Zhang, Bingchao [CN/CN]; Room 811, Building D, 9 Nanhunlunlu, Chaoyang District, Beijing 100102 (CN).

HWang, Long K. [CN/US]; 5452 Redbird Drive, Columbus, IN 47201 (US). LI, Guoqiang [US/US]; 3851 Harveys Path, Greenwood, IN 46143 (US).

ZHANG, Chao [CN/CN]; 2-6-2, 31# building, Yushui Street, Ganjingzi District, Dalian, Liaoning 116038 (CN). WU, Shuqing [CN/CN]; Qijia Village, Thirteen Aobaotao Town, Balinzuoqi, Chifeng, Inner Mongolia 025450 (CN).

WANG, Yali [CN/CN]; 29F, Tower A, Gateway, Beijing 100027 (CN).

Jiang, Zhaoiang [CN/CN]; Room 5-802, Building 205, Jinhui Yihao, Chaoyang District, Beijing 100016 (CN).

Agent: XU & PARTNERS, LLC; Room No. 106, Building No. 1, Universal High-Tech Plaza, 958 Zhen Bei Road, Putuo District, Shanghai 200333 (CN).


Title: SMART SHIFT ASSISTANCE SYSTEM FOR MANUAL TRANSMISSION

Abstract: Systems, apparatuses, and methods disclosed provide for assisting gear shift for a manual transmission of a vehicle. An engine control unit (ECU) receives a gear shift request from a gear selector. The gear shift request requests shifting gear to a desired position. The ECU eliminates an engine torque to substantial zero and indicates the gear is ready to be moved to a neutral position. The ECU then determines whether the gear has been moved to the neutral position. In response to determining the gear has been moved to the neutral position, the ECU adjusts an engine speed to match a gear ratio corresponding to the desired position and a transmission output speed and indicates the gear is ready to be shifted to the desired position. The ECU then determines whether the gear has been shifted to the desired position. In response to determining that the gear has been shifted to the desired position, the ECU recovers the engine torque.

FIG. 1A
Designated States (unless otherwise indicated, for every kind of regional protection available): AIIIP (BW, GH, GM, KE, LR, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GR, HR, HU, IE, IT, LV, LT, LU, MT, NL, NO, PL, PT, RO, SE, SK, SI, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— with international search report (Art. 21(3))
SMART SHIFT ASSISTANCE SYSTEM FOR MANUAL TRANSMISSION

TECHNICAL FIELD

[0001] The present disclosure relates to systems and methods for assisting gear shift for vehicles with manual transmission.

BACKGROUND

[0002] Manual transmission is used in various vehicles, e.g., trucks, buses, cars, and so on. Generally, a manual transmission uses a driver-operated clutch engaged and disengaged by a foot pedal or hand lever for regulating torque transfer from an engine shaft to a transmission input shaft. A manual shift (e.g., stick shift) is used to engage/disengage and select gears for regulating torque transfer from the transmission input shaft to a transmission output shaft. When different gears are selected and engaged, gear ratio may vary, which is a ratio of the engine speed to the transmission output shaft speed. Gear ratio may be changed (i.e., upshifting or downshifting) in order to match the speed and power of the engine to the road speed of the vehicle.

[0003] A manual transmission requires the driver of the vehicle to manually shift the gear. In particular, the driver first disengages the transmission from the engine by, for example, depressing a clutch pedal. The driver then moves the gears being engaged out of engagement to a neutral position. At the neutral position, no gears are engaged and thus the torque is not transmitted from the engine to the transmission. The driver releases the clutch pedal to reengage the transmission to the engine and revs up the engine through the accelerator to achieve a synchronization speed according to the desired gear ratio and the current transmission output speed. When the engine hits the synchronization speed, the driver disengages the clutch again and moves the stick shift to engage the desired gears. The series of manual operations make gear shift complicated.

SUMMARY
[0004] One embodiment relates to an apparatus for assisting gear shift for a manual transmission of a vehicle. The apparatus comprises a gear shift request receiving circuit structured to receive a gear shift request from a gear selector. The gear shift request requests shifting gear to a desired position. The apparatus also comprises a torque changing circuit structured to change an engine torque, an indication presenting circuit structured to present an indication to a driver whether the gear is ready to be moved, a gear position detection circuit structured to determine whether the gear has been moved in response to the indication, and an engine speed synchronization circuit structured to adjust an engine speed to match a gear ratio corresponding to the desired position and a transmission output speed.

[0005] Another embodiment relates to a method for assisting gear shift for a manual transmission of a vehicle. The method comprises receiving a gear shift request from a gear selector. The gear shift request requests shifting gear to a desired position. The method also comprises eliminating an engine torque to substantial zero, indicating the gear is ready to be moved to a neutral position, and determining whether the gear has been moved to the neutral position. In response to determining the gear has been moved to the neutral position, the method adjusts an engine speed to match a gear ratio corresponding to the desired position and a transmission output speed. The method further comprises indicating the gear is ready to be shifted to the desired position and determining whether the gear has been shifted to the desired position. In response to determining that the gear has been shifted to the desired position, the method recovers the engine torque.

[0006] Yet another embodiment relates to a system comprising a shift controller. The shift controller is structured to receive a gear shift request requesting shifting gear to a desired position, eliminate an engine torque to substantial zero, indicate the gear is ready to be moved to a neutral position, and determine whether the gear has been moved to the neutral position. In response to determining the gear has been moved to the neutral position, the shift controller adjusts an engine speed to match a gear ratio corresponding to the desired position and a transmission output speed, indicate the gear is ready to be shifted gear to the desired position, and determine whether the gear has been shifted to the desired position. In response to determining that the gear has been shifted to the desired position, the shift controller recovers the engine torque.
These and other features, together with the organization and manner of operation thereof, will become apparent from the following detailed description when taken in conjunction with the accompanying drawings.

**BRIEF DESCRIPTION OF THE FIGURES**

[0008] FIG. 1A is a schematic diagram of a shift assistance system for manual transmission, according to a first example embodiment.

[0009] FIG. 1B is a schematic diagram of a shift assistance system for manual transmission, according to a second example embodiment.

[0010] FIG. 2A is a schematic diagram of a gear selector according to a first example embodiment.

[0011] FIG. 2B is a schematic diagram of a gear selector according to a second example embodiment.

[0012] FIG. 3A is a schematic diagram of an operator interface with a status indicator and a shift guide indicator, according to a first example embodiment.

[0013] FIG. 3B is a schematic diagram of an operator interface with a status indicator and a shift guide indicator, according to a second example embodiment.

[0014] FIG. 3C is a schematic diagram of an operator interface with a gear selector, a status indicator, and a shift guide indicator, according to a first example embodiment.

[0015] FIG. 3D is a schematic diagram of an operator interface with a gear selector, a status indication, and a shift guide indicator, according to a second example embodiment.

[0016] FIG. 4 is a schematic diagram of a shift controller according to an example embodiment.

[0017] FIG. 5A is a table showing a logic map for upshifting gear according to an example embodiment.
FIG. 5B is a table showing a logic map for downshifting gear during coasting according to an example embodiment.

