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DOOR OPERATOR CALIBRATION

Abstract

An exemplary method involves operating a door operator coupled to a door. The door operator includes a motor operable to move the door in at least one direction and a controller operable to control the motor. The method generally involves a calibration procedure including: with the door at a first position and the door having an initial speed, initiating, by the controller, measurement of a time duration; in response to the door reaching a target speed different from the initial speed, ceasing, by the controller, measurement of the time duration; and determining, by the controller, a maximum speed based on the time duration. The method further includes performing at least one operation based upon the maximum speed.

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Background/Summary

TECHNICAL FIELD

[0001] The present disclosure generally relates to door operators, and more particularly but not exclusively relates to methods of calibrating an automatic door operator.

BACKGROUND

[0002] Door operators are commonly installed to doors to facilitate the opening and/or closing of the door. Certain limits and operating parameters for such installations are set by various standards and codes, such as those set by the Builders Hardware Manufacturers Association (BHMA). For example, the BHMA 156.19 standard for low-power auto-operators sets limits on the amount of kinetic energy that a door may have during normal opening and closing of the door. This kinetic energy is a function of door speed and the mass moment of inertia (MMI) of the door. In many conventional door operators, the task of enforcing the BHMA 156.19 standard falls to installers and/or maintenance personnel, which can result in poor compliance with the standard. For these reasons among others, there remains a need for further improvements in this technological field.

SUMMARY

[0003] An exemplary method involves operating a door operator coupled to a door. The door operator includes a motor operable to move the door in at least one direction and a controller operable to control the motor. The method generally involves a calibration procedure including: with the door at a first position and the door having an initial speed, initiating, by the controller, measurement of a time duration; in response to the door reaching a target speed different from the initial speed, ceasing, by the controller, measurement of the time duration; and determining, by the controller, a maximum speed based on the time duration. The method further includes performing at least one operation based upon the maximum speed. Further embodiments, forms, features, and aspects of the present application shall become apparent from the description and figures provided herewith.

Description

BRIEF DESCRIPTION OF THE FIGURES

[0004] FIG. **1** is a partially-exploded perspective view of a closure assembly including a door operator according to certain embodiments.

[0005] FIG. **2** is a side view of a portion of a door operator module according to certain embodiments.

[0006] FIG. **3** is a schematic block diagram of a portion of the door operator illustrated in FIG. **1**.

[0007] FIG. **4** is a schematic flow diagram of a process according to certain embodiments.

[0008] FIG. **5** illustrates a lookup table according to certain embodiments.

[0009] FIG. **6** is a graph illustrating door speed versus door position according to certain embodiments.

[0010] FIG. **7** is a schematic flow diagram of a process according to certain embodiments.

[0011] FIG. **8** is a schematic flow diagram of a process according to certain embodiments.

[0012] FIG. **9** is a schematic flow diagram of a process according to certain embodiments.

[0013] FIG. **10** is a schematic block diagram of a computing device that may be utilized in connection with certain embodiments.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0014] Although the concepts of the present disclosure are susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and will be described herein in detail. It should be understood, however, that there is no intent to limit the concepts of the present disclosure to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives consistent with the present disclosure and the appended claims.
[0015] References in the specification to “one embodiment,” “an embodiment,” “an illustrative embodiment,” etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may or may not necessarily include that particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. It should further be appreciated that although reference to a “preferred” component or feature may indicate the desirability of a particular component or feature with respect to an embodiment, the disclosure is not so limiting with respect to other embodiments, which may omit such a component or feature. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to implement such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.
[0016] Additionally, it should be appreciated that items included in a list in the form of “at least one of A, B, and C” can mean (A); (B); (C); (A and B); (B and C); (A and C); or (A, B, and C). Similarly, items listed in the form of “at least one of A, B, or C” can mean (A); (B); (C); (A and B); (B and C); (A and C); or (A, B, and C). Items listed in the form of “A, B, and/or C” can also mean (A); (B); (C); (A and B); (B and C); (A and C); or (A, B, and C). Further, with respect to the claims, the use of words and phrases such as “a,” “an,” “at least one,” and/or “at least one portion” should not be interpreted so as to be limiting to only one such element unless specifically stated to the contrary, and the use of phrases such as “at least a portion” and/or “a portion” should be interpreted as encompassing both embodiments including only a portion of such element and embodiments including the entirety of such element unless specifically stated to the contrary.
[0017] In the drawings, some structural or method features may be shown in certain specific arrangements and/or orderings. However, it should be appreciated that such specific arrangements and/or orderings may not necessarily be required. Rather, in some embodiments, such features may be arranged in a different manner and/or order than shown in the illustrative figures unless indicated to the contrary. Additionally, the inclusion of a structural or method feature in a particular figure is not meant to imply that such feature is required in all embodiments and, in some embodiments, may be omitted or may be combined with other features.
[0018] The disclosed embodiments may, in some cases, be implemented in hardware, firmware, software, or a combination thereof. The disclosed embodiments may also be implemented as instructions carried by or stored on one or more transitory or non-transitory machine-readable (e.g., computer-readable) storage media, which may be read and executed by one or more processors. A machine-readable storage medium may be embodied as any storage device, mechanism, or other physical structure for storing or transmitting information in a form readable by a machine (e.g., a volatile or non-volatile memory, a media disc, or other media device).
[0019] With reference to FIG. **1**, illustrated therein is a closure assembly **70** according to certain embodiments. The closure assembly **70** generally includes a door frame **72** and a door **74** swingingly mounted to the frame **72**, for example by one or more hinges. The closure assembly **70** further includes a door operator **80** according to certain embodiments. The illustrated door operator **80** generally includes a traditional door closer **90** and a powered opening module **100** according to certain embodiments.
[0020] The door closer **90** generally includes a closer body **92**, a pinion **94** rotatably mounted to the body **92**, and an armature **96** connected with the pinion **94**. The body **92** is mounted to one of the frame **72** or the door **74**, and the armature **96** is connected between the pinion **94** and the other of

the frame **72** or the door **74**. In the illustrated form, the body **92** is mounted to the door **74**, and the armature **96** is connected between the pinion **94** and the frame **72**. In other embodiments, the body **92** may be mounted to the frame **72**, and the armature **96** may be connected between the pinion **94** and the door **74**.

[0021] During operation of the door closer **90**, opening of the door **74** is correlated with rotation of the pinion **94** in a door-opening direction, and closing of the door **74** is correlated with rotation of the pinion **94** in a door-closing direction opposite the door-opening direction. Additionally, the closer **90** is configured to generate a biasing force urging the pinion **94** in the door-closing direction such that the closer **90** urges the door **74** toward its closed position. For example, the closer **90** may include a rack gear engaged with the pinion **94**, and a spring **98** engaged with the rack gear. In such forms, opening of the door **74** drives the pinion **94** in the door-opening direction, thereby shifting the rack gear in a first direction and compressing the spring **98**. During closing of the door **74**, the spring **98** expands, thereby driving the rack gear in a second direction opposite the first direction and urging the pinion **94** in the door-closing direction, thereby urging the door **74** toward its closed position. While the spring **98** is illustrated as a single individual spring, it should be appreciated that the spring **98** may include plural individual springs. The closer **90** may further include one or more hydraulic passages through which a hydraulic fluid flows to modulate the opening and/or closing speed of the door **74**. Door closers of this type are known in the art, and need not be described in detail herein.

