A control system 7100 and method for a vehicle 10 operable in an autonomous fashion comprises one or more controllers 7110. The control system is configured to receive a first request signal, a first availability signal and a second availability signal. The first request signal is indicative of a request for the vehicle to navigate to a primary navigation goal in an autonomous mode. The first availability signal is indicative of an availability of the primary navigation goal for the vehicle (10). The second availability signal is indicative of an availability of a secondary navigation goal for the vehicle. The one or more controllers, upon receipt of the first request signal and the first availability signal, output a first notification signal to notify a user of the vehicle of an unavailability of the primary navigation goal. The one or more controllers, upon receipt of the second availability signal, subsequently output a second notification signal to notify the user of the availability of the secondary navigation goal for the vehicle. The control system is configured to then cause the host vehicle to navigate to the secondary navigation goal instead of the primary navigation goal in the autonomous mode.
VEHICLE CONTROL SYSTEM AND CONTROL METHOD

TECHNICAL FIELD
The present disclosure relates to a vehicle control system and control method and particularly, but not exclusively, to a control system and a method for controlling the vehicle. Aspects of the invention relate to a control system, to a system, to a method, to a vehicle and to computer software.

BACKGROUND
It is known for a vehicle to autonomously navigate to a pre-set navigation goal.

It is an object of embodiments of the invention to at least mitigate one or more of the problems of the prior art.

SUMMARY OF THE INVENTION
Aspects and embodiments of the invention provide a control system, a system, a method, a vehicle, computer software and a storage medium as claimed in the appended claims.

Alternative Goal Prompt
According to an aspect of the invention, there is provided a control system arranged to operably cause a host vehicle to autonomously navigate to a secondary navigation goal instead of a primary navigation goal in dependence on a request for the host vehicle to navigation autonomously to the primary navigation goal and on an availability of the primary navigation goal for the host vehicle.

According to an aspect of the invention, there is provided a control system for a host vehicle operable in an autonomous mode. The control system comprises one or more controllers. The control system is configured to receive: a first request signal indicative of a request for the host vehicle to navigate autonomously to a primary navigation goal in an autonomous mode; a first availability signal indicative of an availability of the primary navigation goal for the host vehicle; and a second availability signal indicative of an availability of a secondary navigation goal for the host vehicle. The one or more controllers, subsequent to receipt of the first request signal and the first availability signal, output a first notification signal to notify a user of the host vehicle of an unavailability of the primary navigation goal. The one or more controllers, subsequent to receipt of the second availability signal, output a second notification signal to notify the user of the availability of the secondary navigation goal for the host vehicle.
The control system is configured to cause the host vehicle to subsequently navigate to the secondary navigation goal instead of the primary navigation goal in the autonomous mode. Advantageously, the control system can notify the user of an alternative, available navigation goal in the situation where the primary navigation goal is unavailable.

The one or more controllers may collectively comprise: at least one electronic processor having an electrical input for receiving the first request signal, the first availability signal and the second availability signal; and at least one electronic memory device electrically coupled to the at least one electronic processor and having instructions stored therein. The at least one electronic processor may be configured to access the at least one memory device and execute the instructions thereon so as to cause the host vehicle to subsequently navigate to the secondary navigation goal instead of the primary navigation goal in the autonomous mode.

The primary navigation goal may be unavailable due to an obstacle in a navigation path to the primary navigation goal. The obstacle may be at the primary navigation goal, for example another vehicle. The primary navigation goal may be unavailable due to an extent of the host vehicle.

The first request signal may be received when the vehicle is operating in a non-autonomous mode, different to the autonomous mode.

The first notification signal may comprise the second notification signal. In this way, the user can be notified of the availability of the secondary navigation goal at substantially the same time as the user is notified of the unavailability of the primary navigation goal.

The request indicated by the first request signal may be from the user of the host vehicle.

The one or more controllers may determine a location of first divergence between a first navigable area between a start location of the host vehicle and the primary navigation goal, and a second navigable area between the start location and the secondary navigation goal. The one or more controllers may output the second notification signal in dependence on the location of first divergence. Advantageously, the control system can utilise the location of first divergence to navigate the host vehicle autonomously to the secondary navigation goal. In other examples, the control system can utilise the location of first divergence to determine the availability of the secondary navigation goal for the host vehicle.
As used herein, the term navigable area will be understood to mean either a navigable area having a width lateral to a direction of movement of the host vehicle from the start location towards the primary navigation goal, in which a plurality of navigation routes for the host vehicle can be calculated. In some examples, the term navigable area will be understood to mean a single, calculated navigation route.

The location of first divergence may be determined as a centre location in the first navigable area in a direction of travel of the host vehicle from the start location to the primary navigation goal at which a distance from the centre location to a centre location in the second navigable area in a direction of travel of the host vehicle from the start location to the secondary navigation goal first exceeds a predetermined divergence threshold. The predetermined divergence threshold may be less than ten metres. The predetermined divergence threshold may be less than five metres. The predetermined divergence threshold may be greater than one metre.

The predetermined divergence threshold may be substantially a first distance from the centre point of the first navigable area at the location of first divergence to a lateral edge of the first navigable area closest the second navigable area plus a second distance from the centre point of the second navigable area at the location of first divergence to a lateral edge of the second navigable area closest the first navigable area.

The first availability signal may be indicative of an impassable location in the first navigable area. The second availability signal may be indicative of the second navigable area. The one or more controllers may output the second notification signal in dependence on the impassable location in the first navigable area being prior to the location of first divergence in a direction of travel of the host vehicle from the start location to the first navigation goal. Advantageously, the second notification signal can only be output where the host vehicle is not blocked from navigating to the secondary navigation goal by the same obstacle blocking the path of the host vehicle to the primary navigation goal.

