

Controlling Elevator Motion Profile

5 Motion control of an elevator car involves
regulating the movement of an elevator car from an
origin floor to a destination floor. Car motion may
be controlled by using jerk rates, acceleration rates
and deceleration rates to regulate the rate of change
of acceleration and velocity to maintain the forces
acting on a passenger within the car within a
subjective comfort zone. A typical motion profile
10 also includes a maximum desired speed which the
elevator car will attain during longer floor runs,
also known as the contract speed. A feedback loop
may be used to regulate the car motion especially as
the car decelerates to a stop as it approaches the
15 destination floor.

On short runs elevator cars usually do not
achieve their desired maximum speed. On longer runs
an elevator car travels at maximum speed after it is
accelerated to that speed once it leaves the origin
20 floor and it continues at maximum speed until it must
decelerate to stop at the destination floor. For
both short runs and longer runs the overall flight
time, the time period extending from when the
elevator doors are closed at the origin floor until
25 the doors open at the destination floor, may be
reduced if the elevator car accelerates and
decelerates faster either allowing the car to reach a

higher speed on a short run or to operate for longer periods at maximum speed in a longer run. By reducing the flight time between floors, the waiting time for passengers awaiting arrival of an elevator car is reduced, the travel time for passengers in the elevator car is reduced, and the overall capacity of the elevator system to move people is increased.

The designers of elevator systems have typically preselected a particular motion profile for each elevator system which represents a compromise between fast flight times and increased capacity as opposed to slow flight times and increased comfort. The profile selected for each elevator might even differ based upon the particular market where the elevator would be installed and the expectations of passengers on a desired comfort level and the need for faster service. For instance, Far Eastern passengers prefer a motion profile with relatively slow jerk and acceleration rates such that a smoother, more comfortable ride is obtained and are more willing to wait longer for the elevator car to arrive than other passengers. The typical North American passenger has been less concerned with comfort and is more concerned with fast flight times and decreased waiting time and, therefore, would prefer to have the elevator car operated at a faster profile with slightly less passenger comfort due to the higher acceleration and jerk rates.

The present invention minimizes the problem of making compromises between comfort and performance in preselecting a particular motion profile by providing for the selection of varying profiles allowing passenger comfort to be maximized while maintaining a sufficient elevator system capacity to serve all passengers.

According to the invention, there is provided an elevator system including a variable speed motive means, at least one elevator car connecting to the motive means and arranged to travel between floors in a building to service variable intensity traffic in the building and a control system for receiving input signals and controlling the variable speed motive means and the motion of the car, comprising: signal processing means connected to provide input signals to the control system to control the motion of the car, said signal processing means including determining means for determining, in each of a plurality of successive relatively short time intervals, an indication of traffic intensity in the building; means for providing a plurality of predetermined criteria for determining the level of traffic intensity indicated by said indication; motion profile means for providing a plurality of car motion profiles, including a sequence of at least three profiles extending from a slowest profile to a fastest profile, each of said criteria corresponding to one of said profiles in said sequence with the slowest profile corresponding to the criterion indicating the lowest intensity traffic; and selection means for providing, in response to the presence of indication of a peak traffic period, a first profile which is the fastest profile of said plurality of profiles, and for providing, in response to the absence of indication of a peak traffic period, either the profile corresponding to the criterion to which said indication of traffic intensity of the next preceding interval corresponds, or said fastest speed profile if said indication of traffic intensity exceeds all of said criteria; wherein said control system dispatches the elevator car to service a call utilizing the provided one of said profiles to control the motion of the car.

The present invention concerns an elevator system having a variable speed motive means for displacing an elevator car between floors in a building in accordance with a motion profile. In order to provide increased passenger comfort while maintaining sufficient elevator

capacity to service the elevator needs of a building, a selection is made between varying motion profiles. The slowest motion profile which maintains sufficient elevator service for the building is usually selected. A different

5 profile is selected when detection of a preemptory event, such as, operator override, an override scheduled for preselected time periods or the occurrence of peak periods when the building is experiencing a peak traffic pattern, such as up-peak or down-peak periods at the beginning and

10 end of the workday in an office

building.

Signal processing means may be connected to provide input signals to the control system of the elevator system to control the motion of the car. The signal processing means includes motion profile means for generating a series of more than two elevator car motion profiles, the profiles acting to cause the motive means to displace the car such that the travel time between floors is different. Selection means are provided for determining the traffic demand and for selecting which car motion profile will be used to control the motive means.