[0022] In the illustrated form, the closer **90** further includes a spring adjustment mechanism **99** operable to adjust a preload of the spring **98**, and thus the force profile of the spring **98**. The force profile of the spring **98** may also depend upon additional or alternative factors, such as the stiffness of the spring **98** and/or the number of individual springs used. In certain forms, the spring adjustment mechanism **99** may comprise a screw that, when rotated, longitudinally drives a plate engaged with the spring **98** to selectively compress and expand the spring **98**. Those skilled in the art will readily appreciate that adjustment of the preload on the spring **98** adjusts the closing torque imparted to the door **74** by the closer **90**. While the illustrated operator **80** includes a spring adjustment mechanism **99** for adjusting the preload of the spring **98**, it is also contemplated that the preload of the spring **98** may not necessarily be adjustable, and that the spring **98** may instead be provided with a fixed force profile. In further embodiments, such as those in which the door **74** is moved wholly by a motor, the spring **98** may be omitted.

[0023] With additional reference to FIG. **2**, the powered opening module **100** generally includes a case **110**, a motor **120** mounted in the case **110**, a gear train **130** operably connected with the motor **120**, and a control assembly **140** in communication with the motor **120**. As described herein, the powered opening module **100** is configured to generate a force that urges the pinion **94** in the door-opening direction to at least assist in the opening of the door **74**. In certain embodiments, the powered opening module **100** may be of the types described in U.S. patent application Ser. No. 17/225,615 filed Apr. 8, 2021, the contents of which are incorporated by reference in their entirety.

[0024] The module case **110** houses the internal components of the module **100**, and includes an opening operable to receive an exposed end portion **95** of the pinion **94**. The case **110** is configured for mounting to at least one of the closer body **92**, the frame **72**, or the door **74**. In the illustrated form, the module case **110** is configured for mounting to the closer body **92**. Additionally or alternatively, the module case **110** may be configured for mounting to the door **74**. In certain embodiments, such as those in which the closer body **92** is mounted to the frame **72**, the module case **110** may likewise be configured for mounting to the frame **72**.

[0025] The motor **120** is mounted in the case **110**, is drivingly connected with the gear train **130**, and is in communication with the control assembly **140** such that the control assembly **140** is operable to control operation of the motor **120**. The motor **120** includes a body portion **122** and a motor shaft **124** that is rotated by the body portion **122** under control of the control assembly **140**. The motor shaft **124** is engaged with the gear train **130** such that rotation of the motor shaft **124** causes a corresponding rotation of the gear train **130**. In certain embodiments, the motor **120** may, for example, be provided as a DC brushless motor. It is also contemplated that the motor **120** may be provided in another form, such as that of a brushed motor or a stepper motor. The motor **120** is operable to rotate the motor shaft **124** in at least a first direction, and may be further operable to rotate the motor shaft **124** in a second direction opposite the first direction. As described herein, rotation of the motor shaft **124** in the first direction is correlated with opening of the door **74**, and rotation of the motor shaft **124** in the second direction is correlated with closing of the door **74**.

[0026] The gear train **130** is movably mounted in the case **110** and is engaged with the motor **120** such that the motor **120** is operable to drive the gear train **130**. The gear train **130** includes an input gear **132** engaged with the motor shaft **124** and an output shaft **134** engaged with the input gear **132** such that rotation of the motor shaft **124** is correlated with rotation of the output shaft **134**. For example, the input gear **132** may be operably connected with the output shaft **134** via one or more additional gears **136**. In the illustrated form, the gear train **130** is provided as a reduction gear set that provides the output shaft **134** with a greater torque and a lower speed than is provided to the motor shaft **124** by the motor **120**. It is also contemplated that the gear train **130** may be provided in another form, or may be omitted (e.g., in embodiments in which the motor **120** directly rotates the output shaft **134**).

[0027] The output shaft **134** includes a pinion interface **135** sized and shaped to receive the exposed end portion **95** of the pinion **94** for rotational coupling of the output shaft **134** with the pinion **94**. For example, in embodiments in which the end portion **95** of the pinion **94** has a generally hexagonal outer geometry, the pinion interface **135** may have a corresponding hexagonal inner geometry sized and shaped to matingly receive the exposed end portion **95** of the pinion **94**. When the module **100** is mounted to the closer **90**, the pinion **94** and the output shaft **134** are coupled for joint rotation such that rotation of the motor shaft **124** is correlated with rotation of the pinion **94**. More particularly, rotation of the motor shaft **124** in the first direction is correlated with rotation of the pinion **94** in the door-opening direction, and rotation of the motor shaft **124** in the second direction is correlated with rotation of the pinion **94** in the door-closing direction. As such, the first rotational direction for the motor shaft **124** may alternatively be referred to as the opening direction, and the second rotational direction for the motor shaft **124** may alternatively be referred to as the closing direction.

[0028] With additional reference to FIG. **3**, the control assembly **140** is in communication with the motor **120** and an actuator **84**, and is operable to control operation of the motor **120** based on information received from the actuator **84** using power drawn from an electrical power supply **76**. In certain embodiments, the power supply **76** may be provided as an onboard power supply, such as one or more batteries. In other embodiments, the power supply **76** may be an external power supply, such as line power. For example, the module **100** may be provided with a cord **102** including a plug **104** that is plugged into a standard power outlet **77** in the vicinity of the door **74**, where the power outlet **77** serves the function of the power supply **76**. The cord **102** may include an adapter **103** that converts the line power to a power suitable for use by the module **100**, such as about 24 volts (e.g., 24 volts+/−10%). The module **100** may be configured to operate under such reduced voltages, which may obviate the need for a skilled electrician installer by enabling the cord **102** to be plugged into a standard electrical outlet. In certain embodiments, the module **100** may be configured to receive electrical power and/or command signals via a Power-over-Ethernet connection.

[0029] As noted above, the control assembly **140** is in communication with the actuator **84**, and is configured to control operation of the motor **120** based on information received from the actuator **84**. More particularly, the actuator **84** is operable to transmit to the control assembly **140** an actuating signal in response to an actuating input provided by a user, and the control assembly **140** is configured to power the motor **120** to at least assist in opening the door **74** in response to receiving the actuating signal. In certain embodiments, the actuator **84** may be in wired communication with the control assembly **140**. Additionally or alternatively, the actuator **84** may be in wireless communication with the control assembly **140**.

[0030] The control assembly **140** generally includes a controller **142** and memory **143**. The controller **142** may, for example, be provided in the form of a computing device, such as that described below with reference to FIG. **10**. The memory **143** is a non-transitory computer-readable medium having instructions stored thereon, wherein the instructions, when executed by the controller **142**, cause the door operator **80** to perform one or more of the actions described herein. As described herein, the memory **143** may further include one or more lookup tables and/or one or more equations that aid the operator **80** in determining the mass moment of inertia (MMI) of the door **74** and/or a parameter corresponding to the MMI.

[0031] The control assembly **140** may further include a position sensor **144** configured to sense a rotational position of the output shaft **134**, a timing device **146**, and/or a user interface **148** operable to cause the control assembly **140** to perform a calibration procedure as described herein. The user interface **148** may, for example, include one or more buttons or switches that, when operated by a user, cause the control assembly **140** to initiate the calibration procedure. As should be appreciated, the control assembly **140** may further include additional components, such as power conditioning circuitry configured to convert the power received from the power supply **76** to a form usable by the motor **120**. As described herein, the controller **142** is configured to control operation of the motor **120** such that the powered opening module **100** generates a door-opening torque urging the pinion **94** in the door-opening direction to at least assist in opening the door **74** when a user actuates the actuator **84**.

