

Rain Filtering Techniques for Autonomous Vehicle

TECHNICAL FIELD

[0001] The present invention relates to a system and method of using lidar for autonomous vehicle navigation when particulate matter is present in the air such as rain or snow.

BACKGROUND

[0002] An autonomous car is one that is capable of monitoring its environment and navigating without human input. Benefits of autonomous cars include greater vehicle safety, greater efficiency, lower costs, decreased congestion and greater mobility for those who are unfit or not licensed to driver.

[0003] Autonomous cars use sensors to monitor their location and their environment. CMOS cameras, radar and laser light can be used to detect objects and hazards in their surroundings. However, each type of sensor has limitations. For example, CMOS cameras rely on adequate lighting to detect objects. Moreover, the cameras can be ineffective when light is projected back by, for example, headlights of an approaching vehicle. Other shortcomings of cameras include inadequate lighting, motion blurring, limited field-of-view and/or detection range. Radar does not rely on visible light but lacks the resolution needed to identify smaller objects. Laser light can be used to overcome these limitations but can be ineffective during rain or snow.

[0004] Lidar (Light Imaging Detection and Ranging) measures the distance to an object by illuminating it with a pulsed laser light and measuring the reflected pulses with a sensor. In typical use, a lidar system reflects multiple laser pulses off of objects

surrounding the vehicle. Differences in laser return times and wavelengths can then be used to make digital 3D representations of objects.

[0005] However, it is difficult for lidar to transmit through snow, rain, fog and dust in the air. Rain or other particles in the air can reflect laser light back to the system in the same manner as a solid object. As pulsed laser light is reflected back to a lidar system, an autonomous vehicle will unnecessarily slow or stop. This is due to the “false positive” detection of obstacles.

[0006] Methods have been proposed to improve the robustness of lidar during rain or snowy conditions. For example, lidar sensors with “multi-echo” or “last echo” technology can filter reflections caused by dust, rain and fog. They operate under the premise that a portion of the energy from a pulse may be reflected by particle matter. The remainder of the beam can continue to propagate and is reflected by a solid object. When this occurs, the lidar unit can ignore the closer, weaker reflections caused by rain or particulates in the air. While an improvement, this technique is not robust for filtering moderate to heavy rain.

[0007] U.S. Patent No. 9,097,800 describes a method of combining radar with lidar to detect objects. The lidar is used to create a three-dimensional point map in an area surrounding the vehicle. Radar is then used to confirm that objects or hazards are solid materials rather than rain or airborne particles. While the system is designed to prevent false positive lidar detections, it requires the use of a separate radar system. Further, radar has inherently low resolution and can miss objects with weak reflectivity.

[0008] U.S. Patent Application No. 14/576,265 also describes a method of using lidar to confirm the presence of objects near an autonomous vehicle. The lidar detects multiple points of an object (i.e. right, left, top and bottom) to confirm its presence. The approach is similar to multi-echo methods as it requires multiple pulses. As with U.S. Patent No.

9,097,800, it may not be effective in detecting small objects.

[0009] Accordingly, there is a need for system that can allow autonomous vehicles to navigate using lidar in rain or snow.

SUMMARY OF THE INVENTION

[0010] The invention recognizes that there is a need for an improved system for autonomous vehicles to navigate and detect objects and hazards. The system should be reliable and capable of operating in all weather conditions. The invention includes a system and rain filtering algorithm to allow autonomous vehicles to operate in rain or snow.

[0011] The following summary is provided to facilitate an understanding of some of the innovative features unique to the disclosed embodiments and is not intended to be a full description. A full appreciation of the various aspects of the embodiments disclosed herein can be gained by taking into consideration the entire specification, claims, drawings, and abstract as a whole.

[0012] The invention includes a system for detecting object and/or navigating using laser light (i.e. lidar) as well as distinguishing solid objects from particles in the air. The system can include a first lidar device that scans an area by emitting pulses of laser light and detecting laser light that is reflected and a second lidar device that scans the same or substantially the same area by emitting pulses of laser light and detecting laser light that is reflected. A computer can use an algorithm to compare emitted laser light and reflected laser light detected by the first lidar device with emitted laser light and reflected laser light detected by the second lidar device to confirm the presence of a solid object. The presence of a solid object can be confirmed when the first lidar device and the second lidar device detect reflected laser light from the solid object. The first and second lidar devices can be mounted on an autonomous vehicle so that they are 0.5 to 2.5 meters

apart from each other on a horizontal plane.