The selection of a particular motion profile may be based on a factor related to traffic intensity, such as the average registration time (the time period between when a hall button is pushed indicating the origin floor for the hall call button until such time as the elevator car arrives at the origin floor corresponding to the hall call). This time is an indicator of traffic intensity. A series of ranges of a measurement indicative of traffic intensity may be stored and a corresponding motion profile selected for each range when a detected traffic intensity level falls within that range. Alternatively, the selection may be based on predictions of the number of passengers anticipated or predictions of the anticipated average waiting time for a passenger.

The selection of a particular motion profile may also be based on the absence or presence of passengers in the elevator car.

Upon the detection of a peak load condition, such as an office building up-peak in the morning or a down-peak at the close of business, the elevator

car motion profile having the shortest flight time may be selected to increase the system capacity for the elevator. Peak load conditions may be determined by various factors, such as, two cars leaving a lobby having a preselected level of loading within a certain time period of each other, the load sensor sensing the passenger load of each elevator car, a crowd sensor indicating a crowd of people waiting for an elevator car, or two cars reaching the lobby at a certain load level within a certain time period, or other means including but not limited to a timed input or a manually operated switch.

During periods of reduced traffic, the jerk, acceleration and deceleration rates may be reduced increasing the flight time between floors enhancing the smoothness of the ride and the comfort level of the elevator car passenger without increasing the waiting time for passengers awaiting an elevator car beyond a desired level and while maintaining sufficient elevator system capacity to serve all the passengers.

In the past the motion profile selected to operate the elevator car did not vary dependent upon usage or operating parameters. Hence, the motion profile selected would have appropriate jerk and acceleration rates for a smooth passenger ride even if no passengers were in the car and, consequently, the elevator car, even when empty, would take longer to get from the origin floor to the destination floor than it would if it were immediately operated at the highest available acceleration and jerk rates to accelerate to contract speed. Hence, it is possible to increase overall elevator system capacity and to reduce the average waiting time of the passenger for an elevator car by operating the elevator car when there are no passengers in the elevator car at a

faster motion profile resulting in a reduced flight time.

Certain embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings.

Brief Description of the Drawings

Figure 1 is a schematic representation of an elevator system.

Figure 2 is a graph of a velocity profile for the fastest exemplary profile.

Figure 3 is a graph of a velocity profile for the intermediate exemplary profile.

Figure 4 is a graph of a velocity profile for the slowest exemplary profile.

Figure 5 is a flowchart depicting the logic involved in the selection between velocity profiles.

Figure 6 is a flowchart depicting the logic involved in the selection between velocity profiles based on absence or presence of passengers.

Referring first to Figure 1, a schematic representation of an elevator system is shown with elevator car 10 mounted within a shaftway (not shown) for vertical displacement. Elevator car 10 is connected by rope 12 over sheave 14 extending behind car 10 to counterweight 20. Motor 16 acts to control the rotation of drive shaft 18 on which sheave 14 is mounted. Operation of motor 16 effects rotation of sheave 14 thereby causing the elevator car and counterweight to be displaced in a vertical direction.

Motor control 22, sometimes referred to as the drive in the elevator industry, includes the

appropriate power electronics for supplying power to the motor to cause the motor to rotate at selected acceleration, jerk and velocity levels to cause the elevator car to move or be displaced in the desired manner. Appropriate electrical characteristics of the power supplied by the motor are generated via motor control 22.

Controller 24 contains the logic signal processing means to regulate elevator system operation. A car operating panel 11 mounted within the elevator car is connected to controller 24 via travelling cable 26 extending from the elevator car to the controller. Hall call buttons 28, 30, and 32 are arranged on floors 1 through 3 and are all connected via serial link 34 to controller 24. Controller 24 typically contains a programmed microprocessor which receives data indicative of the status of the various buttons in car operating panel 11 and the hall call buttons and is capable of utilizing this information in a variety of control functions. The software necessary to operate the elevator is stored in the controller including software which may generate various velocity profiles.

Figure 2 shows an exemplary velocity profile and is a graph with velocity plotted on the vertical axis and time on the horizontal axis. This profile is chosen to depict flight of an elevator car from an origin floor to a destination floor and it is assumed that the flight is long enough that the elevator car reaches contract speed for some indefinite period of

time. Since the contract speed will not vary with the chosen motion profile, it is shown as a broken line of finite length to indicate that the elevator car may travel at the contract speed for varying lengths of time depending on the distance travelled between the original floor and the destination floor.