[0032] The position sensor **144** is configured to sense the rotational position of the output shaft **134**, and thus the rotational position of the pinion **94**. In certain embodiments, the position sensor **144** may, for example, be provided in the form of a rotary encoder. It is also contemplated that the position sensor **144** may be provided in another form, such as that of an absolute position sensor. In certain forms, the controller **142** may be operable to determine when the door **74** has reached a desired position (e.g., a fully open position) based on information received from the position sensor **144**, and may control operation of the motor **120** based at least in part on the information received from the position sensor **144**. In the illustrated form, the position sensor **144** is associated with the motor shaft **124**, and is operable to determine the rotational position of the output shaft **134** (and thus of the pinion **94** and the door **74**) by monitoring the rotational position of the motor shaft **124**. It is also contemplated that the position sensor **144** may be associated with another component of the door operator **80** to monitor the position of the pinion **94** and the door **74**.

[0033] Those skilled in the art will readily appreciate that while the rotational position of the pinion **94** is correlated with the angular position of the door **74**, this correlation of positions depends upon a number of factors, such as the position of the operator **80** and the configuration of the armature **96**. However, those skilled in the art will readily be able to correlate rotational positions of the pinion **94** with angular positions of the door **74**. As such, the position of the door **74** can be determined based upon the information generated by the position sensor **144**. From this position information, the speed of the door **74** can likewise be determined (e.g., by deriving the door position with respect to time).

[0034] The timing device **146** is operable to monitor times and may, for example, be provided in the form of a timer and/or a clock. As described herein, certain embodiments of the present application involve initiating measurement of a time duration and ceasing measurement of the time duration to thereby determine the time duration. In embodiments in which the timing device **146** includes a timer, initiating measurement of the time duration may involve initiating the timer, and ceasing measurement of the time duration may involve stopping the timer such that the information output by the timer provides the time duration. It is also contemplated that initiating the measurement may involve noting a start time on the clock, that ceasing the time measurement may involve noting an end time on the clock, and determining the time duration may involve subtracting

the start time from the end time.
[0035] During operation of the illustrated closure assembly **70**, the door **74** is biased toward its closed position by the conventional door closer **90**. When a user approaches the closure assembly **70**, the presence of the user and/or the intent of the user to open the door **74** may be detected by the actuator **84**. Depending on the form of the actuator **84**, the actuator **84** may detect the user in a touchless fashion (e.g., by detecting the presence of the user or the waving of a hand or foot), or may detect the presence of the user in response to being physically acted on by the user (e.g., by the user depressing a button of the actuator **84**). Regardless of the manner in which the actuator **84** detects the presence of the user, the actuator **84** may transmit the actuating signal in response to detecting the user and/or the user's intent to open the door **74**.
[0036] Upon receiving the actuating signal from the actuator **84** (e.g., via a wired or wireless communication connection), the control assembly **140** powers the motor **120** with power received from the power supply **76** such that the motor **120** drives the motor shaft **124** in the first or opening direction. As a result, the gear train **130** urges the output shaft **134** and the pinion **94** in the door-opening direction, thereby urging the door **74** toward its open position. In certain embodiments, the torque supplied by the powered opening module **100** is sufficient to drive the door **74** toward its open position against the closing force supplied by the closer **90**. In other embodiments, the module **100** may merely provide a powered assist that aids the user in manually opening the door **74**. In certain embodiments, the control assembly **140** may operate the motor **120** for a predetermined period of time after receiving the actuating signal. Additionally or alternatively, the control assembly **140** may operate the motor **120** until information generated by the position sensor **144** indicates that the door **74** has reached a desired position (e.g., a fully open position). When operation of the motor **120** ceases, the door **74** may return to its closed position under the urging of the conventional door closer **90**.
[0037] In the illustrated form, the actuator **84** is external to the powered opening module **100**. In such forms, the actuator **84** may sense the user and/or the user's intent to open the door **74** directly, for example by detecting the user, the user's gestures, or the user's activation of a pushbutton. It is also contemplated that the actuator **84** may sense the user's intent to open the door **74** in another manner. For example, the actuator **84** may be provided within the powered opening module **100**, and may infer the user's intent to open the door **74** in response to an initial movement of the door **74** toward its open position. In response to detecting such initial movement of the door **74** (e.g., via the position sensor **144**), the control assembly **140** may operate the motor **120** to provide the user with a powered opening assist.
[0038] As should be evident from the foregoing, the control assembly **140** is operable to control the motor **120** to exert a force on the door **74** in at least one direction (i.e., the opening direction and/or the closing direction). As described herein, the control assembly **140** is further operable to perform a calibration procedure that may aid in determining the amount of current to be supplied to the motor **120** during a powered opening operation and/or a powered closing operation. While such calibration will generally be described with specific reference to the door operator **80** illustrated in FIGS. **1-3**, it should be appreciated that the processes described herein may be performed in conjunction with door operators having additional or alternative features. For example, while the illustrated door operator **80** includes a conventional hydraulic closer **90** and a powered opening module **100** releasably mounted to the closer **90**, it is also contemplated that a door operator according to certain embodiments may be provided as an original construction in which one or more features of the closer **90** and/or one or more features of the powered opening module **100** are provided together as a unit. In certain forms, a door operator may omit the spring **98** and/or the hydraulic features such that both opening and closing of the door **74** are performed primarily or wholly by a motor.
[0039] During powered opening and/or powered closing of the door **74**, it may be desirable to ensure that the kinetic energy of the door **74** remains below a threshold value. For a pivoting door,

the kinetic energy can be found according to the equation
[00001]$K=\frac{1}{2}$ .Math. MMI .Math. ^{2},
where K is the kinetic energy, MMI is the mass moment of inertia of the door **74**, and ω is the angular speed of the door **74**. Thus, for a given door **74** with a known MMI, the kinetic energy K can be kept below a threshold value K.sub.max by ensuring that the angular speed of the door does not exceed a maximum speed ω.sub.max, which can be calculated as ω.sub.max=√{square root over (2.Math.K.sub.max/MMI)}.
[0040] In order to ensure that the angular speed ω of the door **74** remains below the maximum speed ω.sub.max, it may be desirable to determine the MMI of the door **74**. As described herein, however, it may be unnecessary to calculate the actual MMI of the door **74**, and certain embodiments of the present application may instead involve measuring or calculating a parameter that merely corresponds to (e.g., is proportional to) the MMI.
[0041] With additional reference to FIG. **4**, an exemplary process **200** that may be performed using the door operator **80** is illustrated. Blocks illustrated for the processes in the present application are understood to be examples only, and blocks may be combined or divided, and added or removed, as well as re-ordered in whole or in part, unless explicitly stated to the contrary. Unless specified to the contrary, it is contemplated that certain blocks performed in the process **200** may be performed wholly by control assembly **140**, or that the blocks may be distributed among one or more of the elements and/or additional devices or systems that are not specifically illustrated in FIGS. **1-3**. Additionally, while the blocks are illustrated in a relatively serial fashion, it is to be understood that two or more of the blocks may be performed concurrently or in parallel with one another. Moreover, while the process **200** is described herein with specific reference to the closure assembly **70** and door operator **80** illustrated in FIGS. **1-3**, it is to be appreciated that the process **200** may be performed with closure assemblies **70** and/or door operators **80** having additional and/or alternative features.
[0042] The process **200** generally involves a calibration procedure **210** and an operation procedure **220**. As described herein, the calibration procedure **210** generally involves determining a maximum speed for the door **74**, and the operation procedure **220** generally involves performing at least one operation based upon the maximum speed.
[0043] The calibration procedure **210** may begin in response to a calibration-initiating input, such as one provided via the user interface **148**. For example, a user may press and hold a button of the user interface **148** until the calibration procedure **210** begins.
[0044] In certain embodiments, the calibration procedure **210** may involve block **212**, which generally involves determining a force profile of the spring **98**. As noted above, the closer **90** may include an adjustment mechanism **99** by which the preload of the spring **98** may be adjusted. For example, the screw of the adjustment mechanism **99** may have a first position corresponding to minimum preload and a second position corresponding to maximum preload, and may be rotatable a known number of times (e.g., about thirty) to move between the first position and the second position. Block **212** may involve determining the number of rotations that have been performed on the screw to adjust the preload of the spring **98**.
[0045] In certain forms, block **212** may involve driving the door to a predetermined open position, operating the motor **120** with a holding current to maintain the door in the predetermined open position, and reducing the holding current until the door **74** begins to move toward its closed position under force of the spring **98**. Such movement of the door **74** may, for example, be detected via the position sensor **144**. Block **212** may further involve determining the force profile of the spring **98** based on the reduced holding current that was provided to the motor **120** when the door **74** begin to move. As described herein, this force profile may be utilized in one or more other blocks of the calibration procedure **210**. It is also contemplated that block **212** may be omitted, for example in embodiments in which the force profile of the spring **98** is known and/or fixed, and/or embodiments in which the spring **98** is omitted and closing of the door **74** is performed by the

