(12) **Oversettelse av endret europeisk patentskrift**
Etter innsigelse

(11) **NO/EP 3273201 B2**

NORGE

(19) NO
(51) Int Cl.
G01C 21/00 (2006.01)
G01C 21/20 (2006.01)

Patentstyret

(45)	Oversettelse publisert	2021.10.04
(80)	Dato for Den Europeiske Patentmyndighets publisering av det meddelte patentet	2021.06.30
(45)	Avgjørelse innsigelse i EPO	2024.09.04
	Avgjørelse innsigelse i Norge	2024.12.16
(86)	Europeisk søknadsnr	17182421.2
(86)	Europeisk innleveringsdag	2017.07.20
(87)	Den europeiske søknadens Publiseringsdato	2018.01.24
(30)	Prioritet	2016.07.21, FR, 1656955
(84)	Utpekte stater	AL; AT; BE; BG; CH; CY; CZ; DE; DK; EE; ES; FI; FR; GB; GR; HR; HU; IE; IS; IT; LI; LT; LU; LV; MC; MK; MT; NL; NO; PL; PT; RO; RS; SE; SI; SK; SM; TR
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(54) Benevnelse **METHOD OF CALCULATING AN ITINERARY FOR AN OFF-ROAD VEHICLE**

(56) Anførte publikasjoner

US-A1- 2005 267 681, WO-A2-2013/075072, US-A1- 2015 158 513, WO-A1-2012/004553, GB-A- 2 334 102, EP-A2- 1 806 562, CN-A- 105 512 628, DE-A1- 102011 078 292, FR-A3- 2 986 647, US-A1- 2006 074 557, US-B2- 7 581 452, EP-A1- 0 908 087, WO-A1-2015/142166, DE-A1- 102005 024 868, DE-B3- 102013 019 098, US-A1- 2004 167 682, US-A1- 2016 176 523, EP-A1- 1 645 888, WO-A1-2015/180180, DE-A1- 102010 038 661, DE-B4- 102010 038 661, US-A1- 2005 195 096, US-B2- 6 487 500, EP-A1- 0 838 797, WO-A1-2012/051665, DE-A1- 10 226 084, DE-A1- 19 956 108, JP-B2- S5 819 555, US-A1- 2016 157 414, WO-A1-03/038730, DE-A1- 10 062 856, DE-A1- 102011 106 170, GB-A- 2 533 140, US-A1- 2014 257 621, US-B2- 8 108 142, WO-A1-2007/141795, DE-A1- 10 200 759, DE-A1- 102014 226 458, JP-A- 2010 250 478, US-A1- 2016 016 663, WO-A1-2005/114110, DE-A1- 10 122 808, DE-A1- 102014 205 040, JP-A- 2006 180 326,
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METHOD OF CALCULATING AN ITINERARY FOR AN OFF-ROAD VEHICLE

The invention relates to a method of calculating an itinerary for an off-road vehicle.

In a known manner, certain improved software programs make it possible to establish an itinerary between a departure point and an arrival point from cartographical data, in particular from satellite images. The software begins by establishing a geo-fence, extending between the departure point and the arrival point. This zone defines all of the possible itineraries to go from the departure point to the arrival point. The zones that are difficult, or even impossible to cross, such as zones including reliefs, dense vegetation, or zones traversed by rivers, are excluded from the geo-fence. Once the geo-fence is established, the software calculates an itinerary to be followed by the vehicle. This itinerary is calculated to facilitate the passage of the vehicle as much as possible. However, this itinerary is not necessarily the shortest or the fastest.

The satellite images are updated at an average frequency of roughly several days. Thus, the maps established from satellite images do not make it possible to identify any obstacles formed several hours before the passage of the vehicle, such as landslides on the route or flooding by a body of water, or to account for certain significant weather events, such as snowfall. Furthermore, the precision of the maps does not make it possible to identify obstacles such as a fallen tree on the route. Lastly, the satellite images do not allow a precise determination of the load carrying or tire grip capacities. Oftentimes, these capacities are estimated from the rainfall indications in the affected zone.

This lack of precision of the cartographical data may result in the vehicle finding itself stuck in the face of an obstacle not taken into account when establishing the itinerary. The vehicle must then maneuver, and sometimes turn around, to bypass this obstacle. However, this type of maneuver may prove delicate for certain types of vehicles, depending on their maneuverability. The maneuver is even more complicated when the itinerary is followed by a convoy of vehicles.

To offset these drawbacks, one solution consists of equipping the vehicle with presence sensors to detect obstacles. However, the range of these sensors is often limited by the natural masks formed by the terrain (reliefs), which does not allow sufficient anticipation of the obstacle. The obstacle is then detected at the last moment. The aforementioned turnaround maneuvers then cannot be avoided.

Another solution consists of the *in situ* performance of prior observations relative to the topography of the terrain (presence of a waterway, a ravine, etc.), as well as penetrometric tests on all of the terrain traversed by the itinerary. However, this requires mobilizing many operators, which is time-consuming, costly and unsuitable for risky zones.