In Figure 2 there is indicated a portion of the curve from point A, when the elevator car is just leaving the destination floor, to point B. This portion from A to B may be a constant jerk portion wherein the rate of change of acceleration or jerk is maintained constant. Thereafter, from point B to point C there is depicted a constant acceleration portion of the profile where the elevator car continues to accelerate at a constant rate. From point C to point D there is depicted another constant jerk portion where the rate of change of acceleration is maintained constant until point D at which point the elevator has reached its contract speed or maximum velocity. The elevator travels at constant velocity for the period depicted by the line from point D to point E, point E being where the car begins to decelerate to stop at its destination floor. The portion of the graph from E to F depicts a constant jerk portion of the profile wherein the elevator car is decelerated at a constantly changing rate to point F. From point F to point G there is depicted a constant deceleration zone indicating the elevator car is decelerated at a constant rate. From point G to point H the elevator car continues to decelerate until it arrives at the destination floor.

Many ways are utilized to coordinate the slowing of the elevator car as it approaches the destination floor such that the elevator car may stop within a very narrow range adjacent the floor. Typically, a feedback control of some nature is utilized to sense the exact position of the car and to effect stopping the car at the desired point.

Figure 3 is a graph of an exemplary intermediate profile having the same segments as Figure 2. The difference between Figure 2 and Figure 3 is that the jerk rate, sections A-B, C-D and E-F, is less than the jerk rate in Figure 2 and the constant acceleration of section B-C and constant deceleration of area F-G are both at reduced rates from Figure 2. What this means is that a passenger riding in an elevator car operated in accordance with the motion profile of Figure 3 senses a smoother, higher quality ride than if the car were operated in accordance with the profile of Figure 2, however, it takes longer to reach contract speed and the average speed of the elevator car is reduced and, consequently, the time elapsed between the elevator doors closing at the origin floor and the elevator doors opening at the destination floor, or flight time, is increased.

Figure 4 is a graph of an exemplary slowest velocity profile. The same segments as for the other profiles are provided, however, the jerk rate and rate of acceleration and deceleration are even more reduced than those depicted in Figure 3, resulting in a slower, more comfortable ride. A comparison between the slope of the curves of the three graphs shows the

reduction in jerk and acceleration rates and the relative positioning of the constant velocity section of each curve indicates that it takes longer to reach constant velocity and longer to decelerate from
5 constant velocity to the destination floor using a slower velocity or motion profile. Again, the slower jerk, acceleration and deceleration rates provide an even increased sense of a smooth quality ride, however, the slower rates increase the flight time
10 between floors. The slope of the various curves of Figures 2, 3 and 4 further indicates the differences in jerk and acceleration rates.

A velocity profile as shown in Figure 2 may be an example of a profile more adapted to the North
15 American marketplace where passengers are more willing to experience some reduced comfort in ride to achieve decreased flight times.

The Figure 4 profile might be a profile more adapted to a Far Eastern market where passengers have
20 become accustomed to a smoother ride and lower acceleration rates and would not object to slightly longer waiting times or reduced elevator performance.

A profile may be defined by a mathematical formula including constants. Various profiles may be
25 generated by changing the constants used to generate the profile. The constants for different profiles may be stored in a "look up" table portion of a computer program and thereafter selected to generate an appropriate profile as are depicted between
30 Figures 2, 3 and 4.

Figure 5 is a flowchart depicting a portion of a program which may select which profile should be used. Beginning at the top of the flowchart in the start position, the logic flows to step 41 wherein the question is asked whether or not there is an external input, such as, a keyboard, a key switch or some other manually operated device which is overriding the logic and indicating that a specific preprogrammed profile should be selected based upon that override. If the answer to logic question 41 is "Yes", the logic flows to block 47 where the preprogrammed profile is selected. If the answer to logic question 41 is "No", logic flows to block 42 and asks the question whether or not there is a programmed input based on time of day. If the answer is "Yes", the logic flow is to block 47 and the preprogrammed profile for that time of day is selected. If the answer to logic question 42 is "No", the logic flows to block 43 wherein it is determined whether or not an elevator system is in an up-peak or down-peak period. If the answer to whether or not an elevator system is in an up-peak or down-peak period is "Yes", then the fastest profile is selected in block 48 and the elevator system operates at peak capacity. If the answer to logic question 43 is "No", the logic flows on to block 44.