motor **120**.

[0046] The calibration procedure **210** includes block **214**, which generally involves initiating measurement of a time duration. Block **214** may, for example, be performed with the door **74** at a predetermined first position and with an initial speed $\omega_{initial}$. The door **74** being at the first position and the initial speed $\omega_{initial}$ may, for example, be determined based on information generated by the position sensor **144**. In certain embodiments, the initial speed $\omega_{initial}$ may be a non-zero speed, while in other embodiments the initial speed $\omega_{initial}$ may be zero.

[0047] The calibration procedure **210** may further include block **215**, which generally involves operating the motor **120** with a known motor torque profile such that the door speed ω_{door} changes. In certain embodiments, operating the motor **120** with the known motor torque profile may involve supplying no current to the motor **120**. In other embodiments, operating the motor **120** with the known motor torque profile may involve supplying the motor **120** with current.

[0048] The calibration procedure **210** may further include block **216**, which generally involves monitoring the door speed ω_{door}. Block **216** may, for example, involve monitoring the information generated by the position sensor **144**, from which the current position of the door **74** may be determined, for example as described above. Those skilled in the art will readily appreciate that the door speed ω_{door} corresponds to the rotational speed of the pinion **94**, and can be calculated (e.g., derived) based on the position information generated by the position sensor **144**.

[0049] The calibration procedure **210** further includes block **217**, which generally involves ceasing measurement of the time duration in response to the door **74** reaching a threshold speed $\omega_{threshold}$. With the measurement stopped, the duration of time Δt for the door **74** to accelerate or decelerate from the initial speed $\omega_{initial}$ to the threshold speed $\omega_{threshold}$ is known. As will be appreciated by those skilled in the art, an angular acceleration a can thus be calculated according to the equation $\alpha=\Delta\omega/\Delta t$, where $\Delta\omega$ is the difference between the initial speed $\omega_{initial}$ and the threshold speed $\omega_{threshold}$, each of which has a known value. Those skilled in the art will further appreciate that the angular acceleration can also be calculated according to the equation $\alpha=\tau/MMI$, where τ is the torque applied to the door **74** by the operator **80**, which torque corresponds to the motor torque profile provided to the motor **120**. Combining the prior two equations indicates that $\tau/MMI=\Delta\omega/\Delta t$, which can be rearranged as $\Delta t=\Delta\omega \cdot MMI/\tau$. Thus, for a given difference $\Delta\omega$ between the initial speed $\omega_{initial}$ and the threshold speed $\omega_{threshold}$, and a given motor torque profile, the time duration Δt is proportional to the MMI of the door **74**. As such, certain embodiments of the processes described herein may utilize the time duration Δt as a proxy for the MMI. It is also contemplated that the processes herein may involve calculating an intermediate parameter proportional to both the time duration Δt and the door MMI, or may involve calculating the MMI itself.

[0050] The calibration procedure **210** further includes block **218**, which generally involves determining the maximum speed ω_{max} based upon the time duration Δt. In certain embodiments, one or more maximum speeds ω_{max} may be stored in one or more lookup tables stored in memory **143**, for example as described herein. In certain embodiments, one or more maximum speeds ω_{max} may be determined computationally by the controller **142** based at least in part on the time duration Δt.

[0051] With additional reference to FIG. **5**, illustrated therein is an example lookup table **300** that may be utilized in block **218** to determine the target speed ω_{max}. The lookup table **300** includes a time column **310** and one or more maximum speed columns, illustrated as 320_1, 320_2 . . . 320_n. It should be appreciated that while the illustrated lookup table **300** has increments of 0.5 seconds for the time duration Δt, larger or smaller increments may be utilized to provide more or less granularity as desired. In the illustrated form, each of the maximum speed columns corresponds to a respective force profile for the spring **98**, which as noted above may be determined in block **212**. In such forms, block **218** may involve selecting the acceptable motor torque profile based on the time duration Δt and the force profile calculated in block **212**. For example, if it is determined that the preload of the spring **98** is at its minimum value and the time duration Δt is 2.2 seconds, block **218** may involve selecting speed ω.sub.15 as the maximum speed ω.sub.max. If it is determined that the preload of the spring **98** corresponds to one turn beyond the minimum and the time duration is 3.8 seconds, then block **218** may involve speed ω.sub.28 as the maximum speed ω.sub.max. As another example, if it is determined that the preload of the spring **98** is at its maximum value and the time duration Δt is 4.4 seconds, block **218** may involve selecting speed ω.sub.N9 as the maximum speed ω.sub.max.

[0052] While the illustrated lookup table **300** includes multiple columns corresponding to different force profiles of the spring **98**, it is also contemplated that the lookup table **300** may include a single speed column, for example in embodiments in which the force profile of the spring **98** is fixed and non-adjustable and/or embodiments in which the spring **98** is omitted. In such forms, block **218** may involve simply selecting the maximum speed ω.sub.max based on the time duration Δt, the MMI, or a calculated value corresponding to one or both of the time duration Δt and/or the MMI.

[0053] As noted above, the maximum speed ω.sub.max may be one that ensures that the door speed ω.sub.door remains low enough to ensure that the kinetic energy of the door **74** remains below a threshold kinetic energy. In certain embodiments, the threshold kinetic energy may be set by an applicable standard, such as the BHMA 156.19 standard. In certain embodiments, the threshold kinetic energy may be about 1.25 lbf-ft, or about 1.7 N-m. Armed with the present disclosure, those skilled in the art will readily be able to derive one or more look-up tables and/or one or more equations relating the time duration Δt to the appropriate maximum speed ω.sub.max.

[0054] As noted above, the illustrated process **200** further includes an operation procedure **220**, which generally involves performing at least one operation based upon the maximum speed ω.sub.max. In certain embodiments, the operation procedure **220** includes block **222**, which generally involves receiving a user selection of a target door speed ω.sub.target. Block **222** may, for example, involve the controller **142** receiving the user selection of the target door speed ω.sub.target via the user interface **148** and/or another device.

[0055] In certain forms, the target door speed ω.sub.target may be provided as an absolute speed value. For example, the user interface **148** may facilitate user selection of an absolute speed value from a set of available absolute speed values. By way of illustration, the user interface **148** may facilitate user selection of the target speed value from a set of values ranging from 10° per second to 30° per second. In such forms, the controller **142** may utilize closed-loop control based upon information received from the position sensor **144** to ensure that the speed of the door **74** ramps up to the selected absolute speed value. In certain embodiments, the door speed may be limited based upon the maximum speed ω.sub.max as described herein.