The use of a reconnaissance vehicle is known in itself, in particular from document CN-A-105,282,517, in which a drone is used to assist firefighters in a fire zone. The drone is equipped with means making it possible to monitor the spread of the fire, which makes it possible to prevent the firefighters from finding themselves encircled by flames. Additionally, US-A-2014 263 822 discloses the use of a drone for agriculture. This drone is equipped with measuring means with which it is possible to estimate the water content of farmland. The drone thus makes it possible to identify the wettest zones, and the driest zones needing more irrigation.

However, neither of these two documents discloses the use of a drone to facilitate the passage of an off-road vehicle.

The scientific publication by Redouane Boumghar et al, titled: "An information-Driven Navigation Strategy for Autonomous Navigation in Unknown Environments", Proceedings of the 2011 IEEE International Symposium on Safety, Security and Rescue Robotics, Kyoto, Japan, proposes a method in which a drone is used for advanced terrain reconnaissance with respect to an autonomous vehicle. In this document, the drone is equipped with onboard measuring means allowing it to detect the presence of an obstacle on the vehicle's path. If applicable, a new path is calculated to avoid the obstacle.

The method described in this document does not account for the nature of the obstacle. Thus, the path is modified even if the vehicle was *a priori* capable of getting past the obstacle, which potentially creates lost time and increased travel time.

The invention more particularly aims to resolve these drawbacks by proposing a new method for calculating an itinerary for an off-road vehicle, making it possible to modify the itinerary more intelligently based on the nature of the obstacle(s) detected on the vehicle's path, and therefore not to increase the travel time needlessly.

To that end, the invention relates to a method according to claim 1.

Owing to the invention, the reconnaissance vehicle that precedes the off-road vehicle may detect the presence of an obstacle on the itinerary of the off-road vehicle that had not been identified by establishing the itinerary from cartographical data or that was too small to be visible from satellite images. Furthermore, the sensors on board the reconnaissance vehicle make it possible to determine the properties of the terrain (load carrying capacity, tire grip, etc.) adopted by the itinerary more precisely. It is then possible to anticipate crossing difficulties for the vehicle in certain locations of the itinerary. This is for example the case when the vehicle is heavy and the ground is unstable, or when the chassis-ground connection of the vehicle is not suitable for slippery ground, such as snowy ground. To that end, the itinerary of the vehicle to reach the arrival point is modified. This procedure for updating the itinerary can be reiterated as many times as necessary based on the number of obstacles identified by the reconnaissance vehicle.

According to advantageous, but optional aspects of the invention, the itinerary calculating method may include one or more of the following features, considered in any technically allowable combination:

- During step c), the computer is used to determine whether the vehicle has sufficient crossing capabilities to follow the itinerary with a crossing speed greater than or equal to a threshold speed value or with different crossing speeds greater than or equal to at least one threshold speed value (the computer defines the setpoint crossing speeds) and, if not, to establish a new itinerary to the arrival point from the cartographical data and/or the values of parameters relative to the trafficability of the terrain.
- During step a), the cartographical data and/or at least one known itinerary outline are used to determine different passage speeds of the vehicle along the entire itinerary.
- Several threshold speed values are determined along the itinerary, and each threshold speed value is substantially equal to a passage speed determined in step a).
- During step c), the computer is used to determine whether the vehicle has sufficient crossing capabilities to follow the itinerary with crossing speeds greater than or equal to different passage speeds of the vehicle determined from cartographical data and/or at least one known itinerary outline.
- The off-road vehicle is also equipped with onboard measuring means, used to compare the values of parameters relative to the trafficability of the terrain with the actual trafficability of the terrain.
- During step c), the values of parameters relative to the trafficability of the terrain are weighted with the correction coefficient, calculated to refine the difference between the values of parameters relative to the trafficability of the terrain and other values of parameters relative to the trafficability of the terrain calculated from measurements done by the measuring means on board the off-road vehicle.
- The correction coefficient is calculated from data extracted from at least one or several tens of journeys in order to correct the measurements of the reconnaissance vehicle owing to feedback from previous journeys.
- The unmanned reconnaissance vehicle is a drone.

- The computer is not on board the off-road vehicle and sends the new itinerary to a GPS (Global Positioning System) on board the vehicle.
- The off-road vehicle moves autonomously.
- In step a), the itinerary is established from cartographical data and/or at least one known itinerary outline.
- In step a), the itinerary is established from waypoints defined by a user.
- The itinerary established in step a) is a straight line connecting the departure point and the arrival point.
- The values of the parameters relative to the trafficability of the terrain include morphological characteristics of the terrain, for example the clay content, water content or soil composition, and/or geometric characteristics of the terrain, for example reliefs, obstacles, or particle size distribution, and/or mechanical properties of the terrain, for example the load-bearing capacity or grip.
- The reconnaissance vehicle is equipped with on board measuring means, which comprise at least the following three elements: a hyperspectral camera to determine the type of vegetation on the ground, a Lidar to detect reliefs, and a geo-radar to assess the compactness of the soil and the cone index (CI).