[0013] In addition to dual-lidar unit technology, the first lidar device and the second lidar device can utilize multi-echo technology to distinguish solid objects from airborne particles. Furthermore, the lidar devices can perform multiple plane scanning to distinguish solid objects from airborne particles.

[0014] The invention also includes a method of detecting objects or obstacles for autonomous driving. A first lidar device scans an area near an autonomous vehicle by emitting laser light and detecting reflected laser light (i.e. echoes). A second lidar device scans an area near an autonomous vehicle by emitting laser light and detecting echoes. Emitted pulses and echoes detected by the first lidar device are compared with emitted pulses and echoes detected by the second lidar device using a computer and an algorithm to detect and confirm the presence of an object or obstacle. The presence of a solid object can be confirmed when both the first lidar unit and the second lidar unit detect echoes from the object.

[0015] An echo that results from rain or snow can be identified by comparing echoes received by the first lidar device with echoes received by the second lidar device. The first lidar device and the second lidar device can use multi-echo scanning. Further, the lidar devices can scan a series of layers or planes. The presence of a solid object can be confirmed when the solid object appears in one or more layers or planes.

[0016] The invention also includes a method of detecting solid objects comprised of the steps of (a) scanning an area near an autonomous vehicle by emitting pulses of laser light and detecting echoes with a first lidar unit, (b) scanning substantially the same area near by emitting pulses of laser light and detecting echoes with a second lidar unit and (c) using an algorithm to compare pulses emitted and echoes received by the first lidar unit with pulses emitted and echoes received by the second lidar unit to detect and confirm the presence of an object or obstacle. A false positive (i.e. particulate matter in the air such as rain or snow) can be identified when one of the lidar units detects an echo

but the other does not.

[0017] Further, the first lidar unit and the second lidar unit can use multi-echo scanning. They can also scan a series of planes. The presence of a solid object can be confirmed when the object appears in more than one plane. Furthermore, the presence of a solid object can be confirmed in the last echo of a multi-echo scan.

[0018] The invention also includes a method for detecting and/or confirming the presence of a solid object using lidar comprised of the steps of (a) using a first lidar device to scan multiple planes, wherein pulses of laser light are emitted and reflected laser light is detected, (b) collecting data related to laser light emitted from the first lidar device and reflected laser light detected by the first lidar device, (c) determining whether reflected light from the first lidar device is the result of particulate matter in the air by comparing multiple planes for the presence and/or absence of reflected light, (d) using a second lidar device to scan multiple planes, wherein pulses of laser light are emitted and reflected laser light is detected, (e) collecting data related to laser light emitted from the second lidar device and reflected laser light detected by the second lidar device, (f) determining whether reflected light from the second lidar device is the result of particulate matter in the air by comparing multiple planes for the presence and/or absence of reflected laser light and (g) using an algorithm to compare data from the first lidar device with data from the second lidar device to confirm that reflected light is the result of a solid object rather than particulate matter in the air. The multiple planes scanned by the first lidar device are in the same area or substantially the same area as the multiple planes scanned by the second lidar device. The presence of a solid object can be confirmed when reflected laser light is detected in four or more of the multiple planes of the first lidar device and/or four or more of the multiple planes of the second lidar device. Further, the first lidar device and the second lidar device can use multi-echo scanning.

INTRODUCTION

[0019] A first aspect of the invention is an improved system and method for detecting

obstacles for autonomous driving using lidar.

[0020] A second aspect of the invention is an improved system and method for autonomous driving that utilizes multiple lidar systems.

[0021] A third aspect of the invention is an improved system and method for autonomous driving that utilizes multiple lidar systems and an algorithm to avoid falsely identifying water or particles in the air as solid objects.

[0022] A fourth aspect of the invention is an improved system and method for autonomous driving that utilizes multi-echo technology, scans multiple layers and employs an algorithm to mitigate interference caused from rain or particles in the air.

[0023] A fifth aspect of the invention is an improved system and method for autonomous driving that utilizes dual lidar systems, multi-echo technology and multiple layer scanning with an algorithm to improve the robustness and mitigate interference caused by rain or particles in the air.