[0056] In certain forms, the target door speed ω.sub.target may correspond to a target pulse width modulation (PWM) duty cycle for the motor **120**. For example, the user interface **148** may facilitate user selection of a duty cycle from a set of available absolute speed values. By way of illustration, the user interface **148** may facilitate user selection of the target duty cycle from a set of values ranging from 40% to 100%. In such forms, the controller **142** may utilize open-loop control to ramp the PWM duty cycle for the motor **120** up to the selected duty cycle. In certain embodiments, the door speed may be limited based upon the maximum speed ω.sub.max as described herein.

[0057] In certain embodiments, the operation procedure **220** may include block **224**, which generally involves providing a warning if the target door speed ω.sub.target selected by the user exceeds or is expected to exceed the maximum speed ω.sub.max. For example, if the maximum speed ω.sub.max for the door **74** is determined to be 20° per second and the user selects a target speed ω.sub.target of 25°, the controller **148** may cause the user interface **148** to provide a visual warning (e.g., a red light) and/or an audible warning (e.g., a tone or spoken message). This may prompt the user to select a lower target speed ω.sub.target in order to comply with the applicable standard(s).

[0058] In certain embodiments, the operation procedure **220** may include block **226**, which generally involves limiting the door speed ω.sub.door to the maximum speed ω.sub.max. For example, if the controller **148** determines (e.g., based upon information received from the position sensor **148**) that the door speed ω.sub.door exceeds the maximum speed ω.sub.max, the controller **148** may dynamically adjust the duty cycle to ensure that the door speed door speed ω.sub.door does not exceed the maximum speed ω.sub.max.

[0059] With additional reference to FIG. **6**, illustrated therein is an example position-speed diagram for the door **74**. In certain embodiments, a “soft start” may be utilized, in which the duty cycle for the motor **120** is ramped up for a predetermined time and/or until the door **74** reaches a predetermined angular position θ′. In certain embodiments, the ramp-up acceleration, and/or the predetermined time or the predetermined position θ′ may be selected by the user.

[0060] Following the optional soft-start, the duty cycle of the motor **120** may be increased to accelerate the door **74** to its target speed ω.sub.target. In certain forms, such as those in which the operator **80** provides a warning in response to the selected target speed ω.sub.target exceeding the maximum speed ω.sub.max, the controller **142** may permit the door **74** to accelerate to the target speed ω.sub.target despite the target speed ω.sub.target exceeding the calculated maximum speed ω.sub.max, as illustrated in association with ω.sub.high. In other embodiments, the controller **142** may operate the motor **120** such that the door speed ω.sub.door is limited to the calculated maximum speed ω.sub.max. In situations where the target speed ω.sub.target is lower than the maximum speed ω.sub.max, the controller **142** may simply allow the door **74** to accelerate to its target speed ω.sub.target, as illustrated in association with ω.sub.low.

[0061] In certain forms, the operation procedure **220** may involve driving the door **74** toward a target position. In certain embodiments, the target position may be an open position. In such forms, block **222** may involve operating the motor **120** in response to actuation of the actuator **84**. In certain embodiments, the target position may be a closed position. In such forms, block **222** may involve operating the motor **120** in response to the door **74** reaching a particular position and/or in response to a predetermined hold-open time expiring.

[0062] As noted above, blocks may be combined or divided, and added or removed, as well as re-ordered in whole or in part. As one example, the determination of the maximum speed ω.sub.max in block **210** may be performed as part of a normal door movement operation. By way of illustration, an initial phase of the door movement may be performed with a known torque profile to accelerate the door **74** to the target speed ω.sub.target, and the time duration may be monitored to determine a maximum speed ω.sub.max for the remainder of the door movement. This maximum speed ω.sub.max may then be used for subsequent door movements, or may be recalculated during each door movement.

[0063] With additional reference to FIG. **7**, an exemplary process **400** that may be performed using the door operator **80** is illustrated. Blocks illustrated for the processes in the present application are understood to be examples only, and blocks may be combined or divided, and added or removed, as well as re-ordered in whole or in part, unless explicitly stated to the contrary. Unless specified to the contrary, it is contemplated that certain blocks performed in the process **400** may be performed wholly by control assembly **140**, or that the blocks may be distributed among one or more of the elements and/or additional devices or systems that are not specifically illustrated in FIGS. **1-3**. Additionally, while the blocks are illustrated in a relatively serial fashion, it is to be understood that two or more of the blocks may be performed concurrently or in parallel with one another. Moreover, while the process **400** is described herein with specific reference to the closure assembly **70** and door operator **80** illustrated in FIGS. **1-3**, it is to be appreciated that the process **400** may be performed with closure assemblies **70** and/or door operators **80** having additional and/or alternative features.

[0064] As described herein, the process **400** is an example implementation of the above-described calibration procedure **210**, and may, for example, be performed in connection with the above-described process **200**. It is also contemplated that the process **400** may be performed in connection with other processes and/or as a standalone process.

[0065] The illustrated process **400** includes block **410**, which generally involves stopping the door **74** at a known initial position θ.sub.initial such that the initial speed ω.sub.initial is equal to zero. In certain embodiments, block **410** may involve supplying the motor **120** with a first current to move the door **74** to the initial position θ.sub.initial, and then supplying the motor **120** with a holding current to hold the door **74** at the initial position θ.sub.initial. It is also contemplated that block **410** may involve the user manually driving the door **74** to the initial position, after which the holding current may be supplied to the motor **120**.

[0066] The process **400** also includes block **440**, which generally involves initiating measurement of the time duration. In the illustrated form, block **440** involves noting the start time to, for example based on information received from a clock of the timing device **146**. It is also contemplated that block **440** may involve initiating measurement of the time duration in another manner, such as by starting a timer of the timing device **146**.

[0067] The process **400** also includes block **450**, which generally involves operating the motor **120** with a known motor torque profile to alter the door speed ω.sub.door. In the illustrated form, the known motor torque profile is a fixed motor torque profile. In other forms, the known motor torque profile may be a variable motor torque profile, for example as described above.

[0068] The process **400** also includes block **460**, which generally involves monitoring the door speed ω.sub.door. More particularly, block **460** is provided as a conditional in which the door speed ω.sub.door is compared to the known threshold door speed ω.sub.threshold. If the door speed ω.sub.door does not correspond to the threshold speed ω.sub.threshold, the conditional **460** continues as indicated by path **460**N. If the door speed ω.sub.door corresponds to the threshold speed ω.sub.threshold, the process **400** continues to block **470**, as indicated by path **460**Y.

[0069] In response to the door speed ω.sub.door corresponding to the threshold speed ω.sub.threshold, measurement of the time duration is ceased in block **470** such that the value of the time duration Δt is known. In the illustrated form, determining the value of the time duration Δt involves recording the end time t.sub.1 in block **472**, and calculating the time duration Δt as the difference of t.sub.1 and to in block **474**. It is also contemplated that block **470** may involve stopping a timer of the timing device **146** such that the time duration Δt corresponds to the final value of the timer.

[0070] The process **400** also includes block **480**, which generally involves selecting the acceptable motor torque profile based on the time duration Δt, for example as described above. While not specifically illustrated, it should be appreciated that the process **400** may involve determining the force profile of the spring **98**. In such forms, block **480** may involve selecting the acceptable motor torque profile based on the time duration Δt and the force profile of the spring **98**, for example as described above.

