Improving the Efficiencies of Elevator Systems Using Fuzzy Logic

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ABSTRACT
This research presents the application of fuzzy logic in elevators. This analyzes the features of elevators and how fuzzy logic could be used to minimize the waiting time, detect when the temperature is high for the car, and determine which floor has highest number of people waiting for the car. High rising building is a common sight in most of the cities today. Fast and efficient elevator transportation is a key feature when creating these kinds of buildings. As the complexity of a system increases, it becomes more difficult and eventually impossible to make a precise statement about its behaviour. Many of the systems build before fuzzy logic use trial and error and effort had to be done over and over to arrive at effective control. Fuzzy logic concepts are used to enable the elevator control system to make decisions. The design criteria include of optimizing movement of elevators with regard to several factors such as waiting time, riding time, energy, load, etc. Software simulation is done in order to capture the performance of the proposed system which is compared to conventional approaches.

Keywords: Fuzzy logic (FL), Elevator. Car, Software simulation.

1. INTRODUCTION

Fuzzy logic (FL) is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or workstation-based data acquisition and control systems [11]. It can be implemented in hardware, software, or a combination of both. FL provides a simple way to arrive at a definite conclusion based upon vague, noisy, or missing input information. FL's approach to control problems mimics how a person would make decisions, only much faster.

Fuzzy Logic (FL) deals with uncertainty or partially true values as oppose to conventional logic which can be true or false. The idea of fuzzy logic was first introduce by Lotfi Zadeh, a professor at the University of California at Berkley. Fuzzy logic is used in system control like elevator control system and analysis design, because it shortens the time for engineering development and sometimes, in the case of highly complex systems, is the only way to solve the problem**.**

Elevators are the primary means of transportation that is used nowadays in tower buildings. The application of fuzzy logic to elevator control system has made the trend higher and better. Dubai has just finished opening its one kilometer tower while Saudi Arabia has announced that they are working on building a one mile tower building! Such high buildings demand high performance elevators, with extra ordinary speed control.

In general, elevators may be classified according to their driving method into three categories; electric, hydraulic and pneumatic elevators. Hydraulic elevators use hydraulic oil driven actuators to raise and lower car and its load, this type of elevators is typically used for low to medium rise buildings. Electric elevators consist of two main types: winding drum and traction elevators. The applications of winding drum machines are very limited by both code restrictions and practical considerations [10]. On the other hand electric traction elevators are elevators in which the energy is applied by means of an electric driven machine. Medium to high speeds and virtually limitless rise allow this elevator type to serve high-rise, medium-rise and low-rise buildings. Electric traction elevator can be further divided into geared and gearless categories: geared traction elevators are designed to operate within the general range of 100 to 450 ft/min, restricting their use to medium rise buildings, while gearless traction elevators speeds are available in the range of 500 to 1500 ft/min. Such designs offer the advantages of longer life and smoother rides [15].

2. RELATED WORKS

The term "fuzzy" was first used by Dr. Lotfi Zadeh in the engineering journal, "Proceedings of the IRE," a leading engineering journal, in 1962. Dr. Zadeh became, in 1963, the Chairman of the Electrical Engineering department of the University of California at Berkeley. E.H. Mamdani is credited with building the world's first fuzzy logic controller, after reading Dr. Zadeh's paper on the subject. Dr. Mamdani, London University, U.K., stated firmly and unequivocally that utilizing a fuzzy logic controller for speed control of a steam engine was much superior to controlling the engine by conventional mathematically based control systems and logic control hardware. Dr. Mamdani found that, using the conventional approach, extensive trial and error work was necessary to arrive at successful control for a specific speed set-point.

Further, due to the non-linearity of the steam engine operating characteristics, as soon as the speed set-point was changed, the trial and error effort had to be done all over again to arrive at effective control. This did not occur with the fuzzy logic controller, which adapted much better to changes, variations and non-linearity in the system.

WAITING for an elevator may seem like nothing more than a matter of standing in line, but in fact sophisticated computers decide the best way to deploy cars in modern office buildings. New artificial intelligence software patented by the Otis Elevator Company could mean more elevators will zoom past a lone person in favour of a large group waiting on a different floor. The invention uses so-called fuzzy logic to estimate how many people are waiting for elevators. Fuzzy logic is a programming method that allows computers to deal with uncertainties or information that is considered partly true. All modern elevator banks are run by complex computer programs that deploy cars with pre-programmed standards -- sending a car to a floor because it is closest, can get there fastest or are already on its way toward that stop. Recent efforts to make those systems smarter include using video cameras or pressure sensitive floor tiles to gather information about traffic flow. But those methods require costly equipment subject to mechanical failure.