The one or more controllers may determine a third navigable area between a current location of the host vehicle and the secondary navigation goal via the location of first divergence, and output the second notification signal in dependence thereon. Advantageously, the second notification signal can only be output where the host vehicle can identify a navigable path from the current location of the host vehicle and the secondary navigation goal. The third navigable area may exclude the start location of the host vehicle. In other words, the host vehicle need
not retrace the route exactly to the start location in order to navigate to the secondary navigation goal.

The current location of the host vehicle may be diverged from the second navigable area.

The control system may be configured to receive a second request signal indicative of a request for the host vehicle to navigate autonomously to the secondary navigation goal in the autonomous mode, wherein the one or more controllers, subsequent to receipt of the second request signal, output an alternative navigation signal to cause the host vehicle to navigate autonomously to the secondary navigation goal in the autonomous mode. Advantageously, the navigation to the secondary navigation goal may be in response to the request for the host vehicle to navigate to the secondary navigation goal. The alternative navigation signal may be output in dependence on the second request signal.

The request indicated by the second request signal may be from the user.

The alternative navigation signal may be to cause the host vehicle to navigate autonomously to the secondary navigation goal via the third navigable area. Advantageously, the host vehicle need not retrace the whole journey back to the start location.

The one or more controllers, subsequent to receipt of the first request signal, may output a first navigation signal to cause the host vehicle to navigate autonomously towards the primary navigation goal in the autonomous mode, and to output the first notification signal thereafter. In this way, it can be seen that the host vehicle may already have started on the path towards the primary navigation goal prior to receiving the first availability signal. The host vehicle can be re-routed en-route.

According to an aspect of the invention, there is provided a system. The system comprises the control system of any preceding claim, including at least a first controller. The at least one controller is arranged to output the first notification signal and the second notification signal. The system comprises notification means configured to receive the first notification signal and to output a first user notification that a primary navigation goal is unavailable in dependence thereon. The notification means is configured to receive the second notification signal and to output a second user notification that a secondary navigation goal is available in dependence thereon. Advantageously, the system can include the notification means to notify the user of the availability of the primary and secondary navigation goals.
The first controller may output both the first notification signal and the second notification signal.

The notification means may comprise a display means to display the first user notification and the second user notification. The display means may be a display unit, such as an electronic display.

The system may comprise an input apparatus to receive the request for the host vehicle to navigate autonomously to the primary navigation goal and to output the first request signal to the control system in dependence thereon. The input apparatus may comprise at least one switch, operable by the user to receive the request. The input apparatus may comprise an interactive display unit, operable by the user to receive the request.

According to an aspect of the invention, there is provided a method for controlling a vehicle operable in an autonomous mode and a non-autonomous mode. The method comprises receiving a request for the vehicle to navigate autonomously to a primary navigation goal in an autonomous mode. The method comprises receiving an availability of the primary navigation goal for the vehicle. The method comprises, subsequent to receipt of the request and the availability of the primary navigation goal, notifying a user of the vehicle of an unavailability of the primary navigation goal. The method comprises receiving an availability of a secondary navigation goal for the vehicle. The method comprises, subsequent to receipt of the availability of the secondary navigation goal, notifying the user of the availability of the secondary navigation goal. The method comprises autonomously controlling the vehicle to navigate to the secondary navigation goal instead of the primary navigation goal in the autonomous mode. Advantageously, the vehicle can notify the user of the availability of and navigate to the alternative navigation goal in the event the primary navigation goal in unavailable.

**Common Elements**

According to an aspect of the invention, there is provided a vehicle comprising a control system according to an aspect of the invention as described hereinbefore, a system according to an aspect of the invention as described hereinbefore or arranged to perform a method according to an aspect of the invention as described hereinbefore.

According to an aspect of the invention, there is provided a mobile terminal comprising the control system according to an aspect of the invention as described hereinbefore. The mobile terminal may comprise communication means, for example a communication unit for wireless
communication with the host vehicle. The communication unit may be a wireless transmitter arranged to wirelessly transmit one or more signals to the host vehicle via a predetermined wireless communication protocol. The one or more signals may include the navigation signal.

According to an aspect of the invention, there is provided computer software which, when executed by a processing means, is arranged to perform a method according to an aspect of the invention. The computer software may be stored on a computer readable medium. The computer software may be tangibly stored on a computer readable medium. The computer readable medium may be non-transitory.

According to an aspect of the invention, there is provided a non-transitory, computer-readable storage medium storing instructions thereon that when executed by one or more processors causes the one or more processors to carry out a method according to an aspect of the invention.

SAE International's J3016 defines six levels of driving automation for on-road vehicles. The terms autonomous driving mode and autonomous mode as used herein will be understood to cover any of the SAE levels one to five. In an embodiment, the autonomous driving modes and autonomous modes disclosed herein will be understood to be of at least SAE level three. In other words, the automated driving system of the host vehicle will control all aspects of the dynamic driving task. The autonomous mode may be referred to as an autonomous driving mode.

The term navigation goal as used herein will be understood to mean a location within a navigable area of an environment of the host vehicle for navigation of the host vehicle thereto. In some examples, the location may be a geographic absolute location, in a coordinate system, such as latitude and longitude. In other examples, the location may be a relative location, relative to one or more other features or regions associated with the environment of the host vehicle. In some examples, the term navigation goal as used herein will be understood to comprise the location within the navigable area as described hereinbefore, in addition to any other characteristics associated with the navigation of the host vehicle to the location of the navigation goal, for example an orientation of the host vehicle at the location of the navigation goal.

In autonomous driving modes of the host vehicle described herein, it will be understood that the control system may control the host vehicle to autonomously navigate through a navigable area, such as in accordance with a navigation goal, utilising a map of the navigable area.
Thus, the map of the navigable area of the host vehicle can be used during autonomous navigation of the host vehicle in the navigable area, for example in accordance with the navigation goal.