In block 44 a logic question asks whether or not the last five minutes average registration time in seconds is less than or equal to a preselected value A. If the answer to logic question 44 is "Yes", the logic flow is to block 49 and profile #1, a

relatively slow profile providing high ride quality, is selected. If the answer to logic question 44 is "No", the logic flow is to block 45 and the same question is asked with a slightly higher value B indicative of an increased demand for elevator service. If the answer to the question whether the last five minutes average registration time is less than or equal to the value B is "Yes", then the logic flows to block 50 and a faster profile is selected.

If the answer to logic question in block 45 is "No", the logic flows to block 46 where the logic question whether the last five minutes average registration time in seconds is less than or equal to value X is asked. If the answer is "Yes", then the logic flows to block 51 and a faster profile #N is selected. Profile #N and value X in blocks 46 and 51 are selected to indicate that there may be any one of a series of profiles generated and it is the appropriate profile in this series that is selected to meet the elevator service demand while providing the appropriate level and providing the most comfortable ride.

If the answer to the logic question in block 46 is "No", the logic flow is to block 52 and the fastest motion profile is selected providing for maximum elevator service.

Referring now to Figure 6, there may be seen a logic flow chart for implementing a computer program to select which profile should be used in the instance where the elevator may be operated at maximum acceleration and jerk rates when no

passengers are present in the car. Beginning at the top of the chart which is marked "Start", the logic flows to Box 1 to ask the logic question "Is a run committed?". This question means is the elevator car and its dispatching system committed to moving from one floor to another. If the answer is "No", the logic continues in a loop until the answer is "Yes". If the answer is "Yes", the logic flows to block 2 and asks the logic question "Does the load weight indicate passengers are present?". If the answer to the logic question in block 2 is "Yes", the logic flows to block 5 and the comfortable profile is selected. If the answer to the logic question in block 2 is "No", the logic flow is then to block 3 and the question of "Are there any car calls?" is asked. If the answer to the question in block 3 of whether there are any car calls is "Yes", the logic flows to block 5 and again the comfortable profile is utilized. If the answer to logic question in block 3 is "No", the logic flows to block 4 and the high performance profile is utilized. From blocks 4 and 5 the logic flow continues through the remainder of the elevator control program.

The run committed question in logic block 1 is utilized merely to establish that the elevator car will be moving from one floor to another. Until the run is committed the number of occupants, if any, in the elevator car may change. If the car is not moving, a motion profile need not be selected. In logic block 2 the question of whether the load in the car is indicative of passengers is asked to determine

if the car is occupied or not. If the car is occupied or if there is additional weight above and beyond that of the car itself, it is desirable not to operate the car at the high performance profile which may be uncomfortable to passengers. Consequently, if the loadweighing device does indicate that passengers are present, then the comfortable profile having lower acceleration and jerk rates is utilized.

Even if there are no passengers indicated to be present by the loadweighing means, the logic flow additionally asks the question of whether or not there are any car calls. Car calls are entered when a person pushes a button within the elevator car indicative of a destination floor. If there are car calls, then it is assumed that there is a passenger in the elevator car even if the loadweighing device does not detect additional load. In any event, if a car call button is pushed, the more comfortable profile is used.

In the manner described we have seen the elevator car may be operated more quickly to travel unoccupied to a destination floor to pick up a waiting passenger. In this manner the overall performance of the elevator system may be increased by allowing operation which would be less comfortable to the passenger to be utilized when there are no passengers in the elevator car.

CLAIMS

1. An elevator system including a variable speed motive means, at least one elevator car connecting to the motive means and arranged to travel between floors in a building to service variable intensity traffic in the building and a control system for receiving input signals and controlling the variable speed motive means and the motion of the car, comprising:
- 10 signal processing means connected to provide input signals to the control system to control the motion of the car, said signal processing means including
- determining means for determining, in each of a plurality of successive relatively short time intervals, an indication of traffic intensity in the building;
- 15 means for providing a plurality of predetermined criteria for determining the level of traffic intensity indicated by said indication;
- motion profile means for providing a plurality of car motion profiles, including a sequence of at least three profiles extending from a slowest profile to a fastest profile, each of said criteria corresponding to one of said profiles in said sequence with the slowest profile corresponding to the criterion indicating the lowest
- 20 intensity traffic; and
- selection means for providing, in response to the presence of indication of a peak traffic period, a first profile which is the fastest profile of said plurality of profiles, and for providing, in response to the absence of indication of a peak traffic period, either the profile corresponding to the criterion to which said indication of traffic intensity of the next preceding interval corresponds, or said fastest speed profile if said
- 30 indication of traffic intensity exceeds all of said criteria;
- 35 wherein said control system dispatches the elevator car to service a call utilizing the provided one of said profiles to control the motion of the car.