The invention and other advantages thereof will appear more clearly in light of the following description of one embodiment of a method for calculating an itinerary according to its principle, provided solely as an example and done in reference to the appended figures, in which:

- Figure 1 is a diagram showing the initial itinerary of an off-road vehicle E and the actual trajectory of the vehicle E as a function of the obstacle(s) O detected by a reconnaissance vehicle D preceding the off-road vehicle E over the entire itinerary, and
- Figure 2 is a diagram showing the different steps of the method for calculating an itinerary according to the invention.

The off-road vehicle E is capable of moving over all types of terrain (road, track, mud, sand, snow, etc.). This may involve a motorized land vehicle (MLV) such as a firefighting vehicle, an emergency vehicle (firefighters), a military vehicle, a construction vehicle or a heavy truck. It may also involve an aircraft during the taxi, takeoff and landing phases.

The vehicle E may be autonomous. In this case, the vehicle E moves automatically without human intervention. Alternatively, the vehicle can be driven by an on board driver or controlled remotely. In the case of a vehicle with a driver, the itinerary is then simply a recommended itinerary for the driver to reach the arrival point.

The invention also applies to a vehicle belonging to a convoy of off-road vehicles, in particular the first vehicle in the convoy, each of the other vehicles following the vehicle in front of it.

The inventive method of calculating an itinerary for an off-road vehicle comprises a first step consisting of establishing an itinerary I1 to be followed by the vehicle E to go from a departure point A to an arrival point B.

The software begins, during a step 100, by determining a geo-fence, which encompasses all possible trajectories that the vehicle E may follow to go from point A to point B without difficulty. The trajectories outside this zone G are therefore trajectories that cannot be followed by the vehicle E, at least not within a reasonable amount of time.

Once the geo-fence G is established, the software calculates the itinerary I1 during a step 102 based on the type of vehicle and the desired performance criteria. For example, the selected itinerary I1 may be the itinerary with the lowest crossing risk, which has the advantage of limiting breakage risks. The selected itinerary I1 may also be the itinerary with the shortest travel time, which is particularly suitable for fire-fighting vehicles or emergency vehicles (firefighters). It is also possible to consider calculating an itinerary I1 with fewer stresses or bumps, in particular for vehicles carrying sensitive products or equipment.

The itinerary I1 is established by dedicated software implemented in a computer, not shown. The computer may or may not be on board the vehicle E. If the computer is not on board the vehicle E, the computer may be shared by several vehicles and sends the itinerary to be followed to each vehicle's GPS system, for example wirelessly.

The itinerary I1 is shown by the curve in dashed lines in figure 1.

The itinerary I1 may also be produced by determining waypoints.

The itinerary is essentially established from cartographical data. This is called a level 1 terrain analysis. This cartographical data makes it possible to identify, *inter alia*, the trunk roads, man-made constructions, reliefs, vegetation and waterways. It in particular includes:

- satellite images of the QUICKBIRD, LANDSAT or MODIS (moderate-resolution imaging spectroradiometer) type,
- pre-established maps, and
- images taken by airplanes or high-altitude drones.

Alternatively, the itinerary I1 may be established from a moving geolocation beacon carried by another vehicle or by a person. This is in particular the case when it is necessary to guide a vehicle over a journey that has already been performed in the past, i.e., a prior reading over the same zone is used. The vehicle can then follow the same itinerary as a previous vehicle to go from a same departure point A to a same arrival point B. The data provided by one or several geolocation beacons and the cartographical data may also be used in a complementary manner.

Advantageously, the computer also establishes passage speeds in each zone traversed by the itinerary. When the vehicle is driven by a driver, these passage speeds are simply recommended speeds. Conversely, in the case of an autonomous vehicle, the speed of the vehicle is adjusted automatically based on the terrain traveled throughout the entire itinerary. For instance, the vehicle will not go as fast on a snow-covered forest path as on a trunk road, for example. In the example, the different passage speeds of the vehicle E over the entire itinerary I1 are determined from cartographical data and/or at least one known itinerary outline.

Other adjustments can be made automatically to the vehicle based on terrain conditions. These may in particular involve:

- the gear ratio of the gearbox,
- the gear ratio of the transfer gearbox,
- selective blocking of the differentials of the front and/or rear axle (jaw clutching of the axles),
- tire pressure (via a remote inflation system of the "Central Tire Inflation System" (CTIS) type), etc.

Throughout the entire journey between point A and point B, the vehicle E is preceded by an unmanned reconnaissance vehicle of the autonomous type or the remotely controlled type. If the reconnaissance vehicle is of the autonomous type, it moves automatically without human intervention. In the example, the reconnaissance vehicle is a drone D, but it is possible to consider, alternatively, a reconnaissance vehicle in the form of a motorized land vehicle. In the latter case, the reconnaissance vehicle then has a high crossing capacity, i.e., it can cross any type of soil (unstable, snowy, muddy, etc.) without difficulties, compared to the vehicle E. However, this land reconnaissance vehicle may be provided to be very light.

