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(54) VEHICLE MANEUVERING AIDS

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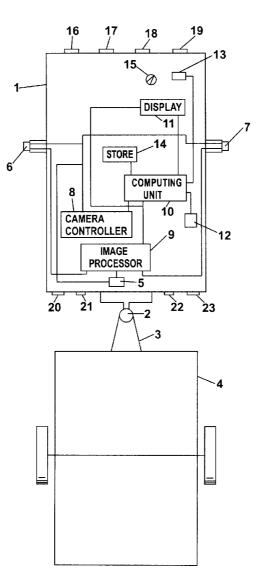
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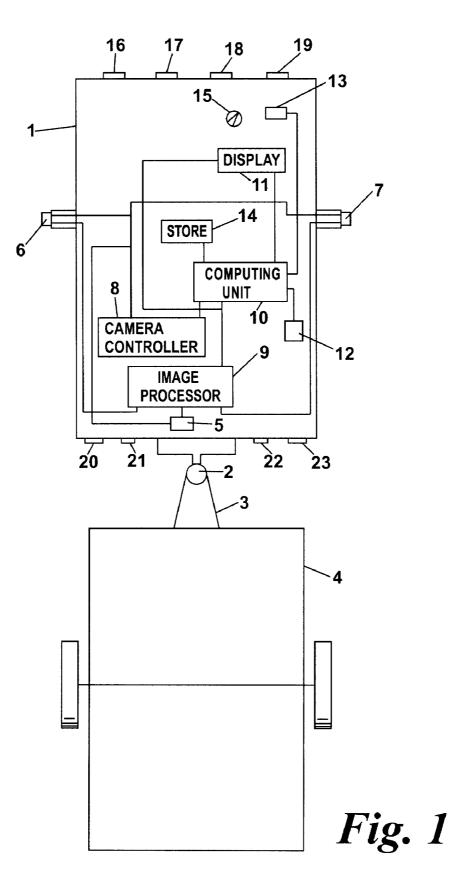
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(57) **ABSTRACT**

A vehicle 1 towing a trailer 4 is fitted with three video cameras 5, 6, 7 fitted to the rear of the vehicle and on each door mirror. A view from any camera can be presented to the driver on a display 11. A predicted trailer path, calculated in a computing unit 10, is also presented to the driver on the display 11 as guide lines overlaid on the camera view. The computing unit 10 is also configured to calculate a hitch angle by tracking the position of a trailer-mounted marker in the camera view.





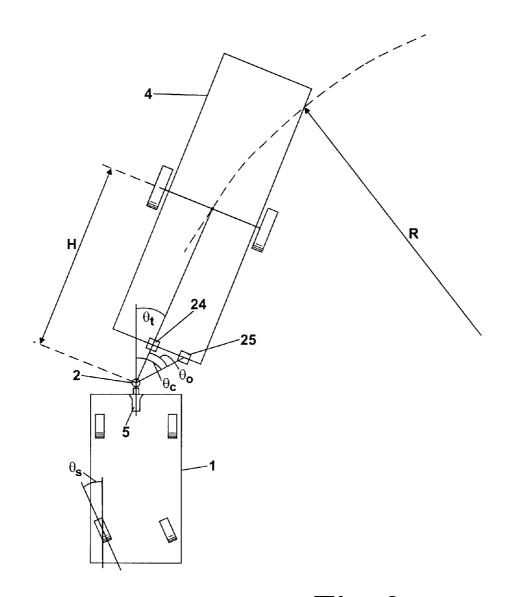
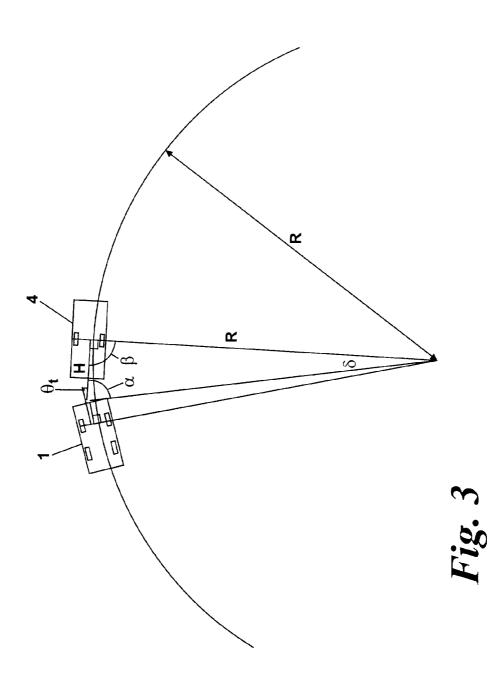