The map may comprise a retrievable map stored on a memory means, such as a non-transitory computer readable medium associated with the host vehicle, or on a cloud-based server accessible by the control system of the host vehicle. Such maps may be uploaded by the user to a cloud-based server. The uploaded map may be shared with other users. Maps uploaded by other users may likewise be shared, such that a user has access to a number of maps which may be downloaded directly from the cloud-based server. In some embodiments, one or more maps may additionally or alternatively be provided by a third-party service provider, such as a map and/or navigation service company, or a provider which generates a map of a particular navigable area on request as a service and makes the map available, whether via an on-line source or otherwise.

In another example, the map may be built by a driver teaching the host vehicle the navigable area in an initial mapping process. The map may be built by the driver teaching the host vehicle a navigable area in an independent mapping process by driving the host vehicle around the navigable area to provide guidance to the host vehicle. While the driver drives the host vehicle around the navigable area, one or more sensing means associated with the host vehicle, such as one or more on-board vehicle sensors, scan at least a portion of the navigable area to gradually build a map of the scanned area, optionally including landmarks, features or environmental attributes. In this way, the map can be used for later localisation and/or autonomous navigation of the host vehicle. The initial mapping process may be selected by the user of the host vehicle for teaching the host vehicle the map of the navigable area. Alternatively, the initial mapping process may be a passive mapping process in which the map is built during movement of the host vehicle in the navigable area. Where the initial mapping process is the passive mapping process, the user may not be notified that the host vehicle is building the map whilst the host vehicle is moving in the navigable area. Thus, the user can be made aware that the map of the navigable area is being or has been built only after building the map has already started.

Any controller or controllers described herein may suitably comprise a control unit or computational device having one or more electronic processors. Thus the system may comprise a single control unit or electronic controller or alternatively different functions of the controller may be embodied in, or hosted in, different control units or controllers. As used herein the term “controller” or “control unit” will be understood to include both a single control
unit or controller and a plurality of control units or controllers collectively operating to provide any stated control functionality. To configure a controller, a suitable set of instructions may be provided which, when executed, cause said control unit or computational device to implement the control techniques specified herein. The set of instructions may suitably be embedded in said one or more electronic processors. Alternatively, the set of instructions may be provided as software saved on one or more memory associated with said controller to be executed on said computational device. A first controller may be implemented in software run on one or more processors. One or more other controllers may be implemented in software run on one or more processors, optionally the same one or more processors as the first controller. Other suitable arrangements may also be used.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

BRIEF DESCRIPTION OF THE DRAWINGS
One or more embodiments of the invention will now be described by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows a schematic representation of a host vehicle;

Figure 2 shows a schematic representation of a control system associated with the host vehicle of Figure 1;

Figures 3 and 7 show a schematic representation of an environment in which the host vehicle can operate;

Figure 4 shows a schematic representation of a system associated with the host vehicle of Figure 1;
Figure 5 shows a flowchart representative of a method associated with control of the host vehicle of Figure 1; and

Figure 6 shows an illustrative example of a host vehicle as described herein.

5

DETAILED DESCRIPTION

Vehicle Systems

A schematic diagram representative of the subsystems associated with a host vehicle 10 in accordance with an embodiment of the invention is shown in Figure 1. The host vehicle 10 is for operating in an autonomous mode, to autonomously navigate through an environment to a navigation goal. The host vehicle 10 may comprise any of the control systems, or systems described herein. The host vehicle 10 may be arranged to perform any of the method described herein.

15

The host vehicle 10 is a land-going vehicle comprising a plurality of wheels 12a, 12b, 12c, 12d, which may be in the form of four wheels 12a, 12b, 12c, 12d. The host vehicle 10 comprises a front drivetrain controller 14 and a rear drivetrain controller 16. The front drivetrain controller 14 is connected to each of the front wheels 12a, 12b. The front drivetrain controller 14 may be mechanically connected to each of the front wheels 12a, 12b. Alternatively or additionally, the front drivetrain controller 14 is electrically connected to each of the front wheels 12a, 12b via one or more motors (not shown). The rear drivetrain controller 16 is connected to each of the rear wheels 12c, 12d. The rear drivetrain controller 16 may be mechanically connected to each of the rear wheels 12c, 12d. Alternatively, the rear drivetrain controller 16 is electrically connected to each of the rear wheels 12c, 12d via one or more motors (not shown). The front drivetrain controller 14 and the rear drivetrain controller 16 each control a motive torque being applied to the wheels 12a, 12b, 12c, 12d for movement of the host vehicle 10 through the environment. It will be appreciated that in some embodiments a single drivetrain controller may perform the functions of the front and rear drive train controller 14, 16. Each of the wheels 12a, 12b, 12c, 12d has associated therewith a respective torque modification controller 18a, 18b, 18c, 18d, which may be in the form of a braking controller 18a, 18b, 18c, 18d. The braking controller 18a, 18b, 18c, 18d can control an application of a braking torque to the rotational movement of the associated wheel 12a, 12b, 12c, 12d. It will be appreciated that the torque modification controllers 18a, 18b, 18c, 18d can be capable of applying additional torque to the wheels 12a, 12b, 12c, 12d. In this case, the drivetrain controllers 14, 16 may not apply torque to the wheels 12a, 12b, 12c, 12d, but can instead be used to control the application of motive torque by the torque modification controllers 18a, 18b, 18c, 18d. Such an arrangement is typically found in electric vehicles. In hybrid electric
vehicles, there may be provided the drivetrain controllers 12, 16 to apply torque to the wheels 12a, 12b, 12c, 12d via a motor, for example an internal combustion engine, as well as the torque modification controllers 18a, 18b, 18c, 18d to apply torque to the wheels 12a, 12b, 12c, 12d via one or more electric motors. In some examples, the host vehicle 10 is powered by hydrocarbon-based fuels via an internal combustion engine. The internal combustion engine is mechanically connected to the front and rear drivetrain controllers 14, 16 (or the single drivetrain controller). Although the preceding disclosure has described a vehicle in which each of the four wheels 12a, 12b, 12c, 12d are driven, it will be understood that not all of the wheels 12a, 12b, 12c, 12d may be driven. For example, only the front wheels 12a, 12b may be driven, for example by the front drivetrain controller 14 or by the torque modification controller 18a, 18b. In an alternative example, only the rear wheels 12c, 12d may be driven, for example by the rear drivetrain controller 16 or by the torque modification controller 18c, 18d.

