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REALISTIC SIMULATED MODEL FOR TESTING AND DEVELOPING A VEHICLE

Sam Lin

Ben Taitelbaum

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ABSTRACT

A computing system may create a realistic simulated model of a driving experience based on sensor data from a sensor system and interconnection mechanisms among automotive entities (e.g., a simulated entity, a real-world entity, etc.) for testing and developing a vehicle. The computing system may represent a platform for converging human-driven and autonomous vehicle simulations (e.g., interoperation between heterogeneous automotive entities) to simulate movement of vehicles in the realistic simulated model. For example, the computing system may allow the swapping of an emulated physical vehicle with a different simulated vehicle (e.g., a prototype vehicle) in the realistic simulated model while producing the same validation results. The computing system may include an information system that stores the repositories for the sensor data and/or metadata (e.g., based on the sensor data) and automotive entities. The information system may also provide a user interface (UI) with functionality for enabling a user (e.g., a vendor testing a prototype vehicle) to initialize and execute realistic simulated models. For example, the information system may enable the user to perform various functions with respect to the realistic simulated model, including, but not limited to, changing the simulation speed of (e.g., slowing time flow, increasing time flow, etc.), configuring, creating, editing, monitoring, analyzing, importing, exporting, starting, pausing, skipping, rewinding, and/or repeating the realistic simulated model.

DESCRIPTION

The present disclosure describes a computing system for testing and developing a vehicle (e.g., an automobile, a motorcycle, a bus, a recreational vehicle (RV), a semi-trailer truck, a tractor or other type of farm equipment, train, a plane, a boat, a helicopter, a personal transport vehicle, etc.) with modern information systems by creating a realistic simulated model of a driving experience based on comprehensive inputs and states, such as sensor data from a sensor system and interconnection mechanisms among automotive entities. The computing system may represent a platform for converging autonomous and human-driven vehicle simulations (e.g., interoperation between heterogeneous automotive entities) to simulate movement of vehicles in the realistic simulated model.

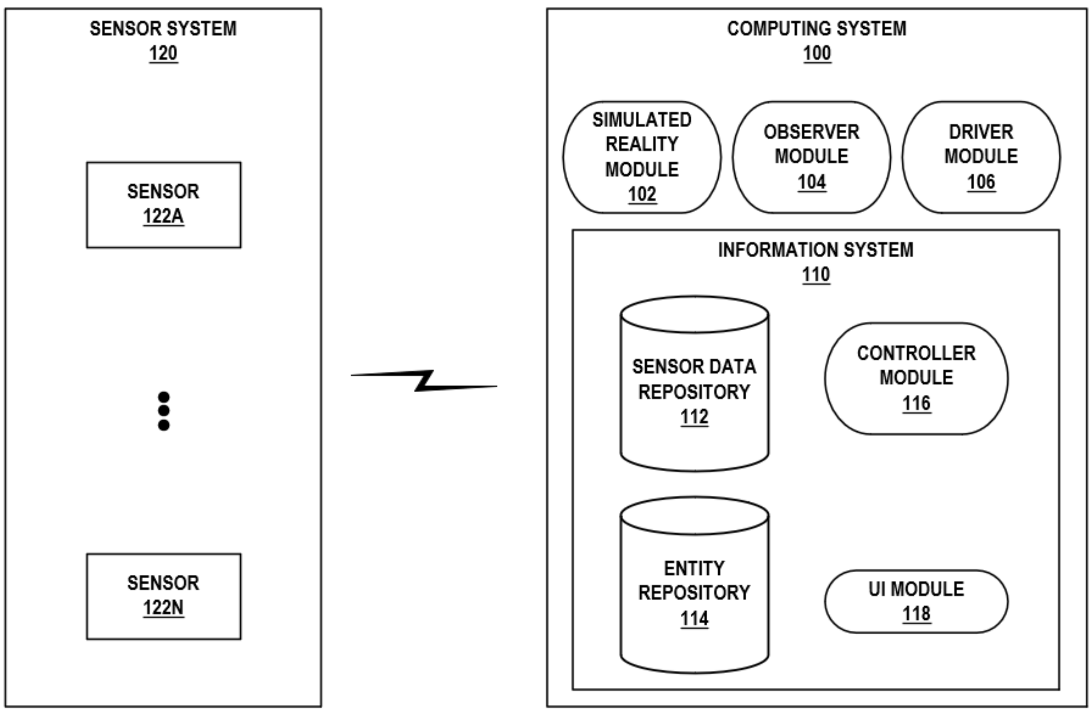

FIG. 1

FIG. 1 is a conceptual diagram illustrating a computing system 100 that creates a realistic simulated model of a driving experience based on sensor data from a sensor system 120 and interconnection mechanisms among automotive entities (e.g., a simulated entity, a real-world entity, etc.) for testing and developing a vehicle. As illustrated by FIG. 1, computing system 100 may include a simulated reality module 102, an observer module 104, and a driver module 106.