FIG. 5C is a table showing a logic map for skip downshifting gear according to an example embodiment.

FIG. 6 is a graph showing various working zones according to an example embodiment.

FIG. 7A is a graph showing road test results of the shift assistance system for upshifting gear, according to an example embodiment.

FIG. 7B is a graph showing road test results of the shift assistance system for consecutive upshifting gear, according to an example embodiment.

FIG. 7C is a graph showing road test results of the shift assistance system for consecutive downshifting gear during coasting, according to an example embodiment.

FIG. 7D is a graph showing road test results of the shift assistance system for skip shifting gear, according to an example embodiment.

FIG. 8 is a flow diagram of a method for assisting gear shift for a manual transmission, according to an example embodiment.

DETAILED DESCRIPTION

For the purposes of promoting an understanding of the principles of the disclosure, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the disclosure is thereby intended, any alterations and further modifications in the illustrated embodiments, and any further applications of the principles of the disclosure as illustrated therein as would normally occur to one skilled in the art to which the disclosure relates are contemplated herein.

Referring to the Figures generally, the various embodiments disclosed herein relate to systems and methods for assisting gear shift for a manual transmission. Conventionally, a driver
who drives a vehicle with manual transmission conducts a series of complex operations to manually shift gear. First, the driver disengages the transmission from the engine by, for example, depressing a clutch pedal. The driver then moves the gears being engaged out of engagement to a neutral position. The driver releases the clutch pedal to reengage the transmission to the engine and revs up the engine through the accelerator to achieve a synchronization speed. When the engine hits the synchronization speed, the driver disengages the clutch again and moves the stick shift to engage the desired gears. As such, the clutch and other components of the transmission are subject to wear and damage caused by frictional forces exerted during gear shift.

[0028] The present systems and methods can assist the driver to shift gear without manually actuating the clutch. In particular, the driver requests to shift gear (upshift or downshift) using a gear selector. The gear selector may be implemented as buttons, switches, rollers, etc. on the shifter, steering wheel, dashboard, or the like. Or, the gear selector may be implemented on a touch screen of an in-vehicle device or a mobile device. Upon receiving the gear shift request, an engine control unit (ECU) of the vehicle eliminates the engine torque to substantial zero (0) and indicates to the driver it is ready to shift gear to neutral. The driver may then shift the gear to the neutral position. Upon determining the gear has been shifted to neutral, the ECU adjusts the engine speed to match the transmission output shaft speed modified (e.g., multiplied) by the gear ratio corresponding to the desired gear. When the engine speed hits the right speed, the ECU indicates to the driver it is ready to shift gear to the desired position. The driver may then shift to the desired gear. In further embodiments, the ECU can determine what is the optimal gear under current circumstances in order to optimize fuel economy, engine performance, brake performance, emission, etc. and recommend the optimal gear to the driver.

[0029] With the systems and methods for assisting manual gear shift being implemented, the driver does not need to operate the clutch for gear shift. Thus, the workload of the driver can be reduced. Clutch/transmission wear and service cost can be reduced. Synchronizers may be omitted, which may further reduce the transmission cost. In addition, shift quality and drivability can be improved as the ECU can accurately control engine torque and speed. As a result, fuel economy and performance as well as emission management can be improved.
Referring now to FIG. 1A, a schematic diagram of a shift assistance system 100 for manual transmission is shown, according to a first example embodiment. The system 100 may be implemented on a vehicle that has a manual transmission. The vehicle may be any type of passenger or commercial automobile, such as a car, truck, sport utility vehicle, cross-over vehicle, van, minivan, automobile, tractor, and so on. The vehicle may generally further include a fuel tank, engine, powertrain system, wheels, aftertreatment system, etc.

The shift assistance system 100 is shown to include an engine control unit (ECU) 110, a manual transmission 120, and an operator interface 130. These components may communicate with each other via wired connection 102, which may be a serial cable, a CAT5 cable, or any other form of wired connection. In one embodiment, the components of system 100 are connected to a vehicle network such as a control area network (CAN) or a manufacturer proprietary network. Each of the components is structured to transmit and/or receive data (e.g., instructions, commands, signals, values, etc.) to/from one or more of other components shown in FIG. 1.

The ECU 110 is shown to include, a processor 112, memory 114, and shift controller 116. The memory 114 stores various instructions (and parameters) that, when executed by the processor 112, control the operation of an engine associated with the ECU 110. The processor 112 may be implemented as a general-purpose processor, an application specific integrated circuit (ASIC), one or more field programmable gate arrays (FPGAs), a digital signal processor (DSP), a group of processing components, or other suitable electronic processing components. The memory 114 may include one or more tangible, non-transient volatile memory or non-volatile memory, e.g., NVRAM, RAM, ROM, Flash Memory, hard disk storage, etc.). Moreover, the memory 114 may include database components, object code components, script components, or any other type of information structure. The shift controller 116 includes various circuits for assisting gear shift described herein, the structure of which will be discussed in detail below with reference to FIG. 4. It should be understood that the ECU 110 may further control other engine/vehicle activities beyond the scope of the present disclosure.

In operation, the ECU 110 may receive data from sensors (not shown in the present figure) positioned throughout the vehicle, receive instructions/performance parameters stored in
the memory 114, and output signals controlling various components of the engine. The sensors can monitor various status and conditions relating to vehicle operation, such as engine speed, engine torque, clutch position, gear position, accelerator position, transmission output shaft speed, emission status, vehicle speed, vehicle weight, road grade and profile, etc. The ECU 110 may change the speed and/or torque of the engine by controlling the amount of air and/or fuel sent to the engine cylinder(s) per engine cycle, ignition timing, variable valve timing, and so on.

[0034] The manual transmission 120 is shown to include a shift enabler 122, neutral gear switch 124, clutch switch 126, and optionally, gear selector 128. Other components of the transmission 120 are omitted from the present figure for the ease of explanation. Regarding mechanical parts, the transmission 120 may include a transmission input shaft driven by an engine output shaft and a transmission output shaft driven by the transmission input shaft. A clutch may be disposed between the engine output shaft and the transmission input shaft for regulating torque transfer from the engine output shaft to the transmission input shaft. The clutch may be engaged or disengaged by the clutch switch 126 (e.g., foot pedal or hand lever). The status of the clutch switch 126 informed the ECU 110 whether the clutch is engaged or disengaged by the foot pedal or hand lever. When the clutch is disengaged (e.g., foot pedal depressed), the clutch switch 126 is open, informing the ECU 110 that the transmission input shaft is disconnected from the engine output shaft. When the clutch is engaged (e.g., foot pedal released), the clutch switch 126 is open, informing the ECU 110 that the transmission input shaft is connected to the engine output shaft.