The host vehicle 10 comprises a vehicle controller 20 to control the operation of the host vehicle 10. The vehicle controller 20 is typically in communication with each of the other motive controllers 14, 16, 18a, 18b, 18c, 18d of the host vehicle 10. The vehicle controller 20 may send and receive vehicle control instructions over one or more data communication networks of the vehicle 10 controlled by a network controller 22. The host vehicle 10 comprises a steering controller 24 to steer the host vehicle 10. Typically, the steering controller 24 will control steering of the host vehicle 10 by steering the front wheels 12a, 12b. The steering controller 24 may be in data communication with the vehicle controller 20 to receive steering control requests therefrom and to steer the host vehicle 10 in dependence on the steering control requests. In some embodiments, the steering controller 24 can receive a user steering input to control the steering of the host vehicle 10. The steering controller 24 may be in data communication with the torque modification controllers 18a, 18b, 18c, 18d to control the torque applied at the wheels 12a, 12b, 12c, 12d to assist in steering the host vehicle 10. The host vehicle 10 comprises a navigation controller 26 to determine a navigation route of the host vehicle 10 through the environment. The route may be between a start location and a destination location. The navigation controller 26 may be in data communication with the vehicle controller 20 to send the determined navigation route to the vehicle controller 20 to cause the host vehicle 10 to navigate in accordance with the determined navigation route. The host vehicle comprises a sensor controller 28 to control one or more sensors (not shown in Figure 1) of the host vehicle 10. The sensors are arranged to sense data indicative of the environment of the host vehicle 10. The data indicative of the environment may be stored in data storage accessible to the vehicle, such as in one or more memory devices of the vehicle. The sensor controller 28 may be in data communication with the vehicle controller 20 to output the data indicative of the environment to the vehicle controller 20 to cause the host vehicle 10
to navigate utilising the data indicative of the environment. The sensor controller 28 may be in data communication with the navigation controller 26 to output the data indicative of the environment to the vehicle controller 20 to cause the host vehicle 10 to determine the navigation route utilising the data indicative of the environment. As will be described hereinafter, it will be understood that the sensors may include a first sensor means in the form of a first plurality of sensors to sense the environment rearward at or from a rear of the host vehicle and a second sensor means in the form of a second plurality of sensors to sense the environment forward at or from a front of the host vehicle. It will be understood that many combinations of sensors are suitable for supporting autonomous navigation of the host vehicle, including any combination of one or more radar sensors, one or more stereoscopic sensors, one or more cameras, one or more LIDAR sensors, and one or more ultrasound sensors.

As will be described in more detail hereinafter, the host vehicle 10 is for autonomously navigating in an autonomous driving mode of the host vehicle 10. The host vehicle 10 may comprise any of the controllers or systems described hereinafter. The host vehicle 10 may be arranged to perform any of the methods described hereinafter.

As will be understood, the host vehicle 10 is typically a land-going vehicle, for example a road vehicle such as a car, a lorry, or any other suitable vehicle.

**Alternative Goal Prompt**
A control system 7100 or control unit 7100 in accordance with an embodiment of the invention is shown in Figure 2.

The control system 7100 is for a host vehicle 10 operable in an autonomous mode and a non-autonomous mode. The host vehicle 10 may be substantially as described with reference to Figure 1 hereinbefore. The control system 7100 comprises one or more controllers 7110. The one or more controllers 7110 include a first controller 7110. The control system 7100 is configured to receive a first request signal, a first availability signal and a second availability signal. The first request signal is indicative of a request for a host vehicle 10 to navigate autonomously to a primary navigation goal in an autonomous mode. The first request signal is typically received when the host vehicle 10 is operating in a non-autonomous mode, different to the autonomous mode. The request is from a user of the host vehicle 10. The first availability signal is indicative of an availability of the primary navigation goal for the host vehicle 10. The first availability signal is typically indicative of the availability of autonomous navigation of the host vehicle 10 to the primary navigation goal in the autonomous mode. The second
availability signal is indicative of an availability of a secondary navigation goal for the host vehicle 10. The second availability signal is typically indicative of the availability of autonomous navigation of the host vehicle 10 to the secondary navigation goal in the autonomous mode. The one or more controllers 7110, subsequent to receipt of the first request signal and the first availability signal, typically in dependence on the first request signal and the first availability signal being received, output a first notification signal. The first notification signal is to notify the user of the host vehicle 10 of an unavailability of the primary navigation goal. In other words, the output of the first notification signal results in notification to the user that the host vehicle 10 cannot (at least currently) autonomously navigate to the primary navigation goal.