Fig. 2



VEHICLE MANEUVERING AIDS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] None

BACKGROUND OF THE INVENTION

[0002] This invention relates to maneuvering aids for vehicles and particularly for vehicles which are towing a trailer, such as a caravan.

[0003] It is known to equip vehicles with external video cameras for displaying to the driver an image of the surroundings in order to provide assistance with parking and reversing maneuvers. A track for a given steering angle can be superimposed on the displayed image including systems that display the view from a rearward-looking video camera onto a touch screen which is used to input a desired destination, such as a parking bay. Steering cues are also displayed on the screen for assisting the driver in the maneuvering operation.

BRIEF DESCRIPTION OF THE INVENTION

[0004] A first feature provides a method for determining hitch angle in a vertical or horizontal plane between a vehicle and a trailer attached to the vehicle by means of a tow hitch. The method includes the steps of tracking a marker associated with the trailer across a field of view of a rearward-looking video camera and converting a lateral displacement of the marker in the field of view to an angular displacement.

[0005] A second feature provides a means for predicting a path of a trailer and displaying the predicted path to the driver of a vehicle to which the trailer is attached. The path being displayed as an overlay on a view from a vehicle-mounted video camera. One method of predicting the trailer path includes the steps of determining a hitch angle, θ_{α} between the vehicle and trailer, determining a hitch length, H, between an axle of the trailer and a point of attachment of the trailer to the vehicle, calculating a turning radius R where R=H/ θ_{α} , where the trailer is predicted to follow the circumference of a circle of radius R. A view from a video camera mounted on the rear of the vehicle or on a door mirror is utilized.

[0006] A third feature tracks obstacles close to the path of a vehicle using multiple vehicle-mounted video cameras with pan and zoom capability. One method of tracking these obstacles includes the steps of detecting the proximity of an obstacle using a vehicle-mounted proximity sensor, panning a vehicle-mounted video camera towards the location of the obstacle, and displaying a video camera view of the obstacle to a driver of the vehicle. A fourth feature reliably informs the vehicle and driver when a trailer is hitched to the vehicle. This is so that systems concerned with dynamic stability control or active suspension, e.g. can be set to the correct operating conditions. Systems that only monitor the trailer's electrical connection cannot distinguish between a trailer and light bars. A rearward-looking camera may be used to detect the presence of a trailer. One method of detecting the trailer includes the steps of comparing an image from a rearward-looking, vehicle mounted video camera with stored data representing a trailer. A fifth feature provides a method for assisting in hitching a trailer to a vehicle. One method of assisting includes the steps of displaying a view from a rearwardlooking, vehicle-mounted video camera on a screen visible to the driver, identifying a tow hitch in the displayed view, zooming the camera view to display a close-up of the vehicle's tow ball and the trailer's tow hitch and adjusting the camera's zoom facility as the vehicle and trailer move relative to one another to maintain a displayed view of the tow ball and hitch.

[0007] A sixth feature includes using one or more vehiclemounted cameras configured to detect strobed light, such as that emitted by emergency vehicles. A warning message can then be generated for display to the driver of the vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a schematic view of a trailer and vehicle, the latter incorporating apparatus for effecting methods of assisting maneuvers of the trailer-vehicle combination, and **[0009]** FIGS. **2** and **3** are plan views of the vehicle-trailer combination of FIG. **1** showing certain geometrical parameters of the combination.

DETAILED DESCRIPTION OF THE INVENTION

[0010] In FIG. 1 a vehicle 1 is provided with a tow ball 2 to which the hitch 3 of a trailer 4 is attached.