The advantage of using a reconnaissance vehicle such as a drone is that, unlike a land vehicle, the range of the onboard measuring means on the drone is limited little or not at all by the reliefs of the terrain (natural masks).

The distance d that separates the reconnaissance vehicle D and the vehicle E may be configured: it depends on the speed of advance of the vehicle and the itinerary calculation time. Preferably, it is at least 150 m, which corresponds to a lag time for the vehicle of at least 18 seconds, considering that the latter is moving at less than 60 km/h.

In the example, it is 300 m, which corresponds to a lag time for the vehicle of 36 s, considering that the latter is moving at 30 km/h.

The reconnaissance vehicle D is provided with a GPS (Global Positioning System) beacon and means for communicating with the vehicle E.

The reconnaissance vehicle D is equipped with on board measuring means, which comprise at least the following three elements:

- a hyperspectral camera,
- a Lidar, and
- a geo-radar.

The hyperspectral camera is used to determine the type of vegetation on the ground, the Lidar (laser radar) is used to detect reliefs, and the geo-radar is used to assess the compactness of the soil and the cone index.

Advantageously, the measuring means further comprise at least one of the following elements:

- a radar,
- a video camera,
- a stereo camera,
- an inertial unit,
- a thermal imaging camera, with which it is possible to evaluate the temperature on the ground and identify snowy or icy zones.

The range of these onboard measuring means combined with the zone coverage capacity of the reconnaissance vehicle make it possible to read data in a cone oriented with an angle of about 45° relative to the vertical and which have a height of about 600 m and a base about 1200 m wide. However, the measuring range may be different based on the type of material used. Likewise, the precision of the measuring means may be adapted as needed.

Advantageously, the reconnaissance vehicle D moves such that its measuring cone remains focused on the trajectory to be followed by the vehicle E, i.e., the reconnaissance vehicle moves such that the axis of its measuring cone remains substantially tangent to the anticipated trajectory.

The data M collected, during a step 200, by the measuring means on board the reconnaissance vehicle D is sent to the computer in real-time, i.e., dynamically. The computer then calculates, during a step 202, values of parameters P relative to the trafficability of the terrain from measurements M done by the reconnaissance vehicle D.

The values of the parameters P relative to the trafficability of the terrain relate to the itinerary portion extending over about 600 m situated about 300 m in front of the vehicle E. These parameter P values include morphological characteristics of the terrain (clay content, water content, soil composition, et.) and/or geometric characteristics of the terrain (relief, obstacles, particle size distribution, etc.) and/or mechanical properties of the terrain (load-bearing capacity, grip, etc.). In particular, the data M collected by the reconnaissance vehicle makes it possible to detect the presence of an obstacle O on the itinerary portion I1, this obstacle not being visible from satellite images. This is called Dynamic Digital Terrain Model (D-DTM), corresponding to a level 2 terrain analysis (precise local trafficability map). Furthermore, if the terrain is a road, the computer is capable of estimating the condition of the surfacing from values read by the reconnaissance vehicle D.

Preferably, the dynamic digital terrain model (D-DTM) makes it possible to establish a dynamic itinerary geo-fence.

In the example, the computer comprises a memory in which at least one parameter is stored representative of the crossing capacities C of the off-road vehicle E following the itinerary. In particular, at least one of the following parameters is stored in the memory of the computer:

- the type of vehicle (transport truck, aircraft, military vehicle, etc.),
- the mass factor,
- the wheel load factor,
- the “clamp” factor,
- the ground clearance factor,
- the motorization factor,
- the traction factor,
- the transmission factor,
- the total laden weight,
- the axle load,
- the number of axles,
- the minimum clearance,
- the number of tires per axle,
- the outer diameter of the tire, inflated, without load,
- the width of the tire, inflated, without load,
- the height of the cross-section of the tire, inflated, without load,
- the Deflection Correction factor,
- the deflection of the tire on a hard surface,

- the Mobility index,
- the Ground Clearance factor,
- the Context Pressure factor,
- the Vehicle Cone Index - one passage,
- the Vehicle Cone Index - 50 passages,
- the Mean Maximum pressure by Maclaurin,
- the Mean Maximum pressure by Rowland,
- the type of driveability (wheels, tracks) and the number of driving wheels if applicable (4 x 4, 6 x 8, etc.),
- the dimensions of the engine (length, width, height, ground clearance, etc.),
- the wheel torque as a function of speed,
- the wheelbase,
- the gauges,
- the approach angle, the angle of departure, the ramp angle,
- the step crossing height,
- the narrow wall crossing height,
- the maximum ford depth,
- the banking capability,
- the suspension characteristics,
- the axle system guiding characteristics.