[0071] With additional reference to FIG. **8**, an exemplary process **500** that may be performed using the door operator **80** is illustrated. Blocks illustrated for the processes in the present application are understood to be examples only, and blocks may be combined or divided, and added or removed, as well as re-ordered in whole or in part, unless explicitly stated to the contrary. Unless specified to the contrary, it is contemplated that certain blocks performed in the process **500** may be performed wholly by control assembly **140**, or that the blocks may be distributed among one or more of the elements and/or additional devices or systems that are not specifically illustrated in FIGS. **1-3**. Additionally, while the blocks are illustrated in a relatively serial fashion, it is to be understood that two or more of the blocks may be performed concurrently or in parallel with one another. Moreover, while the process **500** is described herein with specific reference to the closure assembly **70** and door operator **80** illustrated in FIGS. **1-3**, it is to be appreciated that the process **500** may be performed with closure assemblies **70** and/or door operators **80** having additional and/or alternative features.

[0072] As described herein, the process **500** is an example implementation of the above-described calibration procedure **210**, and may, for example, be performed in connection with the above-described process **200**. It is also contemplated that the process **500** may be performed in connection with other processes and/or as a standalone process.
[0073] The illustrated process **500** includes block **510**, which generally involves operating the motor **120** to drive the door **74** open at a fixed initial speed ω.sub.initial. Block **510** may, for example, involve operating the motor **120** with a first motor torque profile configured to cause the door **74** to open with the predetermined initial speed ω.sub.initial.
[0074] The process **500** includes block **520**, which generally involves monitoring the door position θ.sub.door, for example via the position sensor **144**. In the illustrated form, block **520** is a provided as a conditional in which the door position θ.sub.door is compared to the predetermined initial door position θ.sub.initial. If the door position θ.sub.door does not correspond to the predetermined initial door position θ.sub.initial, the conditional **520** continues as indicated by path **520**N. If the door position θ.sub.door corresponds to the predetermined initial door position θ.sub.initial, the process **500** continues to block **540** as indicated by path **520**Y.
[0075] The process **500** also includes block **540**, which generally involves initiating measurement of the time duration. In the illustrated form, block **540** involves noting the start time to, for example based on information received from a clock of the timing device **146**. It is also contemplated that block **540** may involve initiating measurement of the time duration in another manner, such as by starting a timer of the timing device **146**.
[0076] The process **500** also includes block **550**, which generally involves operating the motor **120** with a known motor torque profile to alter the door speed ω.sub.door. More particularly, in the illustrated form, block **550** involves increasing the torque of the motor **120** to thereby accelerate the door **74** such that the door speed ω.sub.door increases. Thus, in the current embodiment, the threshold speed θ.sub.threshold is greater than the initial speed ω.sub.initial. In certain forms, the known motor torque profile may be a fixed motor torque profile. In other forms, the known motor torque profile may be a variable motor torque profile, for example as described above.
[0077] The process **500** also includes block **560**, which generally involves monitoring the door speed ω.sub.door. In the illustrated form, block **560** is provided as a conditional in which the door speed ω.sub.door is compared to the known threshold speed ω.sub.threshold. If the door speed ω.sub.door does not correspond to the threshold speed ω.sub.threshold, the conditional **560** continues as indicated by path **560**N. If the door speed ω.sub.door corresponds to the threshold speed ω.sub.threshold, the process **500** continues to block **570**, as indicated by path **560**Y.
[0078] In response to the door speed ω.sub.door corresponding to the threshold speed ω.sub.threshold, measurement of the time duration Δt is ceased in block **570** such that the value of the time duration Δt is known. In the illustrated form, determining the value of the time duration Δt involves recording the end time t.sub.1 in block **572**, and calculating the time duration Δt as the difference of t.sub.1 and t.sub.0 in block **574**. It is also contemplated that block **570** may involve stopping a timer of the timing device **146** such that the time duration Δt corresponds to the final value of the timer.
[0079] The process **500** also includes block **580**, which generally involves selecting the acceptable motor torque profile based on the time duration Δt, for example as described above. While not specifically illustrated, it should be appreciated that the process **500** may involve determining the force profile of the spring **98**. In such forms, block **580** may involve selecting the acceptable motor torque profile based on the time duration Δt and the force profile of the spring **98**, for example as described above.
[0080] With additional reference to FIG. **9**, an exemplary process **600** that may be performed using the door operator **80** is illustrated. Blocks illustrated for the processes in the present application are understood to be examples only, and blocks may be combined or divided, and added or removed, as well as re-ordered in whole or in part, unless explicitly stated to the contrary. Unless specified to

the contrary, it is contemplated that certain blocks performed in the process **600** may be performed wholly by control assembly **140**, or that the blocks may be distributed among one or more of the elements and/or additional devices or systems that are not specifically illustrated in FIGS. **1-3**. Additionally, while the blocks are illustrated in a relatively serial fashion, it is to be understood that two or more of the blocks may be performed concurrently or in parallel with one another. Moreover, while the process **600** is described herein with specific reference to the closure assembly **70** and door operator **80** illustrated in FIGS. **1-3**, it is to be appreciated that the process **600** may be performed with closure assemblies **70** and/or door operators **80** having additional and/or alternative features.

[0081] As described herein, the process **600** is an example implementation of the above-described calibration procedure **210**, and may, for example, be performed in connection with the above-described process **200**. It is also contemplated that the process **600** may be performed in connection with other processes and/or as a standalone process.

[0082] The illustrated process **600** includes block **610**, which generally involves operating the motor **120** to drive the door **74** open at a fixed initial speed ω.sub.initial. Block **610** may, for example, involve operating the motor **120** with a first motor torque profile configured to cause the door **74** to open with the predetermined initial speed ω.sub.initial.

[0083] The process **600** includes block **620**, which generally involves monitoring the door position θ.sub.door, for example via the position sensor **144**. In the illustrated form, block **620** is a provided as a conditional in which the door position θ.sub.door is compared to the predetermined initial door position θ.sub.initial. If the door position θ.sub.door does not correspond to the predetermined initial door position θ.sub.initial, the conditional **620** continues as indicated by path **620**N. If the door position θ.sub.door corresponds to the predetermined initial door position θ.sub.initial, the process **600** continues to block **640** as indicated by path **620**Y.

[0084] The process **600** also includes block **640**, which generally involves initiating measurement of the time duration. In the illustrated form, block **640** involves noting the start time to, for example based on information received from a clock of the timing device **146**. It is also contemplated that block **640** may involve initiating measurement of the time duration in another manner, such as by starting a timer of the timing device **146**.

[0085] The process **600** also includes block **650**, which generally involves operating the motor **120** with a known motor torque profile to alter the door speed ω.sub.door. More particularly, in the illustrated form, block **650** involves decreasing the torque of the motor **120** to thereby decelerate the door **74** such that the door speed ω.sub.door decreases. Thus, in the current embodiment, the threshold speed ω.sub.threshold is less than the initial speed ω.sub.initial. In certain embodiments, the threshold speed ω.sub.threshold may be zero. In the illustrated form, the known motor torque profile is a fixed motor torque profile, and may involve operating the motor **120** to generate zero torque. In other forms, the known motor torque profile may be a variable motor torque profile and/or may involve operating the motor **120** to provide a non-zero torque.

[0086] The process **600** also includes block **660**, which generally involves monitoring the door speed ω.sub.door. In the illustrated form, block **660** is provided as a conditional in which the door speed ω.sub.door is compared to the known threshold speed ω.sub.threshold. If the door speed ω.sub.door does not correspond to the threshold speed ω.sub.threshold, the conditional **660** continues as indicated by path **660**N. If the door speed ω.sub.door corresponds to the threshold speed ω.sub.threshold, the process **600** continues to block **670**, as indicated by path **660**Y.