"We propose a way to estimate the same values with software so you don't have to have additional hardware," said David J. Sirag Jr., who designed the Otis program. The fuzzy logic program tracks traffic flow by compiling information about the time elapsed between stops at the same floor, the number of buttons pushed as people board the car, or the changing weight load in the car. "It combines these pieces of evidence to get a rough estimate of how many people are waiting," Mr. Sirag said. "Each piece of information suggests an answer or a range of answers. Fuzzy logic integrates the answers and arrives at some consensus of what the number of people waiting should be".

The software is designed for use in office buildings or hospitals where several elevators operate and traffic patterns change throughout the day. "This is critical at lunch time, when everybody is coming and going from the building, and they're not all in one direction," Mr. Sirag said. "In the morning, everyone is coming into the building so the rule is to get the car back to the lobby as quickly as possible. The same principle is applied at the end of the day." But at noon, "if the car is nearly full and you know you have room for five more people, you need to have a system to estimate how many people are waiting," Mr. Sirag said. "If there's a half-full car and an empty car, but 10 people are waiting, the system will send the empty car." [7].

2.1.1 Zoning

Zoning has been a planning strategy from the start of high rising building elevator planning. Each car is assigned a zone of the building. It answers hall calls within its zone. The goal of the zoning approach is to keep the cars reasonably well separated and thus keep the interval down. In fuzzy logic approach calculation of hall call area and destination call area helps to achieve dynamic zoning.

If the call area is near to 0, algorithm will give a high priority to the lift when selecting the lift. This concept is further developed with a destination controlling system since it has the destination information before assigning a lift to a request.(Siikonen, 1997).

2.1.2 Search Based Approaches

Another control strategy is to search through the space of possible car assignments, selecting the one that optimizes some criterion such as the average waiting time. Greedy search strategies perform immediate call assignment, that is, they assign hall calls to cars when they are first registered, and never reconsider those assignments. Non-greedy algorithms postpone their assignments or reconsider them in light of updated information they may receive about additional hall calls or passenger destinations. Greedy algorithms give up some measure of performance due to their lack of flexibility, but also require less computation time.

Approach used in this research can be considered as a greedy approach. It assigns a car immediately when a request is made. Although this has the disadvantage of greedy algorithms, i.e. lack of flexibility, this has been overcome by various factors. Some of the factors are getting destination information before getting into a lift contrastingly to conventional systems and reducing psychological waiting time by displaying assigned lift earlier. (This is simulated in the simulation software) Also reassignment of lifts will result badly when it comes to dynamic zoning. Also avoiding non greedy approaches may result in less computation thus will be a less complex algorithm which is easy to understand and further develop. (Siikonen, 1997.)

2.1.3 Adaptive and Learning Approaches

Some of the optimization approaches use neural networks for learning traffic pattern to select the best rule set for fuzzy logic, to optimize parking etc (Daniel and Nikovski(ICRA)). However there are many situations in which training examples are costly or even impossible to obtain. Reinforcement learning (Crites and Barto, 1996) is more applicable in these more difficult situations where the only help available is a 'critic' that provide a scalar evaluation of the output that was selected, rather than specifying the best output or a direction of how to change the output. But in the applications of reinforcement learning or any other learning approaches it needs a large set of data to be trained on. This should be concerned regarding the application of real elevator system, since one would want to perform the initial training in simulation in any case, not only because of the large amount of experience needed, but also because performance would be poor during the early stage of training. Even though training will be done in a simulation, traffic generation of a simulator may not be accurate. Also elevator traffic depends so much on the type of the building (Siikonen, 1997).

Thus learning approaches are too much effort when building an algorithm for elevator group controlling. But this approach can be used for forecasting traffic and parking of elevators which will be a future addition to proposed algorithm, which describes only immediate call allocation mechanism if the temperature is very high AND the pressure is slightly low THEN the heat change should be slightly negative, Where temperature and pressure are the observed state variables of the process, and heat change is the action to be taken by the controller.

The vague terms very high, slightly low and slightly negative can be conveniently represented by fuzzy sets defined on the universe of discourse of temperature values, pressure values and heat changes values, respectively. This type of linguistic rule has formed the basis for the design of a great variety of fuzzy controllers described in the literature. A general fuzzy controller consists of four modules: a fuzzy rule base, a fuzzy inference engine and fuzzification /defuzzification modules.