[0035] Torque transfer from the transmission input shaft to the transmission output shaft may be regulated by different gears, which implement different gear ratios (i.e., the ratio of the transmission speed, which equals the engine speed if clutch is fully engaged, to the transmission output shaft speed). The transmission 120 can be shifted between gears by moving the shift enabler 122 (e.g., stick shift). The shift enabler 122 may be placed at one of multiple gear positions, including positions with various gear ratios and a neutral position. At the neutral position, no gears are engaged and thus no torque is transmitted to the transmission output shaft. When the shift enabler 122 is placed at the neutral position, the neutral gear switch 124 is closed so that the gears are out of engagement. When the shift enabler 122 is placed at a position other than the neutral position, the neutral gear switch 124 is opened so that gears can be engaged.
In some embodiments, the gear selector 128 is implemented on the transmission 120 for the driver of the vehicle to request gear shift. FIG. 2A shows a gear selector 202 according to a first example embodiment. The gear selector 202 includes two buttons labeled by "+" and "+" and disposed on the front surface of the shift enabler, i.e., stick shift. When an upshift is desired, the driver may press the "+" button. When a downshift is desired, the driver may press the "+" button. It should be understood that the gear selector 202 may be implemented in various forms and disposed on various components of the transmission 120. For example, the gear selector 202 may be implemented as a rotary switch, slide switch, push switch, roller, mouse button, etc., on the front surface, top surface, side surface or two of the surfaces of the stick shift, on the steering wheel, or the like.

FIG. 2B shows a gear selector 204 according to a second example embodiment. The gear selector 204 is disposed on the top surface of the stick shift and includes a panel having a plurality of button areas arranged in a grid and labeled by "1," "2," "3," "4," "5," and "6." The driver may press the button area with the desired number to request shifting to the desired gear position. It should be understood that the gear selector 204 may be implemented in various forms and disposed on various components. For example, the panel may include any suitable number of button areas representing different gear positions on the stick shift, the steering wheel, or the like.

Referring back to FIG. 1A, the operator interface 130 is shown to include a status indicator 132, shift guide indicator 134, and optionally, gear selector 128. The operator interface 130 enables the driver to interact with the ECU 110 (e.g., read information provided by the ECU 110 and/or send request to the ECU 110). The operator interface 130 may include, but is not limited to, a dashboard, a control panel, an interactive display (e.g., a touchscreen, etc.), and so on. The status indicator 132 may indicate whether it is ready for the driver to move the shift enabler 122. For example, the status indicator 132 may indicate whether the engine torque is substantially zero so that the driver can move the shift enabler to the neutral position. It may also indicate whether the engine speed has reached the synchronization speed so that the driver can move the shift enabler to the desired gear position. The shift guide indicator 134 may indicate the current gear position, the desire gear position, and/or the gear shift direction (e.g., upshift, downshift).
[0039] FIG. 3A shows a first example embodiment of an operator interface 300 with a status indicator and a shift guide indicator. The status indicator is implemented as a light 302, the color of which can change to indicate the status. For example, during normal drive, the color of the light 302 is gray. When the ECU 110 is in the process of preparing for gear shift, e.g., the ECU 100 is eliminating the engine torque for shifting to neutral position or synchronizing engine speed for shifting to desire gear, the color of the light 302 is yellow. Thus, yellow light indicates "In Process." When it is ready for the driver to shift gear, i.e., the engine torque has been eliminated to substantial zero or the engine speed has reached the synchronization speed, the color of the light 302 is green. Thus, green light indicates "Enabled." When the shift fails, e.g., the time for shifting gear expires, the color of the light 302 is red. The shift guide indicator includes arrows 304, desired gear 306, and current gear 308. In some embodiments, the up arrow can be lighted and/or flash to indicate that the gear shift direction is upshifting; the down arrow can be lighted and/or flash to indicate that the gear shift direction is downshifting.

[0040] FIG. 3B shows a second example embodiment of an operator interface 300' with a status indicator and a shift guide indicator, according to a second example embodiment. The operator interface 300' may be implemented on a display unit. The background color of the display can change to indicate the status. For example, gray background indicates normal drive; yellow background indicates ECU is preparing for gear shift (i.e., "In Process"); green background indicates it is ready to shift gear (i.e., "Enabled"); and red background indicates shift fails. The shift guide indicator includes arrows 304, desired gear 306, and current gear 308. In some embodiments, the up arrow can be lighted and/or flash to indicate that the gear shift direction is upshifting; the down arrow can be lighted and/or flash to indicate that the gear shift direction is downshifting. In some embodiments, the operator interface 300' also includes an engine speed indicator 310 and a vehicle speed indicator 312.

[0041] The gear selector 128, when implemented on the operator interface 130, may be displayed along with the status indicator and the shift guide indicator. FIG. 3C shows a first example embodiment of an operator interface 350 with a status indicator, a shift guide indicator, and a gear selector. The status indicator and shift guide indicator may be the same as or similar to those shown in FIG. 3A. The gear selector 352 includes button areas 352 labeled by "+" and
“-.” When an upshift is desired, the driver may press the "+" button area. When a downshift is desired, the driver may press the "-" button area.

[0042] FIG. 3D shows a second embodiment of an operator interface 350' with a status indicator, a shift guide indicator, and a gear selector. The background color of the display can change to indicate the status of normal drive, in process, enabled, and failure, which may be the same as or similar to those shown in FIG. 3B. Up arrow or down arrow may be displayed in area 354 to indicate the shift direction (i.e., upshift or downshift). Button areas 356 labeled by "1," "2," "3," "4," "5," "6," "7," and "8" may be used to select the desired gear and display current and desired gears. For example, the driver may press button area labeled by "6" to request shifting to gear "6." The button area corresponding to the current gear "5" may be displayed in bold font. The button area corresponding to the desired gear "6" may flash. It should be understood that FIGS. 3A through 3D are examples of operator interface configuration, not for limitation. Any suitable configuration can be implemented on the operator interface.

[0043] Referring now to FIG. IB, a schematic diagram of a shift assistance system 100' for manual transmission is shown, according to a second example embodiment. The system 100' may be implemented on a vehicle that has a manual transmission. The shift assistance system 100' is shown to include an ECU 110', a manual transmission 120', and a user device 140 connected through a wireless network 104. The network 104 may facilitate communication between the ECU 110', transmission 120', and user device 140 and can be any suitable type of wireless network, such as Bluetooth, Wi-Fi, etc.

[0044] The ECU 110' may include the same or similar components as the ECU 110, such as the processor 112, memory 114, and shift controller 118. The ECU 110' further includes a network interface 118 that allows the ECU 110' to send and receive data to and from other devices via the wireless network 104. In some embodiments, the network interface 118 is a CAN bus-Bluetooth adapter. The transmission 120' may include the same or similar components as the transmission 120, such as the shift enabler 122, neutral gear switch 124, clutch switch 126, and optionally, gear selector 128. The transmission 120' further includes a network interface 129 that allows the transmission 120' to send and receive data to and from
other devices via the wireless network 104. In some embodiments, the network interface 129 is a CAN bus-Bluetooth adapter.