Next, the computer compares the parameter P values relative to the trafficability of the terrain with the crossing capacities C of the vehicle E and determines, during a step 204, whether the off-road vehicle E is capable of following the itinerary I1, which is required for an autonomous vehicle, but only recommended for a vehicle with a driver. This comparison is done by a computer program pre-saved in the computer. This computer program has, as input parameters, the parameter P values relative to the trafficability of the terrain and the crossing capacities C of the vehicle and makes it possible to obtain, as output, indicators relative to the capacity of the vehicle to follow the itinerary. More specifically, the computer program is designed particularly to verify whether:

- the carrying capacity is sufficient compared to the weight of the vehicle,
- the geometry of the reliefs (slope, ditches, obstacles, etc.) is compatible with the ground clearance of the vehicle, the approach angle, the angle of departure, the banking capability, etc.,
- the depth of a waterway is smaller than the maximum ford depth,
- the tractive strength of the engine is great enough to climb the various hills,

- the soil is adherent enough compared to the type of drivability, etc.

Cleverly, if the vehicle is capable of following the itinerary I1, i.e., if there is no blocking obstacle to be bypassed, the computer calculates the likely mean speed V of the vehicle E over the itinerary portion extending within the range of the reconnaissance vehicle D. This itinerary portion extends approximately, in the example, over 600 m from the position of the reconnaissance vehicle. The computer then compares, during a step 208, the likely mean speed V of the vehicle E with a speed threshold value S. If this speed V is greater than or equal to the threshold speed value S, then the itinerary is not modified (I=I1), as shown by step 210 in figure 2. The algorithm is next reiterated.

Advantageously, the threshold speed value S can be chosen between 5 and 20 km/h, for example about 10 km/h.

Alternatively, the threshold speed value S can be chosen equal or substantially equal to the estimated original speed, i.e., the speed calculated from the level 1 terrain analysis for the itinerary portion in question. The expression "substantially" means that an allowance may be used. For example, the threshold speed value S can be chosen to be 10% lower than the passage speed calculated from the level 1 terrain analysis. It is accepted for the vehicle E to travel at a speed slightly slower than what was provided when calculating the itinerary.

Conversely, if the likely mean speed V of the vehicle E over the itinerary portion in question is below the threshold speed value S, then it is estimated that the terrain traversed by the itinerary I1 is in too poor condition and that following this itinerary I1 would excessively extend the travel time. A new itinerary I2 is then calculated (I=I2), during a step 206, up to the arrival point. The threshold speed value S can be calculated at the origin using the level 1 terrain analysis.

Alternatively, the computer can then be used to determine whether the vehicle has sufficient crossing capabilities to follow the itinerary with different crossing speeds greater than or equal to at least one threshold speed value (the computer defines the setpoint crossing speeds) and, if not, to establish a new itinerary I2 to the arrival point from the cartographical data and/or the values of parameters P relative to the trafficability of the terrain.

Thus, several threshold speed values S are determined along the entire itinerary I1. Each threshold speed value is substantially equal to a passage speed determined from cartographical data and/or at least one known itinerary outline.

This means that the computer is used to determine whether the vehicle E has sufficient crossing capabilities to follow the itinerary I1 with at least one crossing speed V greater than or equal to at least one threshold speed value S and, if not, to establish (step

206) a new itinerary I2 to the arrival point B from cartographical data and/or the values of parameters P relative to the trafficability of the terrain.

Like the initial itinerary I1, the new itinerary I2 is calculated from cartographical data (level 1) and, optionally, from parameter P values relative to the trafficability of the terrain (level 2) calculated using measurements from the reconnaissance vehicle D. In fact, the reconnaissance vehicle D can be commanded to explore a zone not traversed by the initial itinerary.

The new itinerary I2 is sent by the computer to the GPS (Global Positioning System) of the vehicle. In the example shown in figure 1, the vehicle encounters only one obstacle O, and the itinerary is therefore recalculated only once. However, in practice, the itinerary is recalculated as many times as an obstacle that is impossible or difficult to cross is detected on the itinerary of the vehicle E. Owing to this method, any obstacle O present on the path of the vehicle E can be anticipated and easily bypassed (without maneuver) by updating the itinerary.

Advantageously, the vehicle E is also equipped with onboard measuring means. These measuring means can comprise at least one of the following elements:

- a thermal camera,
- a multispectral camera,
- a laser radar (Lidar), suitable for emitting a laser beam,
- a radar, suitable for emitting electromagnetic waves,
- a standard camera.

