Autonomous Ground Vehicle (AGV) Project

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ABSTRACT
The goal of this project is to construct an autonomous mobile vehicle for research in autonomous controls. The guidelines for the DARPA Grand Challenge contest, sponsored by DARPA (Defense Advance Research Project Agents) will be used as the specification goal for the vehicle performance. The contest requires an autonomous vehicle to travel one hundred and seventy primarily off-road miles from Los Angeles to Las Vegas in ten hours. The autonomous truck will operate using a software controller and is equipped with sensors such as: a SICK Laser Measurement System (LMS) and a Global Positioning System (GPS).

I am responsible for writing software that simulates vehicle dynamics, GPS signal, heading, and environmental response data that will be used to test the software controller. The simulated data will be used in conjunction with the software controller to ensure a successful traversal along the designated route. The simulator imitates digital data from the SICK LMS and GPS and sends this data to the controller. The controller then decide whether to use the brake, throttle or whether to change the heading of the vehicle and sends control information back to the simulator. The simulator generates SICK data eight times a second and GPS latitude and longitude twenty times per second.

II. INTRODUCTION

The basis of the autonomous vehicle is a Ford F-150 4X4 truck. The truck has been modified with a drive-by-wire system used to actuate steering, throttle, and brakes.

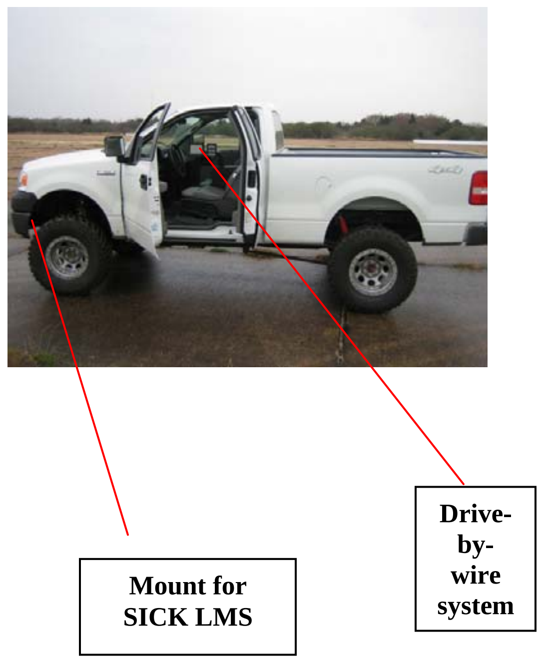

Figure 2.1 Picture of autonomous truck

The vehicle is equipped with obstacle sensing and navigation hardware. The obstacle avoidance sensor, SICK LMS (Laser Measurement System) is a 2D scanning laser rangefinder implemented on the AGV to detect obstacles in the world. The SICK sends out a fan of pulsed beams, each at a specific angle. When the beam contacts the nearest object it reflects off that object and back to the SICK. The SICK then knows the range to the object at the specific angle. Using the information, the Collision Avoidance software can determine the correct course to maneuver through the obstacles. The SICK performs 180 degree forward scans at a frequency of ~ 44 Hz and detects objects at a maximum range of 30m-80m, depending on the object's reflectivity. It operates on the "time of flight" principle. With the time of flight, the range to an object is known based on the speed of light.

$$\textit{Range to Target} = \frac{(\textit{speed of light})(\textit{time of flight})}{2}$$

When the beam hits a target, it will scatter and those reflected beams will travel in all directions. The SICK is only concerned with the first reflected beam it receives, all other reflections are ignored. The first reflection the SICK received traveled along the straight path between the target and the SICK, giving the most accurate range. The other reflections will bounce around in the world, extending their travel. If the SICK did not funnel through them, it could output and erroneous range [2]. The development of vehicle path control software and navigation sensor (GPS) allows the vehicle to autonomously follow waypoints. The low level controller is an algorithm that takes desired heading and velocity and calculates voltages to send to the digital to analog converter card (DAC). The result is a steering angle and throttle position which is then scaled to match required voltages by the EMC hardware. The basic "path" planning calculates desired heading and throttle from information based only on the GPS waypoint files. The waypoint controller combines the low level controller and the basic "path" planning [1]. This allows autonomous navigation. Using obstacle sensing, collision avoidance, and navigational tools the autonomous ground vehicle can autonomously follow waypoint at the maximum target speed of 45 mph.