The one or more controllers 7110, subsequent to receipt of the second availability signal, for example in dependence on the second availability signal being received, output a second notification signal. The second notification signal is to notify the user of the availability of the secondary navigation goal for the host vehicle 10. In other words, the output of the second notification signal results in notification to the user that the host vehicle 10 can autonomously navigate to the secondary navigation goal. The control system 7100 is configured to cause the host vehicle 10 to subsequently navigate to the secondary navigation goal instead of the primary navigation goal in the autonomous mode. Therefore, an alternative navigation goal (secondary navigation goal) can be suggested to the user where the requested navigation goal (primary navigation goal) is unavailable and the host vehicle 10 can autonomously navigate to the alternative navigation goal instead of the requested (or primary) navigation goal. The one or more controllers 7110 comprise an electronic processor 7120 having an electrical input 7140 and an electronic memory device 7130 electrically coupled to the electronic processor 7120. The electronic memory device 7130 has instructions stored therein. The electronic processor 7120 is configured to access the memory device 7130 and execute the instructions thereon so as to autonomously navigate the host vehicle to the secondary navigation goal instead of the primary navigation goal. The electrical input 7140 is for receiving the first request signal, the first availability signal and the second availability signal. The electronic processor 7120 includes an electrical output 7150 for outputting the first notification signal and the second notification signal. The electrical input 7140 and the electrical output 7150 may be combined such as by being formed by an I/O unit or interface unit. For example, the one or more controllers 7110 may comprise an interface to a network forming a communication bus of the host vehicle. The interface bus may be an Internet Protocol (IP) based communication bus such as Ethernet, although embodiments of the invention are not limited in this respect.

The unavailability of the primary navigation goal can be due to an obstacle, such as another vehicle, either at the primary navigation goal, or in a navigation path to the primary navigation
goal. In some embodiments, the one or more controllers 7110 determine that the primary navigation goal is unavailable in dependence on an extent of the host vehicle 10 being greater than an available space at the navigation goal, or at any point along the navigation path.

In this example, the first notification signal comprises the second notification signal. Therefore, the user can be notified of the availability of the secondary navigation goal at substantially the same time as being notified that the primary navigation goal is unavailable.

The one or more controllers 7110 determine a location of first divergence between a first navigable area and a second navigable area. The first navigable area is between a start location of the host vehicle 10 and the primary navigation goal. The second navigable area is between the start location and the secondary navigation goal.

An environment 7200 in which the host vehicle 10 in accordance with an embodiment of the invention can operate is shown schematically in Figure 3. The environment 7200 shown in Figure 3 will help to explain at least some of the uses for an embodiment of the invention. As can be seen, the environment 7200 includes a plurality of navigation goals 7210, 7220 in the form of a primary navigation goal 7210 and a secondary navigation goal 7220. The host vehicle 10, receiving a request for autonomous navigation to the primary navigation goal 7210, considers a received availability of the primary navigation goal 7210. A further vehicle 12 is present at the primary navigation goal 7210, making the primary navigation goal 7210 unavailable for the host vehicle 10. Although the host vehicle 10 is shown at a start location 7225, it will be understood that the host vehicle 10 may have started autonomous navigation to the primary navigation goal 7210 prior to receiving the availability signal indicative of the availability of the primary navigation goal 7210. In this example, first navigable area 7230 is an area with lateral extent and is representative of an area of the environment 7200 within which the host vehicle 10 can manoeuvre during autonomous navigation to the primary navigation goal 7210, for example to avoid small obstacles in the navigation path. In other words, the first navigable area can comprise a plurality of possible navigation routes for the host vehicle 10 between the start location 7225 and the primary navigation goal 7210. The first navigable area 7230 also defines a centre line 7250, sometimes referred to as a centre location 7250 representing a centre-line of the first navigable area 7230 in a lateral direction. As will be seen in Figure 3, second navigable area 7240 is also provided, having a lateral extent and defining a second centre line 7260, sometimes referred to as a second centre location 7250. The second navigable area 7240 can comprise a plurality of possible navigation routes for the host vehicle 10 between the start location 7225 and the secondary navigation goal 7220. In one example, the location of first divergence 7270 referred to previously may be
determined as where the first navigable area 7230 first diverges from the second navigable area 7240, for example as the location associated with the first navigable area 7230 where the centre location 7250 of the first navigation area first separates from the second centre location 7260 by more than a predetermined divergence threshold. The predetermined divergence threshold here is the separation between the centre location 7250 and the second centre location 7260. As will be appreciated, when the host vehicle is before the location of first divergence 7270 in the first navigable area 7230, the host vehicle 10 can continue in the same direction and move instead to the second navigable area 7240 for autonomous navigation to the secondary navigation goal 7220 instead of the primary navigation goal 7210. However, when the host vehicle 10 is beyond the location of first divergence 7270, the host vehicle 10 may need to manoeuvre back to the location of first divergence 7270 to move to the second navigable area 7240 for autonomous navigation to the secondary navigation goal 7220 instead of the primary navigation goal 7210.

If there is a navigation obstacle in the first navigable area 7230 before the location of first divergence 7270, the one or more controllers 7110 determine if it is possible to autonomously navigate to the first navigation goal 7210 around the navigation obstacle and remaining within the first navigable area 7230. If the first navigation goal 7210 is unavailable due to the navigation obstacle being such that autonomous navigation around the navigation obstacle is not possible, then it will be understood that autonomous navigation to the second navigation goal 7220 may also be unavailable due to the same navigation obstacle. For the avoidance of doubt, it is noted that the above-described navigation obstacle is not shown in Figure 3.

Moving back to Figure 2, the one or more controllers 7110 output the second notification signal in dependence on an impassable location in the first navigable area being prior to the location of first divergence 7270 in a direction of travel of the host vehicle 10 from the start location 7225 to the first navigation goal 7210.

The one or more controllers 7110 determine a third navigable area between a current location of the host vehicle and the secondary navigation goal 7220 via the location of first divergence 7270. The second notification signal is output in dependence on the third navigable area being determined. Therefore, the host vehicle 10 can navigate autonomously to the second navigation goal from anywhere in the first navigable area 7230, even when the host vehicle 10 has already moved past the location of first divergence 7270. Typically, the third navigable area excludes the start location of the host vehicle 10 where the host vehicle 10 has already started moving towards the first navigation goal 7210 in the first navigable area 7230. The
third navigable area typically includes areas only part of the first navigable area 7230 and the second navigable area 7240.