The measuring means on board the vehicle E can be used to compare the values of parameters relative to the trafficability of the terrain, established owing to the drone D, with the actual trafficability of the terrain. For example, the camera on board the vehicle E can be arranged to estimate the sinking of the vehicle E into the ground from tire or track marks, which makes it possible to calculate the carrying capacity of the ground based on the weight of the vehicle. It is then possible to calculate a correction coefficient to be applied to the data read by the reconnaissance vehicle D to refine the Dynamic Digital Terrain Model (D-DTM) established owing to the reconnaissance vehicle. This correction coefficient is calculated from data extracted from at least one or several tens of journeys, or even several hundred journeys. The correction coefficient serves to correct the measurements of the reconnaissance vehicle owing to feedback from one or several previous journeys. This in particular makes it possible to establish a learning database over the course of multiple missions, typically military missions. In practice, this data is used as input parameters in very specific algorithms, which can be qualified as "machine learning" algorithms, which make it possible to optimize the measurement of the parameters P relative to the trafficability.

Thus, the values of parameters relative to the trafficability of the terrain are corrected and made closer to reality.

The measuring means on board the vehicle can also be used to detect an obstacle in the immediate vicinity of the vehicle E. In particular, such measuring means can be used in the case where the data read by the drone D, such as the data relative to the characteristics of the terrain (compactness, load bearing, adhesion, etc.) are not sufficiently reliable, for example due to terrain with a very complex nature or the presence of dense vegetation (forest). This is called a level 3 terrain analysis. The level 3 terrain analysis can also be used to bypass a new unforeseen obstacle, such as a fallen tree on the path, not detected by the reconnaissance vehicle D, without necessarily changing itinerary, or to bypass or cross an obstacle already detected by the reconnaissance vehicle D but whose position must be more specifically determined to allow it to be bypassed or crossed. This involves a very localized taking into account of the terrain in front of or around the vehicle E.

As an alternative that is not shown, the geo-fence G and the original itinerary I1 are also calculated, in addition to cartographical data, based on tactical data. This tactical data in particular includes indicators relative to:

- the position of allied bases/troops and the position of enemy bases/troops,
- the penetration axes,
- friendly fire, if applicable, and
- the contact lines.

The technical data is taken from a battle management system (BMS). The technical data can be considered crucial to calculate the itinerary. The itinerary then corresponds to an itinerary with a lower tactical risk, i.e., an itinerary where the vehicle is least exposed to enemy/allied shots, minefields, or ambushes.

According to another alternative, each of the crossing parameters of the vehicle is not stored in memory, but is communicated by the vehicle to a computer outside the vehicle.

According to another alternative that is not shown, the computer is on board the reconnaissance vehicle D.

According to another alternative, the level 3 terrain analysis is also taken into account when calculating each new itinerary.

According to another alternative, the itinerary is modified according to a step 206 only if the reconnaissance vehicle detects a blocking obstacle on the path. In other words, the itinerary is not modified as long as the vehicle E manages to cross, even if to do so, it must adopt a very low speed. This means that step 208 is optional. However, the speed of the vehicle E, if the latter is autonomous, will be adapted based on the level 2 terrain analysis, and in particular decreased automatically to cross an unforeseen obstacle, such as a landslide or a fallen tree on the path.

According to another alternative, the itinerary I1 can be established manually by a user, such as the driver of vehicle E. To that end, the user selects waypoints, i.e., points along the route to be reached to arrive at the arrival point B. The software can then verify whether the itinerary established by the user is among the trajectories included in the geo-fence G calculated in parallel. In the affirmative, the manually established itinerary is maintained. However, if the itinerary established by the user is not fully included in the geo-fence G, a new starting itinerary I1 is then calculated. It should be noted that if it is not possible to establish a geo-fence, i.e., if one does not have cartographical data, or at least cartographical data usable in the relevant zone, the itinerary established manually by the user is automatically maintained.

According to another alternative, if the cartographical data in the zone in question is nonexistent or unusable, the starting itinerary I1 is calculated based on a straight line connecting points A and B. The itinerary may, however, be modified along the way based on measurements done by the reconnaissance vehicle D (level 2 terrain analysis), i.e., values of parameters P relative to the trafficability of the terrain.

The features of the embodiment and alternatives considered above may be combined with one another to create new embodiments of the invention, within the boundaries of the scope defined by the annexed claims.

Patentkrav

1. Fremgangsmåte for beregning av en rute (I1, I2) for en terrengmaskin (E), hvor denne fremgangsmåten omfatter et innledende trinn som består av:

a) å etablere (100, 102) en rute (l1) som skal følges av maskinen (E) for å gå fra et startpunkt (A) til et ankomstpunkt (B),

hvor maskinen (E), langs hele reisen mellom startpunktet og ankomstpunktet, forutgås av et ubemannet rekognoseringskjøretøy (D), som omfatter målemidler ombord,

hvor fremgangsmåten omfatter iterative trinn som utføres langs hele reisen og som består av:

b) å sende målinger (M) tatt av rekognoseringskjøretøyet (D) til en datamaskin,

c) å anvende et datamaskinprogram forhåndslagret i datamaskinen for:

i. å beregne (202) verdier til parametere (P) vedrørende trafikkerbarheten av terrenget ut ifra målinger gjort av rekognoseringskjøretøyet,