Brief Description of Figures

[0024] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0025] The summary above, as well as the following detailed description of illustrative embodiments, is better understood when read in conjunction with the appended drawings. For the purpose of illustrating the disclosure, exemplary constructions of the disclosure are shown in the drawings. However, the disclosure is not limited to specific methods and instrumentalities disclosed herein. Moreover, the drawings are not to scale.

[0026] **FIG. 1A** depicts a conventional multi-echo lidar system.

[0027] **FIG. 1B** depicts a multi-layer scan lidar wherein each scan layer is superimposed on a grid map.

[0028] **FIG. 2** depicts a grid obtained by a multi-layer scan lidar. A solid object will be present on multiple layers.

[0029] **FIG. 3A** is a flowchart of an embodiment wherein a lidar sensor uses last echo filtering and a rain filter algorithm for obstacle feature detection.

[0030] **FIG. 3B** depicts dual lidar units used to detect obstacles according to an embodiment of the invention.

[0031] **FIG. 3C** is a flowchart of an embodiment of the invention wherein dual lidar sensors use last echo filtering and a rain filter algorithm to distinguish return signals caused by rain or particles in the air from those of solid objects.

[0032] **FIG. 4A** depicts an autonomous vehicle with dual lidar sensors separated by a distance "d."

[0033] **FIG. 4B** depicts dual lidar sensors and their respective zones of detection.

[0034] **FIG. 5A** is a plot of a single plane lidar.

[0035] **FIG. 5B** is a plot of a single plane lidar using the dual lidar system.

[0036] **FIG. 5C** is a plot of a multi-plane lidar.

[0037] **FIG. 5D** is a plot of a multi-plane lidar using the dual lidar system.

DETAILED DESCRIPTION OF THE INVENTION

Definitions

[0038] While the invention is primarily described for the navigation of autonomous vehicles, it is understood that the invention is not so limited and can be used to assist with other endeavors that use lidar. Other applications include, for example, using the invention in other vehicles such as robots, drones or unmanned aircraft systems. The invention can also be used to improve the robustness of lidar in landscape imaging and mapping applications when particles such as rain or snow are present in the air.

[0039] Reference in this specification to "one embodiment/aspect" or "an embodiment/aspect" means that a particular feature, structure, or characteristic described in connection with the embodiment/aspect is included in at least one embodiment/aspect of the disclosure. The use of the phrase "in one embodiment/aspect" or "in another embodiment/aspect" in various places in the specification are not necessarily all referring to the same embodiment/aspect, nor are separate or alternative embodiments/aspects mutually exclusive of other embodiments/aspects. Moreover, various features are described which may be exhibited by some embodiments/aspects and not by others. Similarly, various requirements are described which may be requirements for some embodiments/aspects but not other embodiments/aspects. Embodiment and aspect can be in certain instances be used interchangeably.

[0040] The terms used in this specification generally have their ordinary meanings in the art, within the context of the disclosure, and in the specific context where each term is used. Certain terms that are used to describe the disclosure are discussed below, or elsewhere in the specification, to provide additional guidance to the practitioner regarding the description of the disclosure. For convenience, certain terms may be highlighted, for example using italics and/or quotation marks. The use of highlighting has no influence on the scope and meaning of a term; the scope and meaning of a term is the same, in

the same context, whether or not it is highlighted. It will be appreciated that the same thing can be said in more than one way.

[0041] Consequently, alternative language and synonyms may be used for any one or more of the terms discussed herein. Nor is any special significance to be placed upon whether or not a term is elaborated or discussed herein. Synonyms for certain terms are provided. A recital of one or more synonyms does not exclude the use of other synonyms. The use of examples anywhere in this specification including examples of any terms discussed herein is illustrative only, and is not intended to further limit the scope and meaning of the disclosure or of any exemplified term. Likewise, the disclosure is not limited to various embodiments given in this specification.

[0042] Without intent to further limit the scope of the disclosure, examples of instruments, apparatus, methods and their related results according to the embodiments of the present disclosure are given below. Note that titles or subtitles may be used in the examples for convenience of a reader, which in no way should limit the scope of the disclosure. Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure pertains. In the case of conflict, the present document, including definitions, will control.