[0045] The user device 140 is a mobile device which may be, for example, a smartphone, a portable media device, a personal digital assistant (PDA), a laptop computer, a personal computer, or the like. The user device 140 may perform the same or similar functions as the operator interface 130. The user device 140 includes a network interface 142 that allows the user device 140 to send and receive data to and from other devices via the wireless network 104. The user device 140 further includes a user interface 144 that allows the driver to interact with the user device 140. In some embodiments, the user interface 144 may include a display and an input. The display and the input may be combined (e.g., as a touchscreen display device) or discrete devices. The input may include any of speakers, keyboards, notification LEDs, microphones, biometric sensors (e.g., fingerprint scanners), buttons, switches, cameras, or a combination thereof. The user interface 144 may present the same or similar elements as the operator interface 130, such as the status indicator 132, shift guide indicator 134, and optionally, gear selector 128. Besides being presented at a display (e.g., touchscreen), the status indicator, shifter guide indicator, and gear selector may be additionally or alternatively presented through a speaker.

[0046] Referring to FIG. 4, a schematic diagram of a shift controller 400 is shown according to an example embodiment. The shift controller 400 corresponds to the shift controller 116 in FIGS. 1A and 1B. The shift controller 400 includes various circuits 402 through 420 for completing the activities described herein. In one embodiment, the circuits of the shift controller 400 may utilize the processor 112 and/or memory 114 to accomplish, perform, or otherwise implement various actions described herein with respect to each particular circuit. In this embodiment, the processor 112 and/or memory 114 may be considered to be shared components across each circuit. In another embodiment, the circuits (or at least one of the circuits) may include their own dedicated processing circuit having a processor and a memory device. In this latter embodiment, the circuit may be structured as an integrated circuit or an otherwise integrated processing component. In yet another embodiment, the activities and functionalities of circuits may be embodied in the memory 114, or combined in multiple circuits, or as a single circuit. In this regard and while various circuits with particular functionality are shown in FIG. 4, it should
be understood that the shift controller 400 may include any number of circuits for completing the functions and activities described herein. For example, the activities of multiple circuits may be combined as a single circuit, as an additional circuit(s) with additional functionality, etc.

[0047] Certain operations of the shift controller 400 described herein include operations to interpret and/or to determine one or more parameters. Interpreting or determining, as utilized herein, includes receiving values by any method known in the art, including at least receiving values from a datalink or network communication, receiving an electronic signal (e.g. a voltage, frequency, current, or PWM signal) indicative of the value, receiving a computer generated parameter indicative of the value, reading the value from a memory location on a non-transient computer readable storage medium, receiving the value as a run-time parameter by any means known in the art, and/or by receiving a value by which the interpreted parameter can be calculated, and/or by referencing a default value that is interpreted to be the parameter value.

[0048] The shift controller 400 includes a gear shift request receiving circuit 402, torque changing circuit 404, indication presenting circuit 406, gear position detection circuit 408, engine speed synchronization circuit 410, and optionally, optimal gear determination circuit 420. Through these circuits, the shift controller 400 is structured to assist gear shift for a manual transmission.

[0049] The gear shift request receiving circuit 402 is structured to receive a gear shift request from, for example, the gear selector 128. Gear may be changed (i.e., upshifted or downshifted) in order to match the power of the engine to the road speed of the vehicle. When the driver wants to shift gear, the driver may operate the gear selector 128 to make the request. In some embodiments in which the gear selector 128 includes "+" and "-" button/switch/roller as shown in FIG. 2A or FIG. 3C, the driver may press the "+" button to request upshift or "-" button to request downshift. If the driver wants to shift two gears (i.e., skip shift), the driver presses the button twice. If the driver wants to shift three gears, the driver presses the button three times, and so on. In some embodiments in which the gear selector 128 includes a panel of button areas as shown in FIG. 2B or FIG. 3D, the driver may pressure the button area corresponding to the desired gear number. In both cases, the shift guide indicator 134 may display the desired gear number, current gear number, and the shift direction as shown in FIG. 3A, 3B, 3C, or 3D. The
status indicator 132 may indicate that the gear shift is in process and the drive needs to wait. For example, the status light or the display background may change color to indicate "In Process".

[0050] In response to the gear shift request receiving circuit 402 receiving the gear shift request, the torque changing circuit 404 may eliminate the engine torque to substantial zero. The ECU can control the engine output torque on the engine output shaft by controlling various engine parameters such as the fueling amount, ignition timing, etc. When the engine torque is eliminated to substantial zero, the driver can place the shift enabler 122 at the neutral position without clutching.

[0051] In response to the torque changing circuit 404 eliminating the engine torque to substantial zero, the indication presenting circuit 406 indicates that it is ready to move the shift enabler 122 to neutral. For example, the indication presenting circuit 406 may cause the status indicator 132 (e.g., light, display background) to change color to indicate "Enabled."

[0052] The gear position detection circuit 408 is structured to detect whether the driver has moved the shift enabler 122 to neutral. In some embodiments, the gear position detection circuit 408 detects the gear position using the status of the neutral gear switch 124. If the neutral gear switch 124 is open, the gear position detection circuit 408 determines that the gear is not at the neutral position. If the neutral gear switch 124 is closed, the gear position detection circuit 408 determines that the gear is at the neutral position.

[0053] In response to the gear position detection circuit 408 determining that the gear has been moved to neutral, the engine speed synchronization circuit 410 matches the engine speed with the desired gear and the indication presenting circuit 406 indicates that the synchronization is in process. The engine speed circuit 410 may adjust the engine speed to reach a synchronization engine speed, which may be the transmission output shaft speed multiplied by the gear ratio corresponding to the desired gear. If the gear is upshifted, the engine speed synchronization circuit 410 may reduce the engine speed to achieve the synchronization speed because a lower engine speed is needed at the higher gear to achieve the same transmission output shaft speed. If the gear is downshifted, the engine speed synchronization 410 may increase the engine speed to achieve the synchronization speed because a higher engine speed is needed at the lower gear to achieve the same transmission output shaft speed. The synchronization circuit 410 can control
the engine output speed by controlling various engine parameters such as the fueling amount, ignition timing, etc. In some embodiments, the synchronization circuit 410 continuously calculates and controls the engine speed using the gear ratio of desired gear and real-time transmission output shaft speed. During the synchronization process, the indication presenting circuit 406 may cause the status indicator 132 (e.g., light, display background) to change color to indicate "In Process." When the engine speed hits the synchronization speed, the driver does not need to use the clutch to engage the new gear.

[0054] In response to the engine speed synchronization circuit 410 having synchronized the engine speed, the indication presenting circuit 406 indicate it is ready to move the shift enabler 122 to the desired gear position. For example, the indication presenting circuit 406 may cause the status indicator 132 (e.g., light, display background) to change color to indicate "Enabled."

[0055] The gear position detection circuit 408 is structured to detect whether the driver has moved the shift enabler 122 to the desired gear position. In response to the gear position detection circuit 408 detecting that the gear has been shifted to the desired position, the torque changing circuit 404 may recover the engine torque from substantial zero. The ECU can control the engine output torque on the engine output shaft by controlling various engine parameters such as the fueling amount, ignition timing, etc. After the engine torque is recovered, the control of the vehicle may be returned to the driver. In some embodiments, the process of assisting gear shift may be interrupted by the driver. For example, at any stage of the assistance, if the driver opens the clutch switch 126 by, for example, depressing the clutch pedal, the control is returned to the driver.