[0011] The vehicle 1 is fitted with three video cameras. A first video camera 5 is mounted on the rear of the vehicle 1 and looks rearwards towards the trailer 4. This rearward-looking camera has a zoom facility. Two door mirror mounted video cameras 6, 7 are also provided. These door mirror mounted cameras 6, 7 may be panned so that they look forwards, rearwards and to a side of the vehicle 1. All three cameras 5, 6, 7 are controlled by a camera controller 8 and the outputs from each camera are fed to an image processor 9.

[0012] Outputs of the image processor 9 are fed to a computing unit 10 and display screen 11 and the camera controller 8. The computing unit 10 generates signals for controlling the camera controller 8 and display screen 11 which is visible to the driver of the vehicle 1. The computing unit 10 receives signals from a speed sensor 12, a steering angle sensor 13 and a vehicle and trailer parameter store 14. A mode selector switch 15 has an output which is connected to the image processor 9.

[0013] Ultrasonic parking distance sensors 16-23 are provided on the front and the rear of the vehicle. Their outputs are connected to the camera controller 8. Four sensors are fitted at each end of the vehicle in order to give good coverage and resolution.

[0014] Operation of a first embodiment, comprising a method of measuring the hitch angle (in a horizontal plane between the vehicle 1 and the trailer 4) will now be described with reference to FIGS. 1 and 2. The method utilizes a tracking marker such as a mark or sticker attached to the trailer or a vertical edge of the trailer which is visible to the rearward-looking video camera 5. The image processor 9 locates this marker within the camera's field of view and feeds this information to the computing unit 10 which calculates the hitch angle.

[0015] In a first example, a high visibility marker 24 is placed on the centre-line of the trailer 4 (see FIG. 2). From knowledge of the trailer and vehicle geometric parameters e.g. tow hitch length (held in the store 14) and the position of the marker within the camera's 5 field of view, the computing unit 10 can calculate the hitch angle θ_r . Placement of the marker on the trailer's centre-line may not always be possible or convenient. So in a second example, a marker 25 is placed offset from the centre-line by an offset angle θ_a . Then, the

hitch angle= $\theta_c - \theta_o$ where θ_c is the target angle which is calculated in the computing unit **10**.

[0016] The offset angle θ_o is derived by the computing unit **10**, in a learning phase, by noting the value of θ_c when the vehicle is traveling in a straight line, i.e. when the steering angle sensor **13** outputs a value of zero for steering angle θ_s . So, when this condition is fulfilled, $\theta_o = \theta_c$, so the offset angle is now known.

[0017] Extending the principle of the above second example, the image processor 9 can pick out its own marker on the trailer 4. This could be a caravan window or an edge of the trailer, for example. The feature selected can be high-lighted on the display screen 11 so that the driver can confirm that it is actually rigidly connected to the trailer. The computing unit 10 is then adapted to compare the movement of this target with steering movements and check for any anomalies. [0018] As a refinement to the hitch angle calculation, some averaging of the measurements is carried out, particularly in the learning phase. This helps to cancel out the errors due to flexing of the trailer structure.

[0019] The learning phase can be eliminated on trailer reuse. The computing unit **10** can store the learned geometry of the trailer so that it can be recalled. Alternatively, the learning phase can be run continually as a check on the stored values with updating as required. This continual check is useful in any case as a compensation for drift due to other variables.

[0020] By comparing the measured hitch angle θ_t with a reference value held in the store **14** for a given trailer length, the computing unit **10** can detect the onset of jack-knifing while reversing. When this occurs, the computing unit **10** generates a warning signal to the driver. This warning can be audible or a visual signal on the display screen **11**.

[0021] In addition to measuring hitch angle, the invention provides a method for measuring the pitch angle (i.e. in a vertical plane), between the vehicle **1** and trailer **4**. Pitch angle is usually zero or close to zero but can deviate from zero when traveling on uneven ground or reversing down a slipway, for example. The same principles apply, with the image processor **9** selecting a mark or horizontal edge of the trailer. By comparing the pitch angle determined by the computing unit **10** with a reference value, the unit **10** can detect imminent grounding of the hitch **3** and signal a warning to the driver.

[0022] A second embodiment of the invention provides a method of predicting a trailer reversing path and displaying it to the driver by means of an overlay on the display.