As further illustrated by FIG. 1, computing system 100 may also include an information system 110 that in turn includes a data repository 112, an entity repository 114, a controller module 116, and a UI module 118.

In the example of FIG. 1, computing system 100 is a server (e.g., a remote server). However, computing system 100 may be any suitable computing system capable of creating a realistic simulated model, such as one or more desktop computers, laptop computers, mainframes, servers, cloud computing systems, simulated machines, and/or the like. In some examples, computing system 110 may represent a cloud computing system. That is, in some examples, computing system 110 may be a distributed computing system.

As illustrated in FIG. 1, computing system 100, and more particularly information system 110, may communicate with sensor system 120 via a network (e.g., a wide-area network such as the Internet, a local-area network (LAN), a personal area network (PAN), an enterprise network, a wireless network, a cellular network, a telephony network, a Metropolitan area network, one or more other types of networks, a combination of two or more different types of networks, etc.).

Sensor system 120 may include a plurality of sensors 122A-N (collectively, “122”). Sensors 122 may collect sensor data about the operation of a physical vehicle (e.g., a real-world vehicle). For example, sensors 122 may collect sensor data on the position, route, speed, acceleration, deceleration, gear, state, error changes, and/or the like of the physical vehicle. Sensors 122 may also collect sensor data about user input (e.g., steering inputs, accelerator inputs, brake inputs, etc.). Example sensors may include accelerometers, gyroscopes, microphones, cameras, Light Detection and Ranging (LIDAR), radars, sonars, and/or the like. In some examples, sensor system 120 may associate the sensor data with a timestamp so that simulations based on the sensor data represent the influence of the time of day on traffic conditions and events.

To increase scalability and interoperability of computing system 100 and sensor system 120, computing system 100 and/or sensor system 120 may use standard metadata format(s) and protocol(s). In this way, computing system 100 and/or sensor system 120 may significantly reduce the data rate required for storage, connection, and computing while facilitating interoperability of heterogeneous entities (e.g., “plugging” heterogeneous entities into the realistic simulated model, simulating heterogeneous entities in the realistic simulated model, etc.).

In accordance with one or more techniques of this disclosure, computing system 100 may generate a realistic simulated model of a driving experience based on sensor data from sensor system 120 and interconnection mechanisms among automotive entities (e.g., a simulated entity, a real-world entity, etc.) for testing and developing a vehicle. Responsive to receiving the sensor data from sensor system 120, computing system 100 may store the sensor data in sensor data repository 112. Simulated reality module 102 may use the sensor data from sensor data repository 112 to generate a realistic simulated model emulating a real-world driving experience. In some examples, computing system 100 may produce metadata (e.g., data describing or abstracting other data) based on the sensor data, and simulated reality module 102 may use the metadata to generate the realistic simulated model. The metadata may relate to time, inputs from all sources, vehicle locations and states, traffic conditions and events, and/or the like.

Simulated reality module 102 may create one or more driving scenarios in the realistic simulated model for testing and developing a vehicle. The driving scenarios may be based on the sensor data and/or the metadata (collectively, “data”). For example, the driving scenarios may include real world traffic (e.g., traffic conditions and events, vehicle locations and states, etc.), road infrastructure objects, pedestrians, animals, vegetation, and/or the like associated with the data.

Simulated reality module 102 may also be a gateway to connect to a navigation system, enabling plugging in and simulation of the navigation system in the realistic simulated model. For example, simulated reality module 102 may simulate a vehicle under test using a production navigation system and real-world datasets, a navigation system under test, and/or the like. In this way, simulated reality module 102 may test various use cases as well as validate production vehicle models at scale.