[0056] In some embodiment, the shift controller 400 includes an optimal gear determination circuit 420 structured to determine an optimal gear position for the transmission. In some embodiments, the optimal gear position is determined based on at least some of multiple factors, including at least engine performance, brake power, fuel map, emission, powertrain configuration, vehicle weight, road profile, and traffic conditions. The process of determining the optimal gear position will be discussed in more detail with reference to FIG. 6. If the current gear position is different from the optimal gear position determined by the optimal gear determination circuit 420 for a given period of time (e.g., 1 minute), the indication presenting
circuit 406 may recommend the optimal gear position to the driver. For example, the shift guide arrow (e.g., 304 in FIG. 3A, 3B, or 3C, or 354 in 3D) can flash and/or the button area corresponding to the optimal gear position (e.g., 306 in FIG. 3A, 3B, or 3C, or 356 in 3D) can be lighted for a few second (e.g., 5 seconds). If the driver then requests gear shift, the circuits 402 through 410 may assist the gear shift as discussed above. If the driver does not request gear shift for a period of time (e.g., 3 minutes), the ECU may limit the engine torque and/or the engine speed to force the driver to shift gear. In some embodiments, the optimal gear determination circuit 420 continuously calculates the optimal gear considering various factors, such as engine performance, brake power, fuel map, emission logic, powertrain configuration, vehicle weight, road profile/map and traffic conditions.

[0057] Referring now to FIG. 5A, a table of a logic map for upshifting gear from 3 to 4 is shown according to an example embodiment. Before gear shift, the driver is driving the vehicle with a current gear of 3. The gear is not on the neutral position (e.g., the neutral gear switch is open). The engine speed and torque correspond to the gear 3. The driver starts the gear shift process by requesting upshifting to gear 4 through the gear selector (e.g., press the "+" button or the "4" button area). Although the current gear is still 3, the desired gear turns to 4. The status light indicates "In Process" (e.g., the color is yellow). The ECU starts to eliminate the engine torque. When the engine torque reaches substantial zero, the synchronization light indicates "Enabled" (e.g., the color is green). The driver moves the shift enabler (e.g., stick shift) to the neutral position. At the neutral position, the ECU starts to synchronize the engine speed to match the gear ratio corresponding to gear 4 and the current transmission output speed. Since the gear ratio corresponding to gear 4 is smaller than that corresponding to gear 3, the ECU reduces the engine speed. The synchronization light indicates "In Process." When the engine speed reaches the synchronization speed, the synchronization light indicates "Enabled." The driver shifts the shift enabler to the desired gear 4. At gear 4, the ECU starts to recover the engine torque. The synchronization light indicates "In Process." When the torque is recovered, the control is returned to the driver.

[0058] Referring to FIG. 5B, a table of a logic map for downshifting gear from 4 to 3 during coasting is shown according to an example embodiment. Before gear shift, the driver is driving the vehicle with a current gear of 4. The gear is not on the neutral position (e.g., the neutral gear
switch is open). The engine speed and torque correspond to the gear 4. The driver starts the gear shift process by requesting downshifting to gear 3 through the gear selector (e.g., press the "-" button or the "3" button area). Although the current gear is still 4, the desired gear is 3. The synchronization light indicates "In Process" (e.g., the color is yellow). The ECU starts to eliminate the engine torque. (When the vehicle is coasting, the engine torque may be negative.) When the engine torque reaches substantial zero, the synchronization light indicates "Enabled" (e.g., the color is green). The driver moves the shift enabler (e.g., stick shift) to the neutral position. At the neutral position, the ECU starts to synchronize the engine speed to match the gear ratio corresponding to gear 3 and the current transmission output speed. Since the gear ratio corresponding to gear 3 is greater than that corresponding to gear 4, the ECU increases the engine speed. The synchronization light indicates "In Process." When the engine speed reaches the synchronization speed, the synchronization light indicates "Enabled." The driver shifts the shift enabler to the desired gear 3. At gear 3, the ECU starts to recover the engine torque (e.g., to negative). The synchronization light indicates "In Process." When the torque is recovered, the control is returned to the driver.

[0059] Referring to FIG. 5C, a table of a logic map for skip downshifting gear from 5 to 3 is shown according to an example embodiment. The skip downshifting may be needed when the vehicle is going uphill with a full throttle but the engine does not supply enough power. Before gear shift, the driver is driving the vehicle with a current gear of 5. The gear is not on the neutral position (e.g., the neutral gear switch is open). The engine speed and torque correspond to the gear 5. The driver starts the gear shift process by requesting downshifting to gear 3 through the gear selector (e.g., press the "-" button twice or press the "3" button area). Although the current gear is still 5, the desired gear is 3. The synchronization light indicates "In Process" (e.g., the color is yellow). The ECU starts to eliminate the engine torque. When the engine torque reaches substantial zero, the synchronization light indicates "Enabled" (e.g., the color is green). The driver moves the shift enabler (e.g., stick shift) to the neutral position. At the neutral position, the ECU starts to synchronize the engine speed to match the gear ratio corresponding to gear 3 and the current transmission output speed. Since the gear ratio corresponding to gear 3 is greater than that corresponding to gear 5, the ECU increases the engine speed. The synchronization light indicates "In Process." When the engine speed reaches the synchronization speed, the synchronization light indicates "Enabled." The driver shifts the shift enabler to the desired gear
3. At gear 3, the ECU starts to recover the engine torque. The synchronization light indicates "In Process." When the torque is recovered, the control is returned to the driver.

[0060] As discussed above with reference to FIG. 4, the shift controller 400 includes an optimal gear determination circuit 420 structured to determine the optimal gear position for the transmission based on at least some of multiple factors, including at least engine performance, brake power, fuel map, emission, powertrain configuration, vehicle weight, road profile, and traffic conditions. In some embodiments, the determination is made to achieve optimal fuel economy. FIG. 6 shows various working zones corresponding to various combinations of engine speed and engine torque, according to an example embodiment. The area under the curve 602 is where the combination of engine speed and torque can reach. If the combination of engine speed and engine torque falls into the "Performance Zone," it means that the accelerating force for the vehicle is strong. When the engine speed gets steady, the combination of engine speed and engine torque may fall into the "Economy Zone," the "Down Shift Area," or the "Up Shift Area." At the "Economy Zone," the fuel is used with efficiently. At the "Down Shift Area," the engine power thus performance is not desirable and can be improved by downshifting the gear. At the "Up Shift Area," the fuel economy is not desirable and can be improved by upshifting the gear.