[0043] Directional and/or relational terms such as, but not limited to, left, right, nadir, apex, top, bottom, vertical, horizontal, back, front, and lateral are relative to each other, are dependent on the specific orientation of an applicable element or article, are used accordingly to aid in the description of the various embodiments in this specification and the appended claims, and are not necessarily intended to be construed as limiting.

[0044] ~~As applicable, the terms "about" or "generally", as used herein in the~~
specification and appended claims, and unless otherwise indicated, means a margin of +/- 20%. Also, as applicable, the term "substantially" as used herein in the specification

and appended claims, unless otherwise indicated, means a margin of +/- 10%. It is to be appreciated that not all uses of the above terms are quantifiable such that the referenced ranges can be applied.

[0045] The term “multi-echo capability” refers to the ability of a lidar unit to gather and evaluate multiple (e.g. three) echoes per transmitted laser pulse. Once an echo reaches the receiver of the unit, the received intensity is transformed into a voltage. An echo from a solid object will usually yield a high voltage over a long period of time. An echo of a rain drop, however, yields a very low voltage over a short period of time.

[0046] The term “multi-layer technology” refers to a lidar unit that allows for a pitch angle compensation by means of multiple (e.g. four) scan planes with different vertical angles. In a preferred design, the photo diode receiver of the unit include multiple (e.g. four) independent receivers arranged in a line. Each receivers scans a single plane, thus dividing the vertical aperture into multiple planes.

[0047] The term “SLAM” refers to Simultaneous Localization And Mapping which enables accurate mapping where GPS localization is unavailable, such as indoor spaces. SLAM algorithms use LiDAR and IMU (Inertial Measurement Unit) data to simultaneously locate the sensor and generate a coherent map of its surroundings.

[0048] The term “Time-of-Flight Principle” refers to a method for measuring the distance between a sensor and an object, based on the time difference between the emission of a signal and its return to the sensor, after being reflected by an object.

[0049] Other technical terms used herein have their ordinary meaning in the art that they are used, as exemplified by a variety of technical dictionaries. The particular values and configurations discussed in these non-limiting examples can be varied and are cited merely to illustrate at least one embodiment and are not intended to limit the scope thereof.

Description of Preferred Embodiments

[0050] Lidar is fundamentally a distance measuring technology. A lidar system sends light energy to the ground or toward an object. This emitted light can be referred to as a “beam” or “pulse.” The lidar unit measures light that is reflected back to the sensor. This reflected light can be referred to as the “echo” or “return.” The spatial distance between the lidar system and a measured point is calculated by comparing the delay between the pulse and return.

[0051] Lidar is often a preferred system for use in autonomous vehicles because it can accurately map the three-dimensional surroundings of a vehicle to a high resolution. However, rain or particulate matter in the air can render lidar ineffective as the particles reflect laser light back to the lidar unit. As light is reflected, an autonomous vehicle will slow or stop as the airborne particulates are indistinguishable from solid objects.

[0052] FIG. 1A depicts a lidar unit **110** using last echo filtering to detect an object **120**. The technique is also referred to as multi-echo scanning. Rain **115** is depicted between the lidar unit **110** and an object **120**. One pulse can generate multiple echoes (i.e. first echo, intermediate echo, last echo) of laser light to the lidar unit. This can occur when particles in the air such as rain reflect laser light back to the lidar unit **110**. A first echo **130** is depicted wherein the signal is reflected from particles in the air. Intermediate echoes can also occur as a result of particles in the air. A last echo **140** is depicted wherein the signal (i.e. echo) is reflected from a solid object **120**.

[0053] The system can analyze echoes to identify those that are a result of rain or particles in the air. Using a “last echo filter,” the first and intermediate echoes are attributed to rain or particles in the air. The last echo is attributed to a solid object. However, this technique has limitations and is ineffective in heavy rain or with substantial particulate matter in the air.

[0054] FIG. 1B depicts multi-layer scanning, another technique aimed at identifying

echoes or returns from rain **115** or particulate matter in the air. A lidar unit **110** scans multiple angles. A layer **130**, plane or stacked plane can be attributed a scan of each angle. The system can compare data from the layers to confirm the presence or absence of an object. An object that appears on a single layer will likely be attributed to a particle in the air. In a preferred method, the presence of a solid object is confirmed when echoes are detected in four or more adjacent layers.

