, efficient, and universally accessible solution for navigation in unmarked or challenging environments, distinguishing it from all known prior art.

Summary of the Invention

The Breadcrumb Augmented Autonomous Driving System (BAADS) introduces a novel method for autonomous vehicle navigation, centered on the creation of a "vehicle driveline"—the most well-traveled position of an autonomous vehicle through various streets, both marked and unmarked, derived from breadcrumb data collected via multiple positioning systems (e.g., GPS). Individual vehicles record breadcrumb data—sequential positional coordinates—and upload it periodically (e.g., at trip end, daily, or weekly) to a cloud-based global breadcrumb database. Unlike systems dependent on detailed high-definition maps or machine-learned behavioral models, BAADS aggregates this data from all participating vehicles to form a driveline database, serving as a universal reference for autonomous driving systems subscribing to it. This driveline, calculated from weighted breadcrumb trails, requires only a fraction—orders of magnitude smaller—of the massive, publicly sourced data to ensure safety and reliability, remaining inherently robust against partial or missing contributions due to its scale.

The driveline complements existing autonomous systems by providing preferred steering guidance, allowing sensor data to retain priority for real-time hazard avoidance and reaction, thus freeing compute resources for critical safety functions. It enables precise navigation and autonomous turns with extreme confidence, even where road markings are irregular, obscured, or absent, by leveraging the collective driving experience of millions of previous drivers. The driveline adapts dynamically to road changes—such as construction or closures—by reweighting or discarding outdated breadcrumbs. Upon upload, breadcrumb data is immediately weighted and integrated into an anonymized master database, devoid of vehicle-specific identities, ensuring contributor privacy. By relying on a simple, breadcrumb-derived path rather than complex mapping or individual vehicle learning, BAADS offers an efficient, scalable solution for diverse driving contexts, from urban streets to rural roads.

#### Detailed Description

The Breadcrumb Augmented Autonomous Driving System (BAADS) comprises hardware and software components distributed

across individual vehicles and a cloud-based infrastructure. Each vehicle includes: (1) a navigation module (e.g., GPS, Galileo, or inertial systems) for recording breadcrumb data as positional coordinates (latitude, longitude, optionally altitude); (2) a cellular communication module for periodic uploads; and (3) an autonomous driving control module with local memory. The cloud-based system features a global breadcrumb database and a processing system for generating the driveline database.

Operation: During traversal, a vehicle's navigation module records breadcrumb data at regular intervals, forming a trail of positional points. This data is stored locally and uploaded at configurable intervals (e.g., end of trip, daily, or weekly) via the cellular module to the cloud-based global breadcrumb database. Real-time collection is unnecessary due to the massive volume of publicly sourced data from all vehicles, ensuring robustness against partial or missing uploads. Upon receipt, new breadcrumb data is compared to the existing master file, scored for statistical correlation to prior data, and discarded if outside a predefined tolerance; otherwise, it is integrated into the master breadcrumb database. Periodically, the system transforms this database by calculating rolling average vectors of adjacent breadcrumbs, creating a solid, optimized "driveline"—a universal virtual path representing the most well-traveled route. This driveline database requires only a small fraction of the total collected data, demonstrating exceptional efficiency, and is integrated into navigation systems to provide preferred steering guidance for autonomous vehicles.

Vehicles download the driveline data and integrate it with real-time sensor data (e.g., LIDAR, cameras, radar), where sensor inputs retain priority for hazard detection and avoidance, complementing the driveline's role. In unmarked environments, the driveline enables confident navigation and turns, as visualized in accompanying sketches (e.g., FIG. 1-4) showing a two-way street with curves, breadcrumb dots, and the evolving driveline. For connectivity disruptions, the control module caches the driveline

locally, maintaining operation until updates resume. The system adapts to road changes as vehicles contribute new data, ensuring ongoing relevance.

#### Key Features:

- Universal Reference: A single, authoritative driveline database, derived from weighted breadcrumbs, for all subscribing autonomous systems.
- Data Robustness: Massive public sourcing ensures reliability despite data gaps, with minimal data needed for a safe driveline.
- Privacy Protection: Immediate anonymization prevents tracking of individual vehicles; users must opt-in to contribute anonymized data.
- Efficient Design: Requires only a fraction of collected data for a reliable driveline, complementing sensor-driven systems by offloading steering guidance.