The control system 7100 is configured to receive a second request signal. The second request signal is indicative of a request for the host vehicle 10 to navigate autonomously to the secondary navigation goal in the autonomous mode. The one or more controllers 7110, subsequent to receiving the second request signal, typically in dependence on the second request signal being received, output an alternative navigation signal to cause the host vehicle 10 to navigate autonomously to the secondary navigation goal in the autonomous mode. The request indicated by the second request signal is typically from the user. The alternative navigation signal is to cause the host vehicle 10 to navigate autonomously to the secondary navigation goal via the third navigable area.

The one or more controllers 7110, subsequent to receiving the first request signal, typically in dependence on the first request signal being received, output a first navigation signal to cause the host vehicle 10 to navigate autonomously towards the primary navigation goal in the autonomous mode. Where the host vehicle 10 begins moving towards the primary navigation goal, the first notification signal can be output thereafter.

A system 7300 in accordance with an embodiment of the invention is shown in Figure 4. The system comprises the control system 7100 as described hereinbefore with reference to Figure 2. The system 7300 comprises notification means 7310 in the form of a notification unit 7310. The notification means 7310 is configured to receive the first notification signal and, in dependence thereon, to output a first user notification that a primary navigation goal is unavailable. The notification means 7310 typically comprises display means 7310 in the form of a display unit 7310, such as an electronic display 7310. Typically, the notification means 7310 is configured to receive the second notification signal and, in dependence thereon, to output a second user notification that autonomous navigation to the secondary navigation goal is available. The system 7300 comprises an input apparatus 7320. The input apparatus 7320 is to receive the request for the host vehicle to navigate autonomously to the primary navigation goal. The input apparatus 7320 is to output the first request signal to the control system 7100 in dependence on receiving the request. The input apparatus 7320 comprises at least one switch 7320, operable by the user to receive the request. The switch is typically in the form of an interactive display unit 7320.

A method 7400 according to an embodiment of the invention is shown in Figure 5. The method 7400 is a method of controlling the host vehicle 10. In particular, the method 7400 is a method
of autonomously navigating the vehicle 10 to a secondary navigation goal in dependence on autonomous navigation to a primary navigation goal being unavailable. The method 7400 may be performed by the control system 7100 and the system 7300 described hereinbefore with reference to Figures 2 and 4.

The method 7400 broadly comprises steps of receiving 7410 a request for the vehicle to navigate autonomously to a primary navigation goal in an autonomous mode, receiving 7420 an availability of the primary navigation goal for the vehicle, notifying 7430 a user of the vehicle of an unavailability of the primary navigation goal, receiving 7440 an availability of a secondary navigation goal for the vehicle, notifying 7450 the user of the availability of the secondary navigation goal and, in dependence thereon, autonomously controlling 7460 the vehicle to navigate to the secondary navigation goal in the autonomous mode.

Referring to Figure 5, the illustrated embodiment of the method 7400 comprises a step of receiving 7410 a request for the vehicle to navigate autonomously to a primary navigation goal in an autonomous mode. The request is typically from a user of the vehicle. The request may be made remotely, for example from a personal electronic device such as a handheld electronic device.

In step 7420, an availability of the primary navigation goal for the vehicle is received. The availability is typically the availability of autonomous navigation of the vehicle to the primary navigation goal. The availability can be that autonomous navigation of the vehicle to the primary navigation goal is unavailable.

In step 7430, a user of the vehicle is notified of the unavailability of the primary navigation goal. The user is typically notified in dependence on the request for autonomous navigation to the primary navigation goal and the availability of the primary navigation goal being received.

In step 7440, an availability of a secondary navigation goal for the vehicle is received. The availability is typically the availability of autonomous navigation of the vehicle to the secondary navigation goal. The availability can be that autonomous navigation of the vehicle to the secondary navigation goal is available. It will be understood that the availability of the secondary navigation goal for the vehicle can be received prior to step 7430, for example at substantially the same time as receiving the availability of the primary navigation goal for the vehicle in step 7420.
In step 7450, the user is notified of the availability of the secondary navigation goal. The user is notified in dependence on the availability of the secondary navigation goal being received. It will be understood that the availability of the secondary navigation goal may be only a preliminary estimate of the availability. For example, the secondary navigation goal may be deemed to be available if the vehicle is not aware of any obstructions or other reasons why the vehicle could not autonomously navigate to the secondary navigation goal, even if such reasons are discovered subsequently, for example during autonomous navigation towards the secondary navigation goal.

In step 7460, the vehicle is autonomously controlled to navigation to the secondary navigation goal instead of the primary navigation goal in the autonomous mode. The vehicle can autonomously navigate to the secondary navigation goal in dependence on receiving a second request from the user to navigate to the secondary navigation goal instead of the primary navigation goal after the user has been notified of the availability of the secondary navigation goal.

As a result of method 7400, the vehicle can autonomously navigate to a secondary navigation goal instead of a primary navigation goal when autonomous navigation to the primary navigation goal is unavailable.

Vehicle
A representative image of the host vehicle 10 for comprising any of the control systems or systems or associated with performing any of the methods described hereinbefore is shown in Figure 6.

A navigable area 50 for navigation of the host vehicle 10 therein in accordance with any of the methods described hereinbefore is shown in Figure 7. In other words, in autonomous driving modes of the host vehicle 10 described herein, it will be understood that any of the control systems described herein can control the host vehicle 10 to autonomously navigate in the navigable area 50 utilising a map of the navigable area 50. The host vehicle 10 typically autonomously navigates in the navigable area 50 by navigating in accordance with a navigation goal, for example to a navigation goal, utilising the map of the navigable area 50. Thus, the map of the navigable area 50 of the host vehicle 10 can be used during autonomous navigation of the host vehicle 10 in the navigable area 50, for example in accordance with the navigation goal.
The map comprises data indicative of one or more features 54 of an environment 52 associated with the navigable area 50, such as localised features. In one example, the map comprises a retrievable map stored on a memory means, such as a non-transitory computer readable medium associated with the host vehicle 10, or on a cloud-based server accessible by the control system of the host vehicle 10. Such maps may be uploaded by the user to a cloud-based server. The uploaded map may be shared with other users. Maps uploaded by other users may likewise be shared, such that a user has access to a number of maps which may be downloaded directly from the cloud-based server. In some embodiments, one or more maps may additionally or alternatively be provided by a third-party service provider, such as a map and/or navigation service company or a provider which generates a map of a particular navigable area on request as a service and makes the map available, whether via an on-line source or otherwise.