2. A system according to claim 1, wherein said indication of traffic intensity is the average amount of time during said interval that hall calls registered in said interval remained outstanding.

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3. A system according to claim 1 or 2, wherein said motion profile means further provides a number of specific profiles each corresponding to one of a number of related discrete indications; and

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said selection means provides, in response to the presence of any one of said discrete indications, a selected one of said specific profiles corresponding to said discrete indication.

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4. A system according to claim 3, wherein one of said discrete indications comprises an indication of the occupancy of the elevator car, and said selection means provides a specific faster motion profile in response to an indication that the car is unoccupied.

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5. A control for an elevator system having a variable speed motive means for regulating the movement of an elevator car between floors of a building to service variable intensity traffic in the building, said control receiving input signals indicative of the passenger demand for elevator service and providing output signals to the variable speed motive means to effect the desired movement of the elevator car, the control comprising:

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determining means for determining, in each of a plurality of successive relatively short time intervals, an indication of traffic intensity in the building;

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means for providing a plurality of predetermined criteria for determining the level of traffic intensity indicated by said indication;

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motion profile means for providing a plurality of car motion profiles, including a sequence of at least three profiles extending from a slowest profile to a fastest profile, each of said criteria corresponding to one of said



profiles in said sequence with the slowest profile corresponding to the criterion indicating the lowest intensity traffic; and

5 selection means for providing, in response to the presence of indication of a peak traffic period, a first profile which is the fastest profile of said plurality of profiles, and for providing, in response to the absence of indication of a peak traffic period, either the profile corresponding to the criterion to which said indication of
10 traffic intensity of the next preceding interval corresponds, or said fastest speed profile if said indication of traffic intensity exceeds all of said criteria;

15 wherein said control system dispatches the elevator car to service a call utilizing the provided one of said profiles to control the motion of the car.

6. A control according to claim 5, wherein said indication of traffic intensity is the average amount of
20 time during said interval that hall calls registered in said interval remained outstanding.

7. A control according to claim 5 or 6, wherein said motion profile means further provides a number of specific
25 profiles each corresponding to one of a number of related discrete indications; and

said selection means provides, in response to the presence of any one of said discrete indications, a selected one of said specific profiles corresponding to
30 said discrete indication.

8. A control according to claim 7, wherein one of said discrete indications comprises an indication of the occupancy of the elevator car, and said selection means
35 provides a specific faster motion profile in response to an indication that the car is unoccupied.

9. A method of operating an elevator system to provide



variable speed car travel to service variable intensity traffic in a building, comprising:

determining, in each one of a plurality of successive relatively short time intervals, an indication of traffic intensity in the building;

providing a plurality of predetermined criteria for determining the level of traffic intensity indicated by said indication;

providing a plurality of car motion profiles, including a sequence of at least three profiles extending from a slowest profile to a fastest profile, each of said criteria corresponding to one of said profiles in said sequence with the slowest profile corresponding to the criterion indicating the lowest intensity traffic; the method further comprising the steps of:

a) providing, in response to the presence of an indication of a peak traffic period, a first profile which is the fastest profile of said plurality of profiles;

b) providing, in response to the absence of said indication of a peak traffic period, either the profile corresponding to the criterion to which said indication of traffic intensity of the next preceding interval corresponds, or said fastest speed profile if said indication of traffic intensity exceeds all of said criteria; and

dispatching an elevator car to service a call utilizing the provided one of said profiles to control the motion of said car.

10. A method according to claim 9, wherein said indication of traffic intensity is the average amount of time during said interval that hall calls registered in said interval remained outstanding.

11. A method according to claim 9 or 10 comprising: providing a number of specific profiles each corresponding to one of a number of related discrete indications;



providing, in response to the presence of any one of said discrete indications, a selected one of said specific profiles corresponding to said discrete indication; and wherein

5 said steps a) and b) are performed only in the absence of one of said discrete indications.

12. A method according to claim 11, wherein one of said discrete indications comprises an indication of the
10 occupancy of the elevator car, and said method further comprises providing a specific, faster profile in response to an indication that the car is unoccupied.

13. An elevator system substantially as hereinbefore
15 described with reference to the accompanying drawings.

14. A control for an elevator system, substantially as hereinbefore described with reference to the accompanying drawings.

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15. A method of operating an elevator car, substantially as hereinbefore described with reference to the accompanying drawings.