hvor datamaskinen omfatter et minne der det er lagret minst én parameter som representerer krysningskapasitetene (C) til terrengmaskinen (E) som følger ruten (I1), karakterisert ved at trinn c) omfatter å anvende dataprogrammet forhåndslagret i datamaskinen for:

ii. å sammenligne (204) verdiene til parametere vedrørende trafikkerbarheten av terrenget med krysningskapasitetene (C) til maskinen (E), og å bestemme (204) om maskinen har tilstrekkelige krysningskapasiteter til å være i stand til å følge ruten (I1), som er obligatorisk en autonom maskin, men kun anbefalt for en maskin med en fører, hvor datamaskinprogrammet har, som input-parametere, verdier til parametere (P) som vedrører trafikkerbarheten av terrenget og krysningskapasitetene (C) til maskinen (E) og som gjør det mulig å oppnå, som output, indikatorer vedrørende maskinens kapasitet til å følge ruten,

iii. hvis maskinen har tilstrekkelige krysningskapasiteter, å beholde (210) den samme ruten (l1), og

iv. hvis maskinens krysningskapasiteter (C) er utilstrekkelige, å etablere (206) en ny rute (l2) til ankomstpunktet (B) ut ifra kartografiske data og/eller verdier til parametere (P) vedrørende trafikkerbarheten av terrenget.

2. Fremgangsmåte ifølge krav 1, **karakterisert ved at**, under trinn c), datamaskinen anvendes for å bestemme om maskinen (E) har tilstrekkelige krysningskapasiteter til å følge ruten (l1) med en krysningshastighet (V) større enn eller lik en terskelhastighetsverdi (S) eller med forskjellige krysningshastigheter (V) større enn eller lik minst én terskelhastighetsverdi (S) og, hvis ikke, å etablere (206) en ny rute til ankomstpunktet ut ifra de kartografiske dataene og/eller verdiene til parametere (P) vedrørende trafikkerbarheten av terrenget.

3. Fremgangsmåte ifølge krav 1 eller 2, **karakterisert ved at**, under trinn a), de kartografiske dataene og/eller minst en kjent rutetrasé anvendes for å bestemme forskjellige passasjehastigheter for maskinen (E) langs hele ruten (l1).

4. Fremgangsmåte ifølge kravene 2 og 3, **karakterisert ved at** flere terskelhastighetsverdier (S) bestemmes langs ruten (l1) og **ved det at** hver terskelhastighetsverdi er hovedsakelig lik en passasjehastighet bestemt i trinn a).

5. Fremgangsmåte ifølge et av de foregående kravene, **karakterisert ved at** terrengmaskinen (E) også er utstyrt med målemidler ombord, som anvendes for å sammenligne verdiene til parametere vedrørende trafikkerbarheten av terrenget med den faktiske trafikkerbarheten av terrenget.

6. Fremgangsmåte ifølge krav 5, **karakterisert ved at**, under trinn c), verdiene til parametere vedrørende trafikkerbarheten av terrenget vektes med en korreksjonskoeffisient, beregnet for å forfine forskjellen mellom verdiene til parametere vedrørende trafikkerbarheten av terrenget og andre verdier til parametere vedrørende trafikkerbarheten av terrenget beregnet ut ifra målinger gjort av målemidlene ombord på terrengmaskinen (E).

7. Fremgangsmåte ifølge krav 6, **karakterisert ved at** korreksjonskoeffisienten beregnes ut ifra data ekstrahert fra minst én eller flere titalls reiser for å korrigere målingene til rekognoseringskjøretøyet (D) takket være tilbakemelding fra tidligere reiser.

8. Fremgangsmåte ifølge et av de foregående kravene, **karakterisert ved at** det ubemannede rekognoseringskjøretøyet er en drone (D).

9. Fremgangsmåte ifølge et av de foregående kravene, **karakterisert ved at** datamaskinen ikke befinner seg om bord på terrengmaskinen (E) og sender den nye ruten (l2) til et GPS-system ombord på maskinen.

10. Fremgangsmåte ifølge et av de foregående kravene, **karakterisert ved at,** i trinn a), ruten (l1) etableres ut ifra kartografiske data og/eller minst en kjent rutetrasé.

11. Fremgangsmåte ifølge et av de foregående kravene, **karakterisert ved at** verdiene til parameterne (P) vedrørende trafikkerbarheten av terrenget inkluderer morfologiske egenskaper til terrenget, for eksempel leireinnholdet, vanninnholdet eller grunnens sammensetning og/eller geometriske egenskaper til terrenget, for eksempel relieffer, hindringer eller partikkelstørrelsesfordeling og/eller mekaniske egenskaper til terrenget, som for eksempel lastbæreevne eller grep.

12. Fremgangsmåte ifølge et av de foregående kravene, **karakterisert ved at** rekognoseringskjøretøyet (D) er utstyrt med målemidler ombord, som omfatter minst de tre følgende elementene:

- et hyper-spektralt kamera for å bestemme typen av vegetasjon på bakken,
- en Lidar for å detektere relieffene, og
- en georadar for å evaluere kompaktheten av bakken og kjegleindeksen (CI).