[0087] In response to the door speed ω.sub.door corresponding to the threshold speed ω.sub.threshold, measurement of the time duration is ceased in block **670** such that the value of the time duration Δt is known. In the illustrated form, determining the value of the time duration Δt involves recording the end time t.sub.1 in block **672**, and calculating the time duration Δt as the difference of t.sub.1 and to in block **674**. It is also contemplated that block **670** may involve stopping a timer of the timing device **146** such that the time duration Δt corresponds to the final value of the timer.

[0088] The process **600** also includes block **680**, which generally involves selecting the acceptable motor torque profile based on the time duration Δt, for example as described above. While not specifically illustrated, it should be appreciated that the process **600** may involve determining the force profile of the spring **98**. In such forms, block **680** may involve selecting the acceptable motor torque profile based on the time duration Δt and the force profile of the spring **98**, for example as described above.

[0089] It should be appreciated that one or more of the above-described processes **200**, **400**, **500**, **600** may be performed by an appropriately programmed door operator, such as the door operator **80**. Indeed, certain embodiments of the present application relate to a door operator configured to perform calibration and operation procedures along the lines described hereinabove. For example, a door operator **80** according to certain embodiments generally includes a body **92**, a pinion **94** rotatably mounted to the body **92**, a position sensor **144** operable to sense a position of the pinion **94**, a motor **120** operable to exert a torque on the pinion **94**, a controller **142** in communication with the position sensor **144** and the motor **120**, and memory **143** in communication with the controller **142**.

[0090] In certain forms, the memory **143** comprises instructions that, when executed by the controller **142**, cause the door operator **80** to perform a calibration procedure and/or an operation procedure. The calibration procedure generally includes initiating measurement of a time duration Δt at an initial time t.sub.0 at which the pinion **94** has an initial rotational speed, ceasing measurement of the time duration Δt in response to the pinion reaching a target rotational speed, and determining an acceptable motor torque profile based on the time duration Δt. Additionally, the operation procedure generally involves operating the motor **120** according to the acceptable motor torque profile to thereby drive the pinion **94** toward a target position. When the door operator **80** is installed to a closure assembly along the lines of the closure assembly **70**, the calibration procedure will result in selection of a motor torque profile that causes the door **74** to move toward the target position at an acceptable speed during performance of the operation procedure.

[0091] As should be appreciated from the foregoing, the subject matter described herein may aid in ensuring compliance with an applicable standard, such as the BHMA 156.19 standard for low-power auto-operators. More particularly, the subject matter described herein may enable a door operator **80** to automatically determine a parameter corresponding to the MMI of the door **74** and select a motor torque profile for subsequent operation of the door **74**, which may obviate the need for the installer to tune the operator **80** manually. In certain embodiments, the parameter corresponding to the MMI of the door **74** is the time duration Δt required to accelerate or decelerate the door **74** by a known speed difference Δω when a known motor torque is provided.

[0092] Referring now to FIG. **10**, a simplified block diagram of at least one embodiment of a computing device **700** is shown. The illustrative computing device **700** depicts at least one embodiment of a controller that may be utilized in connection with the controller **142** illustrated in FIG. **3**.

[0093] Depending on the particular embodiment, the computing device **700** may be embodied as a server, desktop computer, laptop computer, tablet computer, notebook, netbook, Ultrabook™, mobile computing device, cellular phone, smartphone, wearable computing device, personal digital assistant, Internet of Things (IoT) device, reader device, access control device, control panel, processing system, router, gateway, and/or any other computing, processing, and/or communication device capable of performing the functions described herein.

[0094] The computing device **700** includes a processing device **702** that executes algorithms and/or processes data in accordance with operating logic **708**, an input/output device **704** that enables communication between the computing device **700** and one or more external devices **710**, and memory **706** which stores, for example, data received from the external device **710** via the input/output device **704**.

[0095] The input/output device **704** allows the computing device **700** to communicate with the external device **710**. For example, the input/output device **704** may include a transceiver, a network adapter, a network card, an interface, one or more communication ports (e.g., a USB port, serial port, parallel port, an analog port, a digital port, VGA, DVI, HDMI, Fire Wire, CAT 5, or any other type of communication port or interface), and/or other communication circuitry. Communication circuitry may be configured to use any one or more communication technologies (e.g., wireless or wired communications) and associated protocols (e.g., Ethernet, Bluetooth®, Bluetooth Low Energy (BLE), Wi-Fi®, WiMAX, etc.) to effect such communication depending on the particular computing device **700**. The input/output device **704** may include hardware, software, and/or firmware suitable for performing the techniques described herein.

[0096] The external device **710** may be any type of device that allows data to be inputted or outputted from the computing device **700**. For example, in various embodiments, the external device **710** may be embodied as the actuator **84**, the motor **120**, the memory **143**, the position sensor **144**, the timing device **146**, and/or the user interface **148**. Further, in some embodiments, the external device **710** may be embodied as another computing device, switch, diagnostic tool, controller, printer, display, alarm, peripheral device (e.g., keyboard, mouse, touch screen display, etc.), and/or any other computing, processing, and/or communication device capable of performing the functions described herein. Furthermore, in some embodiments, it should be appreciated that the external device **710** may be integrated into the computing device **700**.

[0097] The processing device **702** may be embodied as any type of processor(s) capable of performing the functions described herein. In particular, the processing device **702** may be embodied as one or more single or multi-core processors, microcontrollers, or other processor or processing/controlling circuits. For example, in some embodiments, the processing device **702** may include or be embodied as an arithmetic logic unit (ALU), central processing unit (CPU), digital signal processor (DSP), and/or another suitable processor(s). The processing device **702** may be a programmable type, a dedicated hardwired state machine, or a combination thereof. Processing devices **702** with multiple processing units may utilize distributed, pipelined, and/or parallel processing in various embodiments. Further, the processing device **702** may be dedicated to performance of just the operations described herein, or may be utilized in one or more additional applications. In the illustrative embodiment, the processing device **702** is of a programmable variety that executes algorithms and/or processes data in accordance with operating logic **708** as defined by programming instructions (such as software or firmware) stored in memory **706**. Additionally or alternatively, the operating logic **708** for processing device **702** may be at least partially defined by hardwired logic or other hardware. Further, the processing device **702** may include one or more components of any type suitable to process the signals received from input/output device **704** or from other components or devices and to provide desired output signals. Such components may include digital circuitry, analog circuitry, or a combination thereof.

[0098] The memory **706** may be of one or more types of non-transitory computer-readable media, such as a solid-state memory, electromagnetic memory, optical memory, or a combination thereof. Furthermore, the memory **706** may be volatile and/or nonvolatile and, in some embodiments, some or all of the memory **706** may be of a portable variety, such as a disk, tape, memory stick, cartridge, and/or other suitable portable memory. In operation, the memory **706** may store various data and software used during operation of the computing device **700** such as operating systems, applications, programs, libraries, and drivers. It should be appreciated that the memory **706** may store data that is manipulated by the operating logic **708** of processing device **702**, such as, for example, data representative of signals received from and/or sent to the input/output device **704** in addition to or in lieu of storing programming instructions defining operating logic **708**. As illustrated, the memory **706** may be included with the processing device **702** and/or coupled to the processing device **702** depending on the particular embodiment. For example, in some embodiments, the processing device **702**, the memory **706**, and/or other components of the computing device **700** may form a portion of a system-on-a-chip (SoC) and be incorporated on a single integrated circuit chip.