[0023] Say, for example, the driver needs to reverse the vehicle and trailer combination into a parking bay.

[0024] Knowing the hitch angle θ_r (either from the method of the first embodiment described above or from some other method or sensor output), and the hitch length H (the distance between the trailer's axle and tow hitch, see FIG. 3) the computing unit 10 computes a trailer path.

[0025] The path of the trailer **4** can be described by a turning radius R. In practice R and θ_t vary during the maneuver but for small steering angle movements can be assumed to be constant. With reference to FIG. **3**, it can be seen that the hitch angle θ_t , hitch length H and turning radius R are associated approximately by equation:

 $\alpha + \beta + \delta = \pi$

[0026] Substituting $\beta = \pi/2$ and $\alpha = \pi/2 - \theta_{\star}$

[0027] gives $\theta_t = \delta$

[0028] tan $\delta = H/R = \delta = \theta_t$ for small θ_t

So $R = H/\Theta_t (\Theta_t \text{ in radians})$

Equation (1)

[0029] The hitch length H may be manually entered into the store **14** for the particular trailer **4** or it may be calculated in the computing unit **10** while the driver performs the following maneuver.

[0030] The vehicle-trailer combination is driven in a circular path and R is derived from the steering angle, θ_s , and the dimensions of the vehicle. The value of θ_t is derived from the camera **5** view. These values are then inserted into equation (1) to give a value for H.

[0031] In an alternative learning process for hitch length, H, while the vehicle-trailer combination is being driven, the value of θ_r calculated from equation (1) using a calculated value for R (from steering angle and vehicle dimensions) and an estimate for H is compared with the measured value of θ_r . The value of H is varied in subsequent calculations until the best match is achieved with the measured value for θ_r . This value of H is then stored.

[0032] The path of the reversing trailer 4 computed by the computing unit 10 is displayed on the display screen 11 as an overlay on top of the view from one of the cameras 5, 6, 7. The path is computed by building up incremental changes as a function of θ_t and R. The projected path is continuously updated as the steering angle θ_s and consequently the hitch angle θ_t vary.

[0033] The path can be overlaid on the rear camera's view, but will only be useful to the driver if the rear corners of the trailer are also displayed, e.g. for a low trailer. For a large trailer, e.g. a caravan, this is not so useful. In this latter case, the projected path is overlaid on to a view from one of the door mirror mounted cameras 6, 7, specifically, the camera which can see the trailer 4 at that particular moment in the maneuver. A correction has to be applied, however, if the trailer path is calculated with respect to the rear camera view.

[0034] Any misalignment in either camera will introduce errors in the information presented to the driver. This is remedied by electronically adjusting the view from the camera by aligning the image (or at least, the pixel data) with known hard points on the vehicle. For example, the mirror camera is looking rearwards but is misaligned laterally. The image processor 9 re-aligns the image to correct the alignment. Taken to the extreme, this will allow the arrangement to be used with the mirror folded in.

[0035] This embodiment can be extended to show the path of the trailer wheels while traveling in a forwards direction so that "kerbing" of the inside trailer wheels can be avoided on sharp bends. Conveniently, the trailer's path can be overlaid on the view from a forward-looking, door mirror mounted camera.

[0036] The learning process can be eliminated on trailer re-use. The store **14** can store the learned geometry of the trailer so that it can be recalled. Reversing assistance is then available straight away. The learning process is then run continually as a check on the stored values with updating as required. This continual check is useful in any case as a compensation for drift due to other variables.

[0037] The overlay tracks showing the projected path of the trailer can, conveniently have their starting point at the trailer's wheels. If the pitch angle of the tow hitch changes markedly then the guide lines comprising the overlay can appear to be in mid air rather than on the ground. If the pitch angle is known, then the computing unit **10** can effect a correction to the guide lines.

[0038] Operation of a third embodiment of the invention, which facilitates the tracking of obstacles, will now be described.

[0039] In this example, the door mirror mounted cameras **6**, 7 are triggered by one or more of the parking distance sensors **16-19** when the vehicle comes within close range of an object. On the display screen **11**, the driver will be presented with a view of the obstacle and a part of the exterior of the vehicle closest to it.