[0061] If the engine operates in the "Down Shift Area" or "Up Shift Area" for a predefined period of time (e.g., 1 minute), the ECU may urge the driver to shift gear by, for example, flashing the shift arrow and/or the desired gear number. If the engine has been operating in the "Down Shift Area" or "Up Shift Area" for a long time (e.g., 3 minutes), the ECU may gradually reduce fueling to limit engine speed and/or torque so that the driver is forced to shift gear. Take downhill situation as an example. When the vehicle is going downhill and the engine brake is enabled, the ECU calculates an optimal gear to achieve safe and nearly constant vehicle speed based on engine brake performance, vehicle speed and changing rate (i.e., acceleration or deceleration), vehicle weight and road grade. The calculated optimal gear may be different from the current gear by 1 gear or more. The ECU may flash the shift arrow or the desired gear number to urge the driver to use engine brake properly. If the vehicle speed increases continuously while the engine speed is below the rated speed, then the optimal gear is lower than the current gear and the driver can downshift gear in order to increase the engine speed, thus increasing engine brake power. If the vehicle speed decreases continuously while the engine
speed is close to the rated speed (which indicates the engine brake power is too high), then the optimal gear is higher than the current gear and the driver can upshift gear in order to decrease the engine speed, thus reducing engine brake power. If the engine speed is higher than the rated speed, the ECM may urge the driver to shift to the gear 1 or 2 levels higher than the current gear in order to reduce engine speed to prevent the risk of engine over speed.

[0062] The methods and systems disclosed herein were tested on a vehicle. FIGS. 7A through 7D show the test results. FIG. 7A shows the road test result for upshifting gear from 3 to 4 with the assistance of the ECU. FIG. 7B shows the road test result for consecutive upshifting gear from 1 all the way through 5. FIG. 7C shows the road test result for consecutive downshifting gear during vehicle coasting from 5 all the way through 1. FIG. 7D shows the road test result for skip shifting gear from 1 to 3, 3 to 5, then 5 back to 3. Curves representing actual engine speed, reference engine speed, engine torque, vehicle speed, and gear position are shown on each figure. It can be seen that with the assistance of the ECM, the substantial zero torque was achieved and the actual engine speed was adjusted to match the reference engine speed soon.

[0063] Referring now to FIG. 8, a flow diagram 800 of a method for assisting gear shift for a manual transmission is shown according to one embodiment. The method 800 may be executed by the shift controller 116 of FIGS. 1A and 1B as well as the shift controller 400 of FIG. 4 implemented on an ECU.

[0064] At operation 802, a gear shift request is received from, for example, a gear selector (e.g., the gear selector 128). Gear may be changed (i.e., upshifted or downshifted) in order to match the power of the engine to the road speed of the vehicle. When a driver wants to shift gear, the driver may operate the gear selector to request such. In some embodiments in which the gear selector includes "+" and "-" button/switch/roller as shown in FIG. 2A or FIG. 3C, the driver may press the "+" button for upshifting or "-" button for downshifting. If the driver wants to shift two gears, the driver presses the button twice. If the driver wants to shift three gears, the driver presses the button three times, and so on. In some embodiments in which the gear selector includes a panel of button areas as shown in FIG. 2B or FIG. 3D, the driver may pressure the desired gear number.
[0065] At operation 804, an engine torque is eliminated to substantial zero. In response to receiving the gear shift request at operation 802, the ECU may eliminate the engine torque to substantial zero. The ECU can control the engine output torque on the engine output shaft by controlling various engine parameters such as the fueling amount, ignition timing, etc. When the engine torque is eliminated to substantially zero, the driver can place a shift enabler at the neutral position without clutching.

[0066] At operation 806, the ECU indicates that it is ready to move the gear to the neutral position. In response to the engine torque being eliminated to substantial zero, the ECU urges the driver to move gear to neutral. For example, the ECU may cause a shift guide indicator (e.g., light, display background) to change color to indicate "Enabled."

[0067] At operation 808, the ECU determines whether the gear has been moved to the neutral position. In some embodiments, the ECU detects the gear position using the status of a neutral gear switch. If the neutral gear switch is open, the ECU determines that the gear is not at the neutral position. If the neutral gear switch is closed, the ECU determines that the gear is at the neutral position.

[0068] In response to determining that the gear has not been moved to the neutral position at operation 808, the ECU determines whether time for switching gear has expired at operation 810. For example, if the gear has not been moved to the neutral position in one minute, the ECU determines that the time has expired. In response to determining that the time has not expired at operation 810, the ECU continues to check whether the gear has been moved to the neutral position. In response to determining that the time has expired at operation 810, the assistance process ends at operation 812. In particular, the ECU can put shift assistance on hold, give the engine control back to the driver, and respond to the accelerator pedal and clutch properly. In some embodiments, the ECU can indicate that this shift fails and wait for the next shift assistance request.

[0069] In response to determining that the gear has been moved to the neutral position at operation 808, the ECU adjusts an engine speed to match a gear ratio corresponding to the desired position and a transmission output speed, at operation 820. In other words, the engine speed is adjusted to reach a synchronization engine speed, which may be the transmission output
shaft speed multiplied by the gear ratio corresponding to the desired gear. If the gear is upshifted, the ECU may reduce the engine speed to achieve the synchronization speed because a lower engine speed is needed at the higher gear to achieve the same transmission output shaft speed. If the gear is downshifted, the ECU may increase the engine speed to achieve the synchronization speed because a higher engine speed is needed at the lower gear to achieve the same transmission output shaft speed. The ECU can control the engine output speed by controlling various engine parameters such as the fueling amount, ignition timing, etc. In some embodiments, the ECU continuously calculates and controls the engine speed using the gear ratio of desired gear and real-time transmission output shaft speed. When the engine speed hits the synchronization speed, the driver does not need to use the clutch to engage the new gear.

[0070] At operation 822, the ECU indicates that it is ready to move the gear to the desired position. In response to the engine speed reaching the synchronization speed, the ECU urges the driver to move gear to the desired position. For example, the ECU may cause a shift guide indicator (e.g., light, display background) to change color to indicate "Enabled."

[0071] At operation 824, the ECU determines whether the gear has been moved to the desired position. In response to determining that the gear has not been moved to the neutral position at operation 824, the ECU determines whether time for switching gear has expired at operation 826. For example, if the gear has not been moved to the desired position in one minute, the ECU determines that the time has expired. In response to determining that the time has not expired at operation 826, the ECU continues to check whether the gear has been moved to the neutral position. In response to determining that the time has expired at operation 826, the assistance process ends at operation 828. In particular, the ECU can put shift assistance on hold, give the engine control back to the driver, and respond to the accelerator pedal and clutch properly. In some embodiments, the ECU can indicate that this shift fails and wait for the next shift assistance request.

[0072] In response to determining that the gear has been shifted to the desired position at operation 824, the ECU recovers the engine torque from substantial zero at operation 830. The ECU can control the engine output torque on the engine output shaft by controlling various
engine parameters such as the fueling amount, ignition timing, etc. When operation 830 is done, the assistance process ends and control of the vehicle is returned to the driver.