II. BACKGROUND

Simulation has been used in a wide range of fields for a variety of human endeavors. It can be used to predict, model, analyze, educate and control. Problems in fields as diverse as business, industrial manufacturing, and engineering have been successfully solved with the use of simulation. Simulation is defined as the process of designing a computerized model of a system or process. This model is then used to conduct experiments for the purpose of either understanding the behavior of the system or used to evaluate various strategies for the operation of a system. When applied to simulation a system is a collection of objects with a well-defined set of interactions. A system's state may change in response to activities. An activity is any process or event that prompts change. Activities can be both internal and external to the system. External activities are called exogenous and internal activities are called endogenous. In a system one activity may prompt another causing very little distinction between exogenous and endogenous activities. Therefore the change in the system state not the activity itself is of primary interest. Systems can be classified in many ways: natural systems versus man-made, continuous versus discrete, deterministic versus stochastic, and open versus closed. Continuous and discrete systems refer to the nature or behavior of

changes with respect to time in the system state. In a continuous system changes in state occur continuously over time. While in a discrete system changes occur in finite sections or jumps. Hybrid systems possess properties of both continuous and discrete systems, some of the system state variables may vary continuously while others vary discretely.
A deterministic system is a system in which the new state of the system is solely determined by the previous state and by the activity. The system's evolution is completely determined by its response to a given activity. In a stochastic system there is randomness when transitioning from one state to another. It is not always possible to assign a probability to the state that the system will assume after a given state and activity. A stochastic system is nondeterministic in the sense that the next state can not be unequivocally predicted if the present state and the activity are known

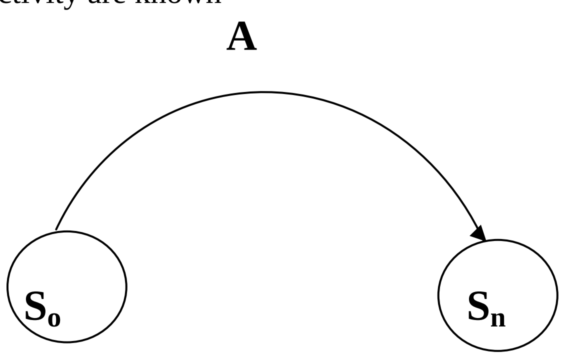

Figure 1.1 Illustrates a deterministic system

Figure 1.1 illustrates a deterministic system. S_o is the state of the system before an activity occurs and S_n is the state of the system after the occurrence of the activity.

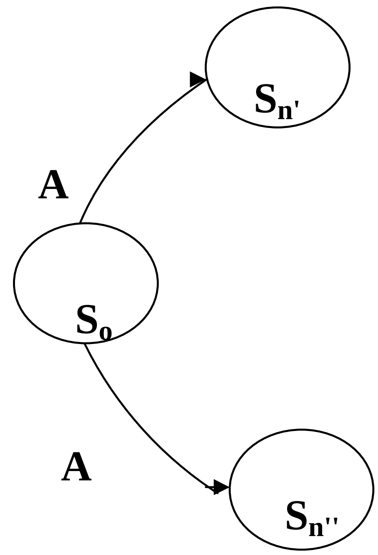

Figure 1.2 Illustrates a stochastic system

Figure 1.2 is a depiction of a stochastic system. $S_{n'}$ and $S_{n''}$ are two possible states that the system can enter after the state S_o in response to activity A
A closed system is a system in which all state changes are prompted by endogenous activities. An open system's state changes in response to both exogenous and endogenous activities. Because there is difficulty when distinguishing from endogenous and exogenous activities it is also difficult to distinguish between open and closed systems.
A discrete system is characterized by changes in the system state that occur in discrete or quantum jumps; a continuous system is characterized by smooth, continuous changes in system state. Simulation models have been used to model both static (time-independent) and dynamic (time-dependent) situations. Most simulation models are dynamic models because most static models can be solved analytically [3]. Dynamic models are time dependent therefore a