[0040] In an off-road or other tight maneuvering situation, the driver may want to continue to observe the object while driving past it. For example, while driving past a boulder, the driver will want to ensure that the boulder is not contacted by the side of the vehicle.

[0041] Clearly it is possible for the driver to manually control the camera to adjust its aim while driving past the object. However, this requires intervention by the driver and may distract him/her from other driving tasks.

[0042] This embodiment makes use of the ability of the cameras 6, 7 to pan and zoom electronically.

[0043] By virtue of the parking distance sensors **16-23** the location of an object relative to the vehicle **1** is known. This information is fed to the camera controller **7** so that the most appropriately located camera can be panned and zoomed in towards the position of the detected obstacle.

[0044] As a further refinement, the computing unit **10** is also provided with the location of the object relative to the vehicle along with steering angle (from the sensor **13**) and speed (from the speed sensor **12**).

[0045] As the vehicle moves onwards, the relative position of the object can be calculated from the wheel speeds combined with the steering angle or from individual wheel speeds. Hence an approximate real time location can be calculated and the camera panned to follow the object without driver intervention, with the computing unit **10** providing a control signal for the camera controller **7**.

[0046] There may be instances where the ground is slippery causing individual wheels to slip or the vehicle to slide. In such cases, speed measurements and/or steering measurements will be in error. To overcome this problem, the image processor **9** is adapted to analyze the image and match the object in the field of view between consecutive frames. This will allow ground velocity errors to be detected and corrected. For example, if the vehicle is sliding sideways towards the object, the camera can be made to pan towards the vehicle.

[0047] As a further enhancement to this second embodiment, the same recognition algorithm is employed in the image processor to enable the cameras 6, 7 to follow a moving object, following initial detection by the parking distance sensors 16-23.

[0048] For example, a child or animal which has been detected is shown as an image on the display screen **11** by the relevant camera. The image processor **9** then tracks the child's (or animal's) position through consecutive frames and the camera controller **7** adjusts pan and zoom controls to keep the moving object in the field of view.

[0049] The video cameras **6**, **7**, **8** may have an enhanced infra-red capability so that they are particularly sensitive in locating hot objects such as people and animals. Such "hotspots" can be identified by the image processor **9** and highlighted on the display screen **11**.

[0050] In an alternative arrangement, the zooming and panning operations are performed by the computing unit 10 instead of by the cameras 6, 7.

[0051] Operation of a fourth embodiment, which enables detection of a trailer, will now be described.

[0052] The rearward facing camera **5** detects the presence of the trailer **4** and sends its image to the computing unit **10** via the image processor **9**. By comparing the received image with parameters stored in the store **14**, the computing unit can determine the type of trailer, e.g. caravan, low loader etc. The size and shape of the trailer can thus give an indication of its weight and aerodynamic drag. This information can be used by vehicle systems such as stability control systems.

[0053] Once the vehicle-trailer combination is on the move, the trailer type can further be confirmed by monitoring the dynamic behavior of the combination using on-board sensors (not shown).

[0054] Operation of a fifth embodiment will now be described. This embodiment provides a means for assisting in attaching the trailer **4** to the vehicle **1**.

[0055] Using the camera system shown, it is possible to simplify the trailer hitching process in that both the trailer and the tow hitch can be seen in a camera image by the driver. This allows hitching of a trailer without the need for external guidance.

[0056] However, the image must necessarily be wide to allow the trailer to be approached but then the image of the tow ball and hitch are small and difficult to resolve. Also, the driver's judgment is still required to steer the vehicle appropriately based on the image.

[0057] This embodiment provides a solution to both these problems. The rear camera image is processed in the image processor **9**.

[0058] Firstly, the driver selects a "hitch mode" using the mode selector switch **15**. In response, the image processor **9** selects the rear camera view to display on the screen **11** and searches for an object with the triangular shape and size characteristics of a typical A-frame tow hitch. When detected, the image is zoomed in to contain the vehicle tow ball **2** and the tow hitch **3**. This can be done electronically by the computing unit **10** or by activating a zoom facility on the camera **5** via the camera controller **7**.