The driving scenarios may also include automotive entities (e.g., a simulated entity, a real-world entity, etc.). Entity repository 114 may store the configuration of and other data associated with the automotive entities. The automotive entities may be emulated vehicles in the realistic simulated model. For example, the driving scenarios may include an emulated physical vehicle (e.g., a simulated vehicle emulating the physical vehicle) that operates in the realistic simulated model based on the data (e.g., position, route speed, acceleration, deceleration, gear, state, error changes, user input, voice input, driver engagement, number of passengers, etc.) associated with the physical vehicle. In this way, simulated reality module 102 may simulate the physical vehicle in the realistic simulated model, which may be useful for validating results of one or more simulation cycles in the realistic simulated model.

The driving scenarios may include an emulated prototype vehicle (e.g., a prototype vehicle that has not been operated in the real-world). For example, simulated reality module 102 may swap the emulated physical vehicle with a simulated vehicle emulating a prototype vehicle in the realistic simulated model and simulate one or more driving scenarios using the emulated prototype vehicle. Due to the comprehensiveness of the data used to generate the realistic simulated model, the driving scenarios with the emulated prototype vehicle may be so accurate that the realistic simulated model produces the same validation results.

Computing system 100 may include information system 110. Information system 110 may store sensor data repository 112 and entity repository 114. Information system 110 may also provide a user interface (UI) with functionality for enabling a user (e.g., a controller of computing system 100, such as a researcher, manufacturer, vendor, etc.) to initialize and execute realistic simulated models. For example, UI module 118 may cause a display to present a graphical user interface (GUI) associated with various functionality to the user. The controller module 116 of information system 110 may then enable the user to perform those various functions with respect to the realistic simulated model. Those functions may include, but are not limited to, changing the simulation speed of (e.g., slowing time flow, increasing time flow, etc.), configuring, creating, editing, monitoring, analyzing, importing, exporting, starting, pausing, skipping, rewinding, and/or repeating the realistic simulated model.

Computing system 100 may include observer module 104. Observer module 104 may allow a user to review the data (e.g., the sensor data, the metadata, etc.) of the realistic simulated model to validate, analyze, and/or troubleshoot the realistic simulated model. In one example, observer module 104 may allow a user to review the realistic simulated model itself for similar reasons. For example, observer module 104 may monitor the simulation cycles and record metadata (e.g., based on the realistic simulated model), entity states, and images, such as screenshots and camera pictures, for a user of computing system 100 to review.

In another example, observer module 104 may compare the results of simulation cycles to the expected results. For example, observer module 104 may compare the results of driving scenarios including an emulated prototype vehicle with the results of driving scenarios including an emulated physical vehicle. Observer module 104 may then determine whether the validation results are the same and, responsive to the determination, notify the user.

In yet another example, observer module 104 may observe the states of one or more automotive entities in the realistic simulated model. For example, observer module 104 may observe the responses of an emulated prototype vehicle and other emulated vehicles in the one or more driving scenarios to collect data on and/or validate the behavior of the realistic simulated model.

Computing system 100 may include driver module 106. Driver module 106 may control the automotive entities in the realistic simulated model. For example, driver module 106 may control an emulated prototype vehicle in one or more driving scenarios. Driving module 106 may control the automotive entities based on a test script and/or a human driver record (e.g., the human driver record of a physical test drive). The driving module may also control the automotive entities in a random fashion to explore breakpoints or test the stability of the realistic simulated model.

Driver module 106 may also control the automotive entities using artificial intelligence. As such, computing system 100 may train autonomous driving systems within the realistic simulated model. For example, computing system 100 may automatically train, evaluate, and validate autonomous driving systems by executing simulation cycles of one or more driving scenarios with the autonomous driving systems within the realistic simulated model.

One or more advantages of the techniques described in this disclosure include reducing the resources (e.g., time, hardware resources, human resources, etc.) for testing and developing vehicles. For example, by using the computing system to create a realistic simulated model, a user may execute simulation cycles of one or more driving scenarios with an emulated prototype vehicle. Such simulations may be especially helpful to the user prior to the production rollout and/or production stage of the prototype vehicle. Another advantage includes the scalability of simulations within the realistic simulated model because the multiple and various driving scenarios may be concurrently simulated and for various geographical areas, weather conditions, traffic conditions, and/or the like. Yet another advantage includes avoiding damages, accidents and even loss of life that may otherwise occur in a real-world test setting. One more related advantage includes efficiently and safely training, evaluating, and/or validating autonomous driving systems for the reasons described above.

It is noted that the techniques of this disclosure may be combined with any other suitable technology or combination of technologies, including those listed as references below.

References

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2. US Patent Application No. 20190318267
3. Pintér et al., “Automating simulation for safer self-driving.” AImotive Insights, May 10, 2019.