[0099] In some embodiments, various components of the computing device **700** (e.g., the processing device **702** and the memory **706**) may be communicatively coupled via an input/output subsystem, which may be embodied as circuitry and/or components to facilitate input/output operations with the processing device **702**, the memory **706**, and other components of the computing device **700**. For example, the input/output subsystem may be embodied as, or otherwise include, memory controller hubs, input/output control hubs, firmware devices, communication links (i.e., point-to-point links, bus links, wires, cables, light guides, printed circuit board traces, etc.) and/or other components and subsystems to facilitate the input/output operations.

[0100] The computing device **700** may include other or additional components, such as those commonly found in a typical computing device (e.g., various input/output devices and/or other components), in other embodiments. It should be further appreciated that one or more of the components of the computing device **700** described herein may be distributed across multiple computing devices. In other words, the techniques described herein may be employed by a computing system that includes one or more computing devices. Additionally, although only a single processing device **702**, I/O device **704**, and memory **706** are illustratively shown in FIG. **10**, it should be appreciated that a particular computing device **700** may include multiple processing devices **702**, I/O devices **704**, and/or memories **706** in other embodiments. Further, in some embodiments, more than one external device **710** may be in communication with the computing device **700**.

[0101] While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only the preferred embodiments have been shown and described and that all changes and modifications that come within the spirit of the inventions are desired to be protected.

[0102] It should be understood that while the use of words such as preferable, preferably, preferred or more preferred utilized in the description above indicate that the feature so described may be more desirable, it nonetheless may not be necessary and embodiments lacking the same may be contemplated as within the scope of the invention, the scope being defined by the claims that follow. In reading the claims, it is intended that when words such as “a,” “an,” “at least one,” or “at least one portion” are used there is no intention to limit the claim to only one item unless specifically stated to the contrary in the claim. When the language “at least a portion” and/or “a portion” is used the item can include a portion and/or the entire item unless specifically stated to the contrary.

Claims

1-13. (canceled)

14. A door operator, configured for use with a door, the door operator comprising: a body; a pinion rotatably mounted to the body; a position sensor operable to sense a position of the pinion; a motor operable to exert a torque on the pinion; a controller in communication with the position sensor and the motor; and memory in communication with the controller; wherein the memory comprises instructions that, when executed by the controller, cause the door operator to perform a calibration procedure comprising: initiating measurement of a time duration at an initial time at which the pinion has an initial rotational speed; ceasing measurement of the time duration in response to the pinion reaching a threshold rotational speed; and determining a maximum speed for the door based upon the time duration; and wherein the memory further comprises instructions that, when executed by the controller, cause the door operator to perform an operation based upon the maximum speed for the door.

15. The door operator of claim 14, further comprising a spring biasing the pinion in a door-closing direction, the spring having a force profile; wherein the memory further comprises instructions that, when executed by the controller, cause the door operator to determine the force profile of the spring; and wherein determining the maximum speed based upon the time duration comprises determining the maximum speed based upon the time duration and the force profile of the spring.

16. The door operator of claim 14, wherein the operation comprises limiting a rotational speed of the pinion based upon the maximum speed.

17. The door operator of claim 14, wherein to perform the calibration procedure further comprises operating the motor with a known motor torque profile for the time duration.

18. The door operator of claim 17, wherein operating the motor with the known motor torque profile involves generating, by the motor, a non-zero torque during at least a portion of the time duration.

19. The door operator of claim 14, wherein to perform the calibration procedure further comprises calculating a mass moment of inertia parameter based upon the time duration; and wherein determining the maximum speed based upon the time duration comprises determining the maximum speed based upon the mass moment of inertia parameter.

20. The door operator of claim 14, wherein the operation comprises providing a warning in response to a user-selected speed exceeding the maximum speed.

21. A door operator configured for use with a door, comprising: a body; a pinion rotatably mounted to the body; a position sensor operable to sense a position of the pinion; a motor operable to exert a torque on the pinion; a controller in communication with the position sensor and the motor; and memory in communication with the controller; wherein the memory comprises instructions that, when executed by the controller, cause the door operator to perform a calibration procedure comprising: operating the motor with a known torque profile; determining a time duration, the time duration beginning when the pinion has a predetermined initial rotational speed and ending when the pinion reaches a threshold rotational speed; and determining a maximum door speed based on the time duration; and wherein the memory further comprises instructions that, when executed by the controller, cause the door operator to perform an operation based upon the maximum door speed.

22. The door operator of claim 21, wherein operating the motor with the known motor torque profile involves generating, by the motor, a non-zero torque during at least a portion of the time duration.

23. The door operator of claim 21, wherein to perform the calibration procedure further comprises calculating a mass moment of inertia parameter based upon the time duration; and wherein determining the maximum door speed based upon the time duration comprises determining the maximum door speed based upon the mass moment of inertia parameter.

24. The door operator of claim 21, further comprising a user interface operable to receive a user selection of a user-selected target door speed; wherein the operation comprises providing a warning in response to the user-selected target door speed exceeding the maximum door speed.

25. The door operator of claim 21, wherein the operation comprises limiting a rotational speed of the pinion based upon the maximum speed.

26. The door operator of claim 21, further comprising a spring biasing the pinion in a door-closing direction, the spring having a force profile; wherein the memory further comprises instructions that, when executed by the controller, cause the door operator to determine the force profile of the spring; and wherein determining the maximum speed based upon the time duration comprises determining the maximum speed based upon the time duration and the force profile of the spring.

27. A door operator configured for use with a door, comprising: a body; a pinion rotatably mounted to the body, wherein the pinion is operably coupled with the door such that rotation of the pinion is correlated with swinging movement of the door; a position sensor operable to sense a position of the pinion; a motor operable to exert a torque on the pinion to thereby affect the swinging movement of the door; a control assembly in communication with the position sensor and the motor; wherein the control assembly is configured to perform a calibration procedure comprising: operating the motor with a known torque profile; determining a time duration, wherein the door has an initial door speed at a beginning of the time duration, and wherein the time duration ends when the door reaches a threshold door speed; and determining a maximum allowable door speed for the door based upon the time duration; and wherein the control assembly is further configured to perform an operation based upon the maximum allowable speed for the door.

28. The door operator of claim 27, wherein operating the motor with the known motor torque profile involves causing the motor to exert on the pinion a non-zero torque during at least a portion of the time duration.

29. The door operator of claim 27, wherein determining the time duration comprises: initiating measurement of the time duration when the door has the initial door speed and a predetermined initial door position; and ceasing measurement of the time duration in response to the door reaching the threshold door speed.

30. The door operator of claim 27, wherein to perform the calibration procedure further comprises calculating a mass moment of inertia parameter based upon the time duration; and wherein determining the maximum allowable speed for the door based upon the time duration comprises determining the maximum allowable speed for the door based upon the mass moment of inertia parameter.

31. The door operator of claim 27, further comprising a spring biasing the pinion in a door-closing direction, the spring having a force profile; wherein the control assembly is further configured to determine the force profile of the spring; and wherein determining the maximum allowable speed for the door based upon the time duration comprises determining the maximum allowable speed for the door based upon the time duration and the force profile of the spring.

32. The door operator of claim 27, further comprising a user interface operable to receive a user selection of a user-selected target door speed; wherein the operation comprises providing a warning in response to the user-selected target door speed exceeding the maximum allowable speed for the door.

33. The door operator of claim 27, wherein the operation comprises limiting a rotational speed of the door based upon the maximum allowable speed for the door.