[0059] There may be an optional "confirm" function for the driver to confirm that the identified object is the trailer or to adjust the location for unusually shaped hitches. As the vehicle approaches (or moves away from) the trailer, the zoom setting is adjusted to maintain the view of both the hitch and tow ball. Consequently, when the tow ball **2** is close to the hitch **3**, the driver will be given the optimum view to allow accurate alignment.

[0060] In an alternative mode of operation, the image processor **9** is continuously monitoring the rear camera's output and the driver does not need to use the mode selector switch. On detection of the hitch **3**, the image processor **9** presents the rear camera view to the display **11**.

[0061] Optionally, and as an additional safety feature, if the parking distance sensors **16-23** detect an object in the path of the vehicle and close enough to risk a collision but outside the zoomed image, the image is zoomed out to show the object.

[0062] In a further mode of operation of this fourth embodiment, the computing unit **10** generates an overlay image on the display screen **11** which is the projected trajectory of the tow ball **2**. This is calculated from the vehicle's steering angle (provided by the steering angle sensor **13**) and from vehicle geometry parameters held in the store **14**. (This projected trajectory can assist in initially finding the hitch by panning the camera to look along the trajectory).

[0063] The trajectory is overlaid as a guide line on the zoomed image. In this way, the driver can adjust the steering angle to cause the trajectory and hitch to coincide. Reversing the vehicle will then place the hitch over the tow ball.

[0064] In some vehicles, it may not be possible to locate a camera on the body of the vehicle such that it has the view of the tow ball. For example, the tow ball may be obscured by the bumper. In this case, a "virtual tow ball" is applied to the image, i.e. a dot vertically above the actual location of the tow ball, to allow alignment and ranging of the hitching operation. The exact placement of the dot can be determined with reference to other fixed points in the image, e.g. the periphery of the vehicle as well as a predetermined absolute position. This allows for tolerance in the installation of the camera.

[0065] As the computing unit **10** knows the location of the tow ball **2** and the hitch **3** and also knows the current steering angle, it is possible to display to the driver instructions to steer left or right to optimize the alignment.

[0066] This could be integrated with other vehicle control mechanisms (not shown) such that the guidance information is applied automatically via the power steering system to steer the vehicle to align the tow hitch. The brake and throttle could be controlled automatically as well.

1. An apparatus displaying the predicted path of a trailer attached to a vehicle, comprising:

- at least one rearward-looking video camera having an output;
- a steering angle sensor outputting the steering angle of the vehicle;
- a computing unit receiving the video camera output and steering angle and computing a predicted trailer path; and
- a display displaying the video camera output and the predicted trailer path.

2. The apparatus of claim 1, wherein the predicted trailer has wheels and the predicted trailer path is represented as overlay tracks beginning at the trailer wheels.

3. The apparatus of claim **2**, wherein the predicted trailer path is shown while traveling in a forwards direction.

4. The apparatus of claim 1, wherein the computing unit derives a hitch angle θ_t from the camera output and uses the hitch angle θ_t to determine the predicted trailer path.

5. The apparatus of claim 1, wherein said at least one rearward-looking video camera comprises a camera mounted on each vehicle side mirror.

6. The apparatus of claim 1, wherein the trailer has a geometry and further comprising a store receiving the trailer geometry.

7. The apparatus of claim 6, further comprising the computing unit learning the trailer geometry from observing a maneuver and storing the learned geometry in the store.

8. An apparatus displaying the predicted path of a trailer having trailer wheels attached to a vehicle, comprising:

- at least one rearward-looking video camera mounted on each vehicle side mirror having an output;
- a steering angle sensor outputting the steering angle of the vehicle;
- a computing unit receiving the video camera output and steering angle and derives a hitch angle θ_t from the camera output and uses the hitch angle θ_t to determine the predicted trailer path; and
- a display displaying the video camera output and the predicted trailer path is represented as overlay tracks beginning at the trailer wheels.

9. An apparatus tracking objects close to the path of a vehicle, comprising:

- at least one vehicle-mounted video camera with pan capability, the camera having an output;
- a vehicle-mounted proximity sensor sensing the location of the object;
- a steering angle sensor outputting the steering angle of the vehicle;
- a speed sensor outputting the speed of the vehicle;
- a computing unit receiving the speed and steering angle and calculating a relative position of the object and panning the camera to follow the object; and

a display displaying the video camera output.