#### [Diagrams]:

- FIG. 1: Black-and-white map sketch of a two-way street with gentle left and right curves, featuring dots down the middle of each lane, representing breadcrumb data.
- FIG. 2: Same street with a straight line averaging three consecutive dots, extending beyond the start and end points as an average vector.
- FIG. 3: Same street with line vectors connecting sets of three dots, shifting one dot at a time along the breadcrumb path.
- FIG. 4: Same street with a single, smooth moving average line weaving through the breadcrumb path, representing the finalized driveline.

#### Claims

1. A breadcrumb augmented autonomous driving system, comprising:
  - a plurality of vehicles, each equipped with a navigation module configured to record breadcrumb data representing positional coordinates along a traversed route from one or more positioning systems, including satellite-based systems, and a cellular communication module configured to periodically upload the breadcrumb data to a cloud-based global breadcrumb database;

- a cloud-based processing system configured to aggregate the breadcrumb data from all contributing vehicles, compare new data to existing records for statistical correlation, discard non-conforming data, integrate conforming data into a master breadcrumb database, and periodically transform it into a driveline database—a universal, standalone virtual path distinct from comprehensive maps or machine-learned models, representing the most well-traveled route and being inherently robust against partial or missing data due to massive public sourcing; and

- an autonomous driving control module in each vehicle configured to navigate the vehicle along the driveline database, complementing real-time sensor data prioritized for hazard avoidance, requiring only a fraction of the collected data for reliability.

2. The system of claim 1, wherein the breadcrumb data is uploaded from each vehicle to the cloud-based global breadcrumb database at configurable discrete intervals, such as end of trip, daily, or weekly, distinct from real-time transmission, to optimize data aggregation.

3. The system of claim 1, wherein the cloud-based processing system includes an algorithm configured to:

- score new breadcrumb data for statistical correlation to the master breadcrumb database;
- discard data outside a predefined tolerance as non-conforming;
- integrate conforming data into the master database with updated weights based on recurrence; and
- periodically calculate rolling average vectors of adjacent breadcrumbs to form the driveline database.

4. The system of claim 3, wherein the driveline database adapts to road changes by reweighting or discarding outdated breadcrumbs based on aggregated data or external inputs.

5. The system of claim 3, wherein the driveline database is integrated into navigation systems to provide preferred steering guidance, enabling autonomous turns and lane changes in unmarked environments.

6. The system of claim 1, wherein the autonomous driving control module integrates the driveline database with real-time data from LIDAR, video, infrared, and camera sensors, prioritizing sensor data for hazard detection.

7. The system of claim 6, wherein the driveline database serves as the primary steering reference when real-time sensor data indicates irregular or absent visual road markings.

8. The system of claim 1, wherein the autonomous driving control module includes a local memory configured to store a cached version of the driveline database, enabling navigation during periods of cellular connectivity disruption.

9. The system of claim 1, wherein the cloud-based processing system immediately weighs and integrates uploaded breadcrumb data into the master breadcrumb database, which is devoid of vehicle-specific identifiers, ensuring contributor anonymity.

10. A method for autonomous vehicle navigation, comprising:

- recording breadcrumb data via navigation modules in a plurality of vehicles during route traversal, using one or more positioning systems;
- periodically uploading the breadcrumb data from each vehicle to a cloud-based global breadcrumb database at configurable intervals, such as end of trip, daily, or weekly;
- aggregating the breadcrumb data by comparing new data to existing records for statistical correlation, discarding non-conforming data, integrating conforming data into a master breadcrumb database, and periodically transforming it into a driveline database—a universal virtual path reflecting the most well-traveled route, distinct from high-definition maps or adaptive models, inherently robust against partial or missing data due to massive public sourcing and requiring only a fraction of the data for reliability; and

- autonomously navigating each vehicle along the driveline database, complementing real-time sensor data prioritized for hazard avoidance, using an autonomous driving control module.

11. The method of claim 10, further comprising:

- maintaining a first dataset of weighted breadcrumbs and a second dataset of the driveline database in the global database;

- immediately weighing and integrating uploaded breadcrumb data into the anonymized master database without retaining vehicle identities; and

- creating a new breadcrumb when no overlap occurs with existing data within statistical tolerance.

12. The method of claim 11, wherein generating the driveline database includes calculating rolling average vectors of adjacent weighted breadcrumbs, adapting to dynamic road changes by reweighting or discarding obsolete data, and integrating the driveline into navigation systems for preferred steering guidance.