simulator has different techniques for depicting a time change in a system. The periodic scan technique adjusts the simulation clock by one predetermined unit and then examines the system to determine whether any events occurred during that interval. If an event occurred, the event or events are simulated, otherwise no action is taken. The simulation clock is then advanced another unit and the process is repeated. One problem with the periodic scan approach is that the exact occurrence time of events is not known, because each event is treated as if it transpired at the end of the interval in which it occurred. In the event scan approach the clock is advanced by the amount necessary to trigger the occurrence of the next event, not by a fixed interval. This approach requires some scheme for determining when events are to occur. The event approach avoids some of the problems inherent in the periodic scan approach. My model is a hybrid system. It contains both continuous and discrete properties. To ensure that the hybrid system is modeled accurately there are certain methods that should be used to approach the problem.

III. METHODOLOGY

One approach used in problem solving is called system methodology. System methodology consists of four phases: planning, modeling, validation and application. In the planning process there is a thorough analysis of the problem to be solved and the factors pertaining to the system and its environment that are likely to affect the solution of the problem. The second phase of the problem-solving process is the modeling phase. In this phase a system model is constructed and is used as a representation of the real system. The characteristics of this model should be representative of the characteristics of the real system. The next step in the problem-solving process is validation. A model is validated by proving that the model is a correct representation of the real system [3].

When I began simulating the sensors on the autonomous sensors I first analyzed how each sensor worked and how it should be modeled. To begin simulating the Global Positioning Sensor of the autonomous ground vehicle I read a text file containing multiple waypoints. The first latitude and longitude were used as the starting position of the truck. I then gave a value for throttle and steering angle. Throttle, steering angle, old x and y positions, heading, speed, yaw, velocity and a specified amount of time were then inputted into a function. The function then used differential equations to calculate new x and y positions, heading, speed, yaw, and velocity. The x and y positions are then used to calculate latitude and longitude. The equations to calculate latitude and longitude were made by using the equations to solve for Cartesian values and working backwards. The latitude and longitude is then converted to degrees minutes and fractions of minutes so that it can be written to a serial port that the software controller later reads. The problem of simulating the GPS sensor was analyzed through planning, modeled using a computer program and validated by the construction of a graph that illustrates the movement of the truck therefore completing the problem-solving process.

IV. RESULTS

The simulator simulates vehicle dynamics including: position, heading, speed, velocity and yaw. The simulator also simulates GPS data twenty times a second. To ensure that the simulator is working correctly graphs were produced. The x and y positions were plotted and a set steering angle and throttle was inputted into the function. When given a steering angle and a throttle the vehicle travels in a circle which is depicted in Figure 4.1.

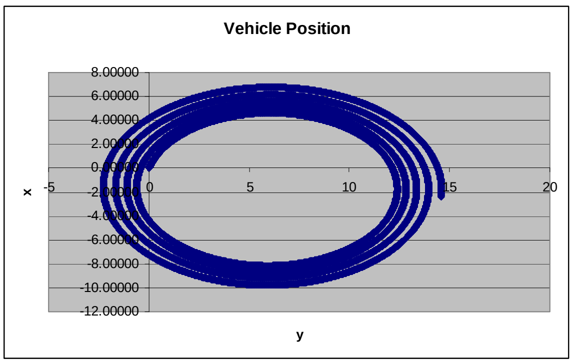

Figure 4.1 Illustration of truck position with fixed steering angle and throttle

V. CONCLUSION

The simulator simulates the navigational sensors used on the truck. This data will be used when simulating obstacle sensing, and when determining the desired path to each waypoint.
The simulator can be used with the software controller to ensure a successful traversal to each waypoint instead of continuous testing of the AGV. It can also be used to improve the software controller by exposing it to different situations and seeing its response.

VI. ACKNOWLEDGEMENTS

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VII. REFERENCES

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