10. The apparatus of claim **9**, wherein the camera further comprises zoom capability and the computing unit zooms the camera when following the object.

11. An apparatus informing a vehicle when a trailer is hitched to the vehicle, comprising

- a rearward-looking camera having an output; and
- an image processor receiving the output and comparing the output with parameters stored in a store to determine the presence of the trailer.

12. The apparatus of claim **11**, further comprising comparing the output with the stored parameters to determine the type of trailer.

13. The apparatus of claim 12, further comprising using the trailer type in a vehicle control system.

14. The apparatus of claim 13, wherein the vehicle control system is a stability control system and the type of trailer is trailer weight.

15. The apparatus of claim 12, wherein the trailer type is confirmed by monitoring the dynamic behavior of the vehicle and trailer.

16. An apparatus for assisting in hitching a trailer having a tow hitch to a vehicle, comprising:

- at least one vehicle-mounted video camera having an output;
- an image processor receiving the camera output and identifying the tow hitch and displaying the output as an image;
- a display displaying the image, the image processor zooming the image to display a close-up of the tow hitch and adjusting the image zoom as the vehicle moves relative to the trailer to maintain the tow hitch in the image.

17. The apparatus of claim **16**, further comprising a steering angle sensor outputting the steering angle of the vehicle;

- a computing unit receiving the video camera output and steering angle and computing a projected vehicle trajectory; and
- displaying the projected vehicle trajectory overlaid as a guide line on the zoomed image.

18. The apparatus of claim **17**, wherein the vehicle has a tow ball not visible to the camera and further comprising displaying a virtual location of the tow ball on the display.

19. A method of predicting the path of a trailer attached to a vehicle comprising the steps of:

- obtaining a view from a first rearward-looking, vehiclemounted video camera on a screen visible to the driver; determining the predicted path of the trailer;
- displaying the predicted trailer path as an overlaid track on the rearward-looking view.

21. The method of claim **19**, further comprising the step of determining a hitch angle, θ_r , between the vehicle and trailer and using θ_r to calculate the predicted trailer path.

22. The method of claim **19**, further comprising the step of calculating a turning radius R where $R=H/\theta_{\rho}$, where the trailer is predicted to follow the circumference of a circle of radius R and using R to calculate the predicted trailer path.

23. The method of claim **19**, further comprising the steps of:

- determining a hitch length, H, between an axle of the trailer and a point of attachment of the trailer to the vehicle;
- determining a hitch angle, θ_t , between the vehicle and trailer;
- calculating a turning radius R where $R=H/\theta_r$, where the trailer is predicted to follow the circumference of a circle of radius R; and

using H, θ_{p} and R to calculate the predicted trailer path.

24. The method of claim 21, wherein the hitch length H is determined by driving the vehicle-trailer combination in a circular path, while measuring a vehicle steering angle θ_s , calculating the radius R of the circular path from θ_s and knowledge of the dimensions of the vehicle, measuring a hitch angle θ_t and calculating a hitch length H from the relationship H=R θ_t .

- **25**. The method of claim **19**, further comprising the steps of:
 - obtaining a view from a second rearward-looking, vehiclemounted video camera,
 - determining which of the first and second camera views shows the trailer; and

displaying the determined view on the screen.

26. The method of claim **21**, wherein the hitch angle θ_t is determined by the steps of:

- tracking a marker associated with the trailer across a field of view of the rearward-looking video camera; and
- converting a lateral displacement of the marker in the field of view to an angular displacement.

27. A method of predicting the path of a trailer attached to a vehicle comprising the steps of:

measuring the vehicle steering angle;

- obtaining first and second views from at least two rearward-looking, vehicle-mounted video cameras;
- determining a trailer view from the first and second camera views;
- displaying the trailer view on a screen visible to the driver; determining a hitch angle, θ_{i} , between the vehicle and trailer and using the trailer view;
- calculating a predicted path of the trailer from the hitch angle and steering angle; and
- displaying the predicted trailer path as an overlaid track on the trailer view.

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