[0073] It should be understood that no claim element herein is to be construed under the provisions of 35 U.S.C. § 112(f), unless the element is expressly recited using the phrase "means for." The schematic flow chart diagrams and method schematic diagrams described above are generally set forth as logical flow chart diagrams. As such, the depicted order and labeled steps are indicative of representative embodiments. Other steps, orderings and methods may be conceived that are equivalent in function, logic, or effect to one or more steps, or portions thereof, of the methods illustrated in the schematic diagrams. Further, reference throughout this specification to "one embodiment", "an embodiment", "an example embodiment", or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment", "in an embodiment", "in an example embodiment", and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment.

[0074] Additionally, the format and symbols employed are provided to explain the logical steps of the schematic diagrams and are understood not to limit the scope of the methods illustrated by the diagrams. Although various arrow types and line types may be employed in the schematic diagrams, they are understood not to limit the scope of the corresponding methods. Indeed, some arrows or other connectors may be used to indicate only the logical flow of a method. For instance, an arrow may indicate a waiting or monitoring period of unspecified duration between enumerated steps of a depicted method. Additionally, the order in which a particular method occurs may or may not strictly adhere to the order of the corresponding steps shown. It will also be noted that each block of the block diagrams and/or flowchart diagrams, and combinations of blocks in the block diagrams and/or flowchart diagrams, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and program code.

[0075] Many of the functional units described in this specification have been labeled as circuits, in order to more particularly emphasize their implementation independence. For example, a
circuit may be implemented as a hardware circuit comprising custom very-large-scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A circuit may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices or the like.

[0076] As mentioned above, circuits may also be implemented in machine-readable medium for execution by various types of processors, such as the controller 200 of FIG. 2. An identified circuit of executable code may, for instance, comprise one or more physical or logical blocks of computer instructions, which may, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified circuit need not be physically located together, but may comprise disparate instructions stored in different locations which, when joined logically together, comprise the circuit and achieve the stated purpose for the circuit. Indeed, a circuit of computer readable program code may be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated herein within circuits, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different storage devices, and may exist, at least partially, merely as electronic signals on a system or network.

[0077] The computer readable medium (also referred to herein as machine-readable media or machine-readable content) may be a tangible computer readable storage medium storing the computer readable program code. The computer readable storage medium may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, holographic, micromechanical, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. As alluded to above, examples of the computer readable storage medium may include but are not limited to a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a portable compact disc read-only memory (CD-ROM), a digital versatile disc (DVD), an optical storage device, a magnetic storage device, a holographic storage medium, a micromechanical storage device, or any suitable combination of the foregoing. In the context of
this document, a computer readable storage medium may be any tangible medium that can contain, and/or store computer readable program code for use by and/or in connection with an instruction execution system, apparatus, or device.

[0078] Computer readable program code for carrying out operations for aspects of the present invention may be written in any combination of one or more programming languages, including an object oriented programming language such as Java, Smalltalk, C++ or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages.

[0079] The program code may also be stored in a computer readable medium that can direct a computer, other programmable data processing apparatus, or other devices to function in a particular manner, such that the instructions stored in the computer readable medium produce an article of manufacture including instructions which implement the function/act specified in the schematic flowchart diagrams and/or schematic block diagrams block or blocks.

[0080] Accordingly, the present disclosure may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the disclosure is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.
What is claimed is:

1. An apparatus for assisting gear shift for a manual transmission of a vehicle, the apparatus comprising:
   a gear shift request receiving circuit structured to receive a gear shift request from a gear selector, wherein the gear shift request requests shifting gear to a desired position;
   a torque changing circuit structured to change an engine torque;
   an indication presenting circuit structured to present an indication to a driver whether the gear is ready to be moved;
   a gear position detection circuit structured to determine whether the gear has been moved in response to the indication; and
   an engine speed synchronization circuit structured to adjust an engine speed to match a gear ratio corresponding to the desired position and a transmission output speed.

2. The apparatus of claim 1, wherein the torque changing circuit is structured to:
   eliminate the engine torque to substantial zero in response to receiving the gear shift request; and
   recover the engine torque in response to the gear being shifted to the desired position.

3. The apparatus of claim 2, wherein the indication presenting circuit is structured to:
   indicate the gear is ready to be moved to a neutral position in response to the engine torque being substantial zero; and
   indicate the gear is ready to be moved to the desired position in response to the engine speed matching the gear ratio corresponding to the desired position and the transmission output speed.

4. The apparatus of claim 3, where in the gear position detection circuit is structured to:
   determine whether the gear has been moved to the neutral position in response to indicating the gear is ready to be moved to the neutral position; and
   determine whether the gear has been shifted to the desired position in response to indicating the gear is ready to be shifted to the desired position.
5. The apparatus of claim 4, wherein the engine speed synchronization circuit is structured to adjust the engine speed to match the gear ratio corresponding to the desired position and the transmission output speed in response to the gear being moved to the neutral position.

6. The apparatus of claim 1, further comprising an optimal gear determination circuit structured to determine the desired position based on at least some of multiple factors, wherein the indication presenting circuit is further structured to indicate the desired position to the driver in response to the desired position being different than a current position of the gear.

7. The apparatus of claim 6, wherein the multiple factors include at least engine performance, brake power, fuel map, emission, powertrain configuration, vehicle weight, road profile, and traffic conditions.

8. A method for assisting gear shift for a manual transmission of a vehicle, the method comprising:
   receiving a gear shift request from a gear selector, wherein the gear shift request requests shifting gear to a desired position;
   eliminating an engine torque to substantial zero;
   indicating the gear is ready to be moved to a neutral position;
   determining whether the gear has been moved to the neutral position;
   in response to determining the gear has been moved to the neutral position, adjusting an engine speed to match a gear ratio corresponding to the desired position and a transmission output speed;
   indicating the gear is ready to be shifted to the desired position;
   determining whether the gear has been shifted to the desired position; and
   in response to determining that the gear has been shifted to the desired position, recovering the engine torque.

9. The method of claim 8, wherein determining whether the gear has been moved to the neutral position includes determining a state of a neutral gear switch.
10. The method of claim 8, wherein adjusting the engine speed includes adjusting the engine speed to a synchronization speed which is the transmission output speed multiplied by the gear ratio corresponding to the desired position.

11. The method of claim 9, further comprising:
   determining the desired position based on at least some of multiple factors; and
   recommending the desired position to a driver in response to the desired position being different than a current position of the gear.

12. The method of claim 11, wherein the multiple factors include at least engine performance, brake power, fuel map, emission, powertrain configuration, vehicle weight, road profile, and traffic conditions.

13. A system comprising:
   a shift controller structured to:
       receive a gear shift request requesting shifting gear to a desired position;
       eliminate an engine torque to substantial zero;
       indicate the gear is ready to be moved to a neutral position;
       determine whether the gear has been moved to the neutral position;
       in response to determining the gear has been moved to the neutral position, adjust an engine speed to match a gear ratio corresponding to the desired position and a transmission output speed;
       indicate the gear is ready to be shifted gear to the desired position;
       determine whether the gear has been shifted to the desired position; and
       in response to determining that the gear has been shifted to the desired position, recover the engine torque.