In another example, the map may be built by a driver teaching the host vehicle 10 the navigable area 50 in an initial mapping process. The map may be built by the driver teaching the host vehicle 10 a navigable area 50 in an independent mapping process by driving the host vehicle 10 around the navigable area 50 to provide guidance to the host vehicle 10. While the driver drives the host vehicle 10 around the navigable area 50, one or more sensing means associated with the host vehicle 10, such as one or more on-board vehicle sensors, scan at least a portion of the navigable area 50 to gradually build a map of the scanned area, optionally including landmarks, features or environmental attributes. In this way, the map can be used for later localisation and/or autonomous navigation of the host vehicle 10. The initial mapping process may be selected by the user of the host vehicle 10 for teaching the host vehicle 10 the map of the navigable area 50. Alternatively, the initial mapping process may be a passive mapping process in which the map is built during movement of the host vehicle 10 in the navigable area 50. Where the initial mapping process is the passive mapping process, the user may not be notified that the host vehicle 10 is building the map whilst the host vehicle 10 is moving in the navigable area 50. Thus, the user can be made aware that the map of the navigable area 50 is being or has been built only after building the map has already started.

In some examples, the navigable area is a constrained area in which the host vehicle is capable of autonomous navigation. The navigable area may be different from a highway road, such as a privately-owned location with no public right of way. In this way, autonomous navigation of the host vehicle in the navigable area can be performed in an environment having fewer other users navigating in the navigable area, and with relatively constrained mapping requirements, which may simplify the complexity of reliable and accurate autonomous navigation of the host vehicle. The navigable area may have a size of less than 5 km², less
than 2 km², less than 1 km², or less than 500 m². The navigable area may be the grounds of a building, for example a private commercial premises, a public commercial premises, or a private residential premises. For example, the navigable area may be the grounds of an office, a factory, an airport, a shopping centre, a hospital, a hotel, an apartment building, a house, or of any other building. In some examples, the navigable area may not include a building and may be, for example, a field. The navigable area may comprise a car park. The navigable area may comprise a driveway of a residential building, such as a house. The navigable area may be bounded by a boundary fence (or wall) of the premises. The boundary fence (or wall) may comprise a gate or similar to permit access for the host vehicle onto the navigable area.

It will be appreciated that embodiments of the present invention can be realised in the form of hardware, software or a combination of hardware and software. Any such software may be stored in the form of volatile or non-volatile storage such as, for example, a storage device like a ROM, whether erasable or rewritable or not, or in the form of memory such as, for example, RAM, memory chips, device or integrated circuits or on an optically or magnetically readable medium such as, for example, a CD, DVD, magnetic disk or magnetic tape. It will be appreciated that the storage devices and storage media are embodiments of machine-readable storage that are suitable for storing a program or programs that, when executed, implement embodiments of the present invention. Accordingly, embodiments provide a program comprising code for implementing a system or method as claimed in any preceding claim and a machine readable storage storing such a program. Still further, embodiments of the present invention may be conveyed electronically via any medium such as a communication signal carried over a wired or wireless connection and embodiments suitably encompass the same.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of any foregoing embodiments. The invention extends to any novel one, or any novel combination, of the features disclosed in this
specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed. The claims should not be construed to cover merely the foregoing embodiments, but also any embodiments which fall within the scope of the claims.
CLAIMS

1. A control system for a host vehicle operable in an autonomous mode, the control
system comprising one or more controllers, the control system configured to:

   receive:

   a first request signal indicative of a request for the host vehicle to
navigate autonomously to a primary navigation goal in an autonomous mode;
   a first availability signal indicative of an availability of the primary
navigation goal for the host vehicle; and

   a second availability signal indicative of an availability of a secondary
navigation goal for the host vehicle,

   wherein the one or more controllers:

   subsequent to receipt of the first request signal and the first availability
signal, output a first notification signal to notify a user of the host vehicle of an
unavailability of the primary navigation goal; and

   subsequent to receipt of the second availability signal, output a second
notification signal to notify the user of the availability of the secondary
navigation goal for the host vehicle,

   wherein the control system is configured to cause the host vehicle to
subsequently navigate to the secondary navigation goal instead of the primary
navigation goal in the autonomous mode.

2. The control system of claim 1 wherein the one or more controllers collectively
comprise:

   at least one electronic processor having an electrical input for receiving the first
request signal, the first availability signal and the second availability signal; and

   at least one electronic memory device electrically coupled to the at least one
electronic processor and having instructions stored therein;

   and wherein the at least one electronic processor is configured to access the
at least one memory device and execute the instructions thereon so as to cause the
host vehicle to subsequently navigate to the secondary navigation goal instead of the
primary navigation goal in the autonomous mode.

3. The control system of claim 1 or claim 2, wherein the one or more controllers determine
a location of first divergence between:

   a first navigable area between a start location of the host vehicle and the
primary navigation goal; and
a second navigable area between the start location and the secondary navigation goal; and wherein the one or more controllers output the second notification signal in dependence on the location of first divergence.

4. The control system of claim 3, wherein the location of first divergence is determined as a centre location in the first navigable area in a direction of travel of the host vehicle from the start location to the primary navigation goal at which a distance from the centre location to a centre location in the second navigable area in a direction of travel of the host vehicle from the start location to the secondary navigation goal first exceeds a predetermined divergence threshold.