[0055] Each scan angle/layer can be superimposed on a grid map as depicted in FIG. 2. The results of a scan are represented on four layers. Of four scanned angles, each angle is depicted on a horizontal grid. Each shaded square indicates that the lidar unit detected an echo. A conventional lidar system will indicate the presence of two objects, **215** and **225**. Analysis of data from multiple layers can distinguish a false positive reading from a true reading.

[0056] If obstacles are detected in scan layer 1 but not in scan layer 2 or N at the exact position, then the obstacles can be identified as a particle in the air such as rain. Although the first object **215** is present in multiple layers, it is absent in an intermediate layer (Scan Layer 3). Further, its location varies among layers. In this circumstance, the system can conclude that the echoes are attributable to rain or particles in the air. In contrast, the second object **225** is present in multiple consecutive layers at the same location. With this data, the system can confirm that signals are attributable to a solid object. In a preferred method, an echo in four cells is used to confirm the presence of an object or obstacle. If the object is in three or fewer cells, it is attributed to rain or airborne particulates.

[0057] FIG. 3A is a flowchart that depicts a lidar unit that employs both last echo filtering and a rain filter algorithm. The lidar unit can use a last echo filter **305** and a rain filter algorithm **315** that analyzes data from multi-layer scanning for obstacle feature and detection **325**. This improves the reliability and robustness of lidar when airborne particles such as rain are present.

[0058] FIG. 3B depicts an embodiment of the invention wherein two lidar units function concurrently to improve the robustness of an autonomous vehicle navigation system and allow it to operate during rainy or snow conditions. The system can include a first (i.e. left) lidar unit **210** and a second (i.e. right) lidar unit **220** that scan substantially the same area. Data can be collected from each lidar unit and compared using an algorithm to confirm that a signal is the result of a solid object.

[0059] If the first lidar unit receives reflected light from an object, the system confirms the presence of an object using the second lidar unit. The system can use an algorithm to analyze data from each lidar unit which includes emitted light, reflected light (i.e. echoes) as well as the angles of reflection and movement of objects. In this manner, the second lidar unit confirms that reflected light received by the first lidar unit is the result of a solid object. A reflected pulse (i.e. echo) that is detected by one of the units, without confirmation from the other, can be attributed to a particle in the air and classified as a false positive. The following principles can be applied to this method:

- Solid objects/obstacles are detected by both lidar units (**210**, **220**).
- An echo that is detected by the left lidar unit **210** that is not detected by right lidar unit **220** can be attributed to a particle in the air such as rain.
- An echo that is detected by the right lidar unit **220** that is not detected by left lidar unit **210** can be attributed to a particle in the air such as rain.

[0060] This dual-unit approach can be combined with other filter techniques to improve its robustness and reliability such as a last echo filter and/or multi-layer scanning. FIG. 3B depicts a first echo **130** along with a last echo **140**.

[0061] FIG. 3C is a flowchart that depicts a system of two lidar units according to an embodiment of the invention. The first lidar unit **210** and the second lidar unit **220** can use last echo filtering (**310**, **320**). Data from each unit is collected, processed and analyzed using a rain filter algorithm **330**. The algorithm can, for example, attribute an

echo to rain if it is detected by one lidar unit rather than the pair. This leads to more robust obstacle and feature detection **340**. An autonomous vehicle can avoid objects/hazards without slowing and/or stopping due to false positive signals from rain or particles in the air.

[0062] FIG. 4A depicts a preferred arrangement of the system wherein a first lidar unit **210** and a second lidar unit **220** are mounted on the roof of an automobile **410** and separated by a distance “d” from one another. The distance “d” can be determined empirically and is preferably between 0.5 meters and 2.5 meters. However, the lidar units can be separated by a distance according to variables such as the vehicle size, resolution of the lidar units, anticipated distance of objects/hazards and the amount of particulate matter in the air. The ideal distance can vary from, for example, 1 cm for a small mobile robot to several meters for a large drone. As it may be appreciated, the first lidar unit **210** and a second lidar unit **220** can be mounted at other external positions on the vehicle (e.g. the bumper or hood). In a preferred arrangement, the lidar units are position on a horizontal plane with one another so that laser beams are emitted on the same planes.