14. The system of claim 13, further comprising a gear selector structured to transmit the gear shift request to the shift controller.

15. The system of claim 14, wherein the gear selector enables a driver to select upshifting or downshifting.
16. The system of claim 14, wherein the gear selector enables a driver to select the desired position from a plurality of gear positions.

17. The system of claim 13, further comprising a neutral gear switch, wherein the shifter controller is structured to determine whether the gear has been moved to the neutral position by determining a state of the neutral gear switch.

18. The system of claim 13, further comprising a user interface structured to interact with a driver, wherein the shift controller is structured to present indication through the user interface.

19. The system of claim 13, wherein the shift controller is further structured to:
   determine the desired position based on at least some of multiple factors;
   recommend the desired position to a driver in response to the desired position being different than a current position of the gear.

20. The system of claim 13, wherein the multiple factors include at least engine performance, brake power, fuel map, emission, powertrain configuration, vehicle weight, road profile, and traffic conditions.
Shift Controller

400

Gear shift request receiving circuit

402

Torque changing circuit

404

Indication presenting circuit

406

Gear position detection circuit

408

Engine speed synchronization Circuit

410

Optimal gear determination circuit

420

FIG. 4
<table>
<thead>
<tr>
<th>Item</th>
<th>Stage</th>
<th>Before</th>
<th>Start</th>
<th>0 Torque</th>
<th>Go To Neutral</th>
<th>Synchronize Speed</th>
<th>Shift To Next Gear</th>
<th>Recovery Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver</td>
<td></td>
<td>Drive</td>
<td></td>
<td>Shift</td>
<td>Wait</td>
<td>Shift</td>
<td>Wait</td>
<td>Drive</td>
</tr>
<tr>
<td>Current Gear</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>N</td>
<td>N</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Designed Gear</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutral Gear</td>
<td>Not</td>
<td>Not</td>
<td>Not</td>
<td>YES</td>
<td>YES</td>
<td>Not</td>
<td>Not</td>
<td></td>
</tr>
<tr>
<td>Synch Light</td>
<td>NA</td>
<td>Yellow</td>
<td>Green</td>
<td>Yellow</td>
<td>Green</td>
<td>Yellow</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Engine Speed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engine Torque (Indicated, means Fueling)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIG. 5A**

<table>
<thead>
<tr>
<th>Item</th>
<th>Stage</th>
<th>Before</th>
<th>Start</th>
<th>0 Torque</th>
<th>Go To Neutral</th>
<th>Synchronize Speed</th>
<th>Shift To Next Gear</th>
<th>Recovery Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver</td>
<td></td>
<td>Drive</td>
<td></td>
<td>Shift</td>
<td>Wait</td>
<td>Shift</td>
<td>Wait</td>
<td>Drive</td>
</tr>
<tr>
<td>Current Gear</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>N</td>
<td>N</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Designed Gear</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutral Gear</td>
<td>Not</td>
<td>Not</td>
<td>Not</td>
<td>YES</td>
<td>YES</td>
<td>Not</td>
<td>Not</td>
<td></td>
</tr>
<tr>
<td>Synch Light</td>
<td>NA</td>
<td>Yellow</td>
<td>Green</td>
<td>Yellow</td>
<td>Green</td>
<td>Yellow</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Engine Speed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engine Torque (Indicated, means Fueling)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIG. 5B**
<table>
<thead>
<tr>
<th>Item</th>
<th>Stage Before</th>
<th>Stage Start</th>
<th>0 Torque</th>
<th>Go To Neutral</th>
<th>Synchronize Speed</th>
<th>Shift To Next Gear</th>
<th>Recovery Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver</td>
<td>Drive</td>
<td>Shift</td>
<td>N</td>
<td>N</td>
<td>Shift</td>
<td>Wait</td>
<td>Drive</td>
</tr>
<tr>
<td>Current Gear</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>N</td>
<td>N</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Designed Gear</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Neutral Gear</td>
<td>Not</td>
<td>Not</td>
<td>Yes</td>
<td>YES</td>
<td>Not</td>
<td>Not</td>
<td>Not</td>
</tr>
<tr>
<td>Synch Light</td>
<td>NA</td>
<td>Yellow</td>
<td>Green</td>
<td>Yellow</td>
<td>Green</td>
<td>Yellow</td>
<td>NA</td>
</tr>
<tr>
<td>Engine Speed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Engine Torque (Indicated, means Fueling)

FIG. 5C

![Figure 5C Diagram showing engine speed and torque zones]

FIG. 6

![Figure 6 Diagram showing engine speed and torque zones]
Receive gear shift request

Eliminate engine torque to substantial zero

Indicate ready for neutral

Neutral position?

Expired?

Adjust engine speed

Indicate ready for desired gear

Desired gear?

Expired?

Assistance end

Recovered torque

FIG. 8
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

B60W 30/19(2012.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B60W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database consulted during the international search (name of data base and, where practicable, search terms used)

CNPAT,WPLEPDOC,CNKI,IEEE:assist+, manual, transmiss+, shift+, gear, torque

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>CN 105270387 A (DONGFENG COMMERCIAL VEHICLE CO., LTD.) 27 January 2016 (2016-01-27) description, paragraphs [0014]-[0022], figures 1-4</td>
<td>1-20</td>
</tr>
<tr>
<td>A</td>
<td>CN 103192823 A (SAIC MOTOR CO., LTD.) 10 July 2013 (2013-07-10) the whole document</td>
<td>1-20</td>
</tr>
<tr>
<td>A</td>
<td>US 5569115 A (ROCKWELL INTERNATIONAL CORPORATION) 29 October 1996 (1996-10-29) the whole document</td>
<td>1-20</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"Q" document member of the same patent family

Date of the actual completion of the international search
08 April 2018

Date of mailing of the international search report
20 April 2018

Name and mailing address of the ISA/CN
STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA
6, Xitucheng Rd., Jintan Bridge, Haidian District, Beijing 100088 China

Authorized officer
YANG,Yingying

Facsimile No. (86-10)62019451
Telephone No. 86-(10)-53961527

Form PCT/ISA/210 (second sheet) (January 2015)
## INTERNATIONAL SEARCH REPORT

### Information on patent family members

**International application No.**

**PCT/CN2017/093547**

<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date (day/month/year)</th>
<th>Patent family member(s)</th>
<th>Publication date (day/month/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN 105270387 A</td>
<td>27 January 2016</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>CN 103192823 A</td>
<td>10 July 2013</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>US 5569115 A</td>
<td>29 October 1996</td>
<td>DE 69617432 A2</td>
<td>18 July 2002</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 0837787 A1</td>
<td>29 April 1998</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AU 6638096 A</td>
<td>26 February 1997</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO 9704982 A1</td>
<td>13 February 1997</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BR 9609848 A</td>
<td>09 March 1999</td>
</tr>
<tr>
<td>WO 2015179482 A1</td>
<td>26 November 2015</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

*Form PCT/ISA/210 (patent family annex) (January 2015)*