5. The control system of claim 4, wherein the predetermined divergence threshold is substantially a first distance from the centre point of the first navigable area at the location of first divergence to a lateral edge of the first navigable area closest the second navigable area plus a second distance from the centre point of the second navigable area at the location of first divergence to a lateral edge of the second navigable area closest the first navigable area.

6. The control system of claim 4 or claim 5, wherein the predetermined divergence threshold is less than 10 metres.

7. The control system of any of claims 3 to 6, wherein the first availability signal is indicative of an impassable location in the first navigable area, and wherein the second availability signal is indicative of the second navigable area, and wherein the one or more controllers output the second notification signal in dependence on the impassable location in the first navigable area being prior to the location of first divergence in a direction of travel of the host vehicle from the start location to the first navigation goal.

8. The control system of any of claims 3 to 7, wherein the one or more controllers determine a third navigable area between a current location of the host vehicle and the secondary navigation goal via the location of first divergence, and output the second notification signal in dependence thereon.

9. The control system of claim 8, wherein the current location of the host vehicle is diverged from the second navigable area.
10. The control system of any preceding claim, wherein the control system is configured to receive a second request signal indicative of a request for the host vehicle to navigate autonomously to the secondary navigation goal in the autonomous mode, wherein the one or more controllers, subsequent to receipt of the second request signal, output an alternative navigation signal to cause the host vehicle to navigate autonomously to the secondary navigation goal in the autonomous mode.

11. The control system of claim 10 when dependent on claim 8, wherein the alternative navigation signal is to cause the host vehicle to navigate autonomously to the secondary navigation goal via the third navigable area.

12. The control system of any preceding claim, wherein the one or more controllers, subsequent to receipt of the first request signal, output a first navigation signal to cause the host vehicle to navigate autonomously towards the primary navigation goal in the autonomous mode, and to output the first notification signal thereafter.

13. A system, comprising:
   the control system of any preceding claim, including at least a first controller, wherein the at least one controller is arranged to output the first notification signal and the second notification signal;
   notification means configured to receive the first notification signal and to output a first user notification that a primary navigation goal is unavailable in dependence thereon, and receive the second notification signal and to output a second user notification that a secondary navigation goal is available in dependence thereon.

14. The system of claim 13, wherein the notification means comprises a display means to display the first user notification and the second user notification.

15. The system of claim 13 or claim 14, comprising an input apparatus to receive the request for the host vehicle to navigate autonomously to the primary navigation goal and to output the first request signal to the control system in dependence thereon.

16. A method for controlling a vehicle operable in an autonomous mode and a non-autonomous mode, the method comprising:
   receiving a request for the vehicle to navigate autonomously to a primary navigation goal in an autonomous mode;
   receiving an availability of the primary navigation goal for the vehicle,
subsequent to receipt of the request and the availability of the primary navigation goal, notifying a user of the vehicle of an unavailability of the primary navigation goal;

receiving an availability of a secondary navigation goal for the vehicle;

subsequent to receipt of the availability of the secondary navigation goal, notifying the user of the availability of the secondary navigation goal; and

autonomously controlling the vehicle to navigate to the secondary navigation goal instead of the primary navigation goal in the autonomous mode.

17. A vehicle comprising the control system of any of claims 1 to 12 or the system of any of claims 13 to 15.

18. Computer software which, when executed, is arranged to perform a method according to claim 16.

19. A non-transitory, computer-readable storage medium storing instructions thereon that when executed by one or more processors causes the one or more processors to carry out the method of claim 16.
### Application No: GB1813055.9
### Examiner: Mr Mike Leaning
### Claims searched: 1-19
### Date of search: 10 February 2019

#### Patents Act 1977: Search Report under Section 17

#### Documents considered to be relevant:

<table>
<thead>
<tr>
<th>Category</th>
<th>Relevant to claims</th>
<th>Identity of document and passage or figure of particular relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1, 2, 10 and 13-19.</td>
<td>US2016/223347 A1 (RICCI et al.) Please see especially paragraphs 0566 and 0038.</td>
</tr>
<tr>
<td>X</td>
<td>1, 2 and 13-19.</td>
<td>US2017/003687 A1 (KOJO et al.) Please see the whole document, especially paragraphs 0080 and 0056.</td>
</tr>
</tbody>
</table>

#### Categories:

<table>
<thead>
<tr>
<th>X</th>
<th>Document indicating lack of novelty or inventive step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>Document indicating lack of inventive step if combined with one or more other documents of same category</td>
</tr>
<tr>
<td>&amp;</td>
<td>Member of the same patent family</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A</th>
<th>Document indicating technological background and/or state of the art.</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>Document published on or after the declared priority date but before the filing date of this invention.</td>
</tr>
<tr>
<td>E</td>
<td>Patent document published on or after, but with priority date earlier than, the filing date of this application.</td>
</tr>
</tbody>
</table>

#### Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC²:

- Worldwide search of patent documents classified in the following areas of the IPC
- G01C; G05D

The following online and other databases have been used in the preparation of this search report

- EPODOC, WPI

#### International Classification:

<table>
<thead>
<tr>
<th>Subclass</th>
<th>Subgroup</th>
<th>Valid From</th>
</tr>
</thead>
<tbody>
<tr>
<td>G05D</td>
<td>0001/00</td>
<td>01/01/2006</td>
</tr>
<tr>
<td>G01C</td>
<td>0021/34</td>
<td>01/01/2006</td>
</tr>
<tr>
<td>G01C</td>
<td>0021/34</td>
<td>01/01/2006</td>
</tr>
<tr>
<td>G05D</td>
<td>0001/02</td>
<td>01/01/2006</td>
</tr>
</tbody>
</table>