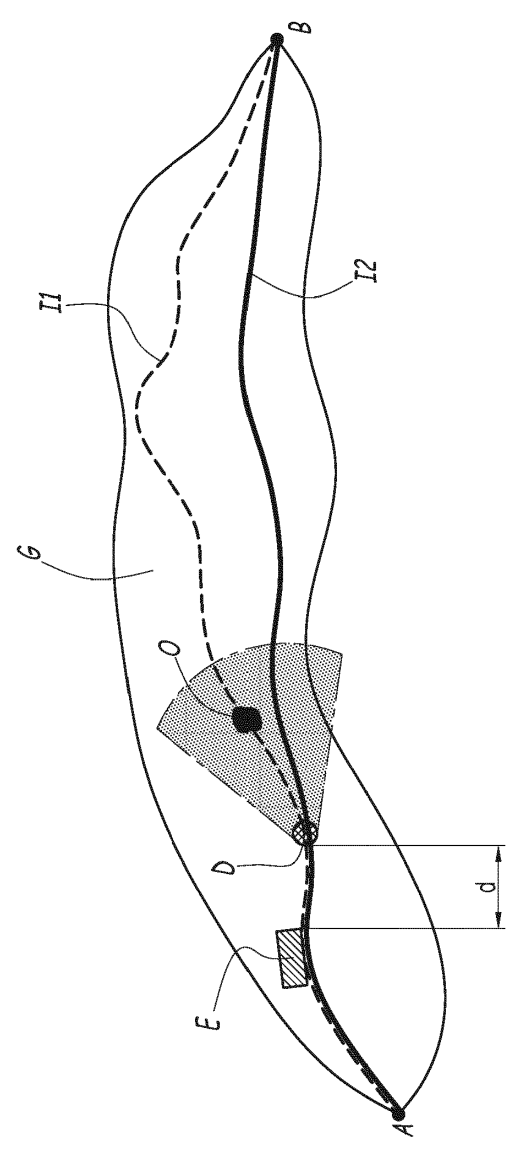

Fig.1

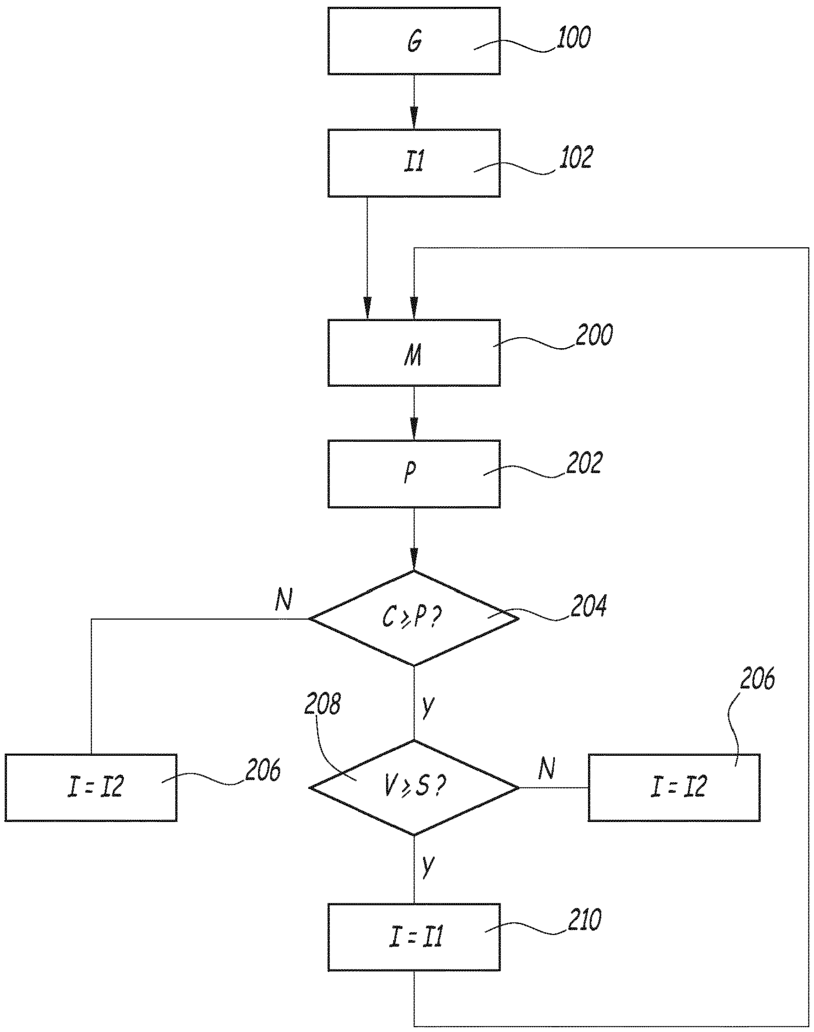

Fig.2