[0063] FIG. 4B depicts the zones of detection **400** of a first (i.e. left) lidar unit **210** and a second (i.e. right) lidar unit **220**. Each system scans a substantially circular area to detect an object **120**. The scans overlap in the center area **235**. The number and direction of the rays emitted by each sensor can vary based on the lidar unit and the setting.

[0064] While the units scan substantially the same area, data collected from the area of overlap can be analyzed with an algorithm to confirm that a signal is the result of a solid object. Rain or particles in the air can reflect laser light to the lidar units. A solid object **120** is detected from laser light reflected to both lidar units.

[0065] The two lidar units function concurrently and echoes are analyzed. Multi-unit technology can be combined with last echo filtering techniques and multi-layer scanning to improve the robustness of autonomous vehicle navigation and allow operation during

conditions where particles such as rain or snow are present in the air.

WORKING EXAMPLE

Use of Lidar for Vehicle Navigation in Rain

[0066] The system was tested with an autonomous vehicle in a rain tunnel with a steady flow of rain of 10 millimeters (mm) per hour. Lidar units were affixed to the roof of a vehicle at a distance of approximately one meter from each other. Two types of lidar were used: a single plane (LMS151 unit) and a four-plane (LDMRS unit). The lidar units used multi-echo technology.

[0067] FIG. 5A – 5D are top view representations of the environment with an autonomous vehicle at the center. The horizontal axis represents the distance away from the front and rear of the vehicle in meters. The vertical axis represents the distance away from the sides of the vehicle in meters. Each segment depicts a distance of 5 meters.

[0068] FIG. 5A is a plot of a single plane lidar using multi-echo scanning. The circled areas are known locations of solid objects (pillars in the rain tunnel). The solid objects are detected along with additional areas from false positives from rain drops **505**. Most of the false-positives are detected in the area in front of the vehicle **505**.

[0069] The test was repeated using a (single plane) dual lidar system wherein a first lidar system and a second lidar system scan the area. FIG. 5B is a plot of a single plane lidar with data from the dual lidar system. Only scan points detected by both the first lidar system and the second lidar system are included. As in FIG. 5A, the horizontal axis represents the distance away from the front and rear of the vehicle. The vertical axis represents the distance away from the sides of the vehicle.

[0070] Return signals attributable to rain can be identified by comparing FIG. 5A and FIG. 5B. Without the dual lidar system, false positives are present and attributed to

echoes from rain drops in the air **505**. These false positives are absent with the use of the dual lidar system. The circled areas are structural objects of (e.g. pillars) that are present and detected in both tests.

[0071] FIG. 5C and FIG. 5D demonstrate the use of a multi-plane lidar filter in detecting false positive echoes. FIG. 5C is a plot of a multi-plane lidar (unfiltered). The horizontal axis represents the distance away from the front and rear of the vehicle. The vertical axis represents the distance away from the sides of the vehicle. Each segment depicts a distance of 5 meters. Points along the horizontal axis indicate the detection of false positives due to rain.

[0072] The test was repeated using a (multi-plane) dual system wherein a first lidar system and a second lidar system scan the area. FIG. 5D is a plot of a multi-plane lidar that uses a dual lidar system. Many of the plotted points are absent with the use of a dual lidar filter. These points are attributed to rain drops in the air. The points that are present in both FIG. 5C and FIG. 5D can be attributed to physical objects (i.e. features).

[0073] Additional modifications/components can improve the robustness of the system in heavy rain (e.g. rain of more than 20 mm/hour). One approach is to use lidar units capable of analyzing additional layers (e.g. five or more layers) for better penetration in rain. Lidar units with higher refresh rates can also be used to filter out rain droplets. A mechanical air blower can be implemented to provide an air curtain with a range (e.g. up to one meter) to reduce the amount of rain drop being detected by the lidar units.

[0074] It will be appreciated that variations of the above disclosed and other features and functions, or alternatives thereof, may be combined into other systems or applications. Also, various unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

[0075] Although embodiments of the current disclosure have been described comprehensively, in considerable detail to cover the possible aspects, those skilled in the art would recognize that other versions of the disclosure are also possible.