3. ELEVATOR MODEL

The long-life, smoothness and high horsepower of gearless traction elevators provide a durable elevator service that can outline the building itself. The first high-rise application of gearless traction elevator was in the Beaver building New York City in 1903, which was followed by such notable installations such as the singer building which was demolished in 1972 and the Woolworth buildings, to name few. Typically elevator machines are either roped with a single or double wrap arrangement. Single wrap arrangement provides traction by the use of grooves that will pinch the ropes with varying degrees of pressure depending on the groove's shape and it's undercutting. The most effective single-wrap arrangement gives 180 degrees of the rope contact with the sheave without deflecting the sheave. On the other hand, double-wrap arrangement is used for high-speed gearless traction machines of 4mps or more to obtain traction and to minimize rope wear. Conventional elevators are either roped as 1:1 or 2:1 for both car and counter-weight. The savings on using a faster motor that can be built smaller and lighter than lower speed DC motors makes 2:1 roping more attractive for a full range of speed requirements from (0.5-3.5 mps) or more. Also, an advantage in lifting capacity as the 2:1 argument allows the use of higher-speeds and therefore a smaller but faster elevator motor. Finally, the mechanical advantage of 2:1 roping requires that only half the weight to be lifted.

3.1 Fuzzy controllers: An overview

Fuzzy controllers, contrary to classical controllers, are capable of utilizing knowledge elicited from human operators. This is crucial in control problems for which it is difficult or even impossible to construct precise mathematical models, or for which the acquired models are difficult or expensive to use. These difficulties may result from inherent nonlinearities, the time varying nature of the processed to be controlled, large unpredictable environmental disturbances, degrading sensors or other difficulties in obtaining precise and reliable measurements and a host of other factors. It has been observed that experience human operators are generally able to perform well under these circumstances.

The knowledge of an experienced human operator may be used as an alternative to a precise model of the controlled process. While this knowledge is also difficult to express in precise terms, an imprecise linguistic description of the manner of the controller can usually be articulated by the operator with relative ease. This linguistic description consists of a set of control rules that makes the use of fuzzy propositions. A typical form of these rules is exemplified by the rule. If the temperature is very high AND the pressure is slightly low THEN the heat change should be slightly negative, where temperature and pressure are the observed state variables of the process, and heat change is the action to be taken by the controller. The vague terms very high, slightly low and slightly negative can be conveniently represented by fuzzy sets defined on the universe of discourse of temperature values, pressure values and heat changes values, respectively. This type of linguistic rule has formed the basis for the design of a great variety of fuzzy controllers described in the literature. A general fuzzy controller consists of four modules: a fuzzy rule base, a fuzzy inference engine and fuzzification/ defuzzification modules.

FL incorporates a simple, rule-based IF X AND Y THEN Z approach to a solving control problem rather than attempting to model a system mathematically. The FL model is empirically-based, relying on an operator's experience rather than their technical understanding of the system. For example, rather than dealing with temperature control in terms such as "SP = 500F", "T <1000F", or "210C <TEMP <220C", terms like "IF (process is too cool) AND (process is getting colder) THEN (add heat to the process)" or "IF (process is too hot) AND (process is heating rapidly) THEN (cool the process quickly)" are used. These terms are imprecise and yet very descriptive of what must actually happen. Consider what you do in the shower if the temperature is too cold: you will make the water comfortable very quickly with little trouble. Since the start of elevator systems, each and everyone carried out the same operations just by using up and down hall call buttons and giving the destination inside a car, not allowing that much of processing of data to be done.

However, this type of system provides some disadvantages such that the supervisory system of the elevators does not receive information on the destination of the passengers before they board the car. Consequently, car assignments are based on far less than 50% of the traffic information that passenger could supply earlier to the system and therefore assignments are obviously poor in quality. Such inherent disadvantage present in conventional system can be improved by using a destination oriented system. The choice of optimization target in the cost function is important when considering the overall elevator performance and the service level. The most general optimization target in group controls has been the minimization of the average and maximum hall call times. Recently the cost functions have become more comprehensive. Instead of one target, multiple targets are optimized. A number of costs, such as call time, passenger waiting and journey times, car load factor, energy consumption, transportation capacity and number of starts, can be considered during the call allocation. When optimizing one target, the other features may suffer.

For instance, when optimizing the energy consumption, the passenger waiting times may increase. Several optimization targets can be optimized within one control if the most suitable target is switched or prioritized according to the prevailing traffic pattern or requests. Fuzzy logic is used as an intelligent approach to optimize multiple targets such as waiting time, riding time, load and distance. This system determines the optimum car for a particular request. System requires the passengers to enter their destination before entering to the car, using a numeric keypad which is located in the requesting floor. The system then assigns the passenger to a car and displays the assigned car back to the user.

3.1.1. How Fl is used

1. Define the control objectives and criteria: What am I trying to control? What do I have to do to control the system? What kind of response do I need? What are the possible system failure modes?
2. Determine the input and output relationships and choose a minimum number of variables for input to the FL engine (typically error and rate-of-change-of-error).
3. Using the rule-based structure of FL, break the control problem down into a series of IF X AND Y THEN Z rules that define the desired system output response for given system input conditions. The number and complexity of rules depends on the number of input parameters that are to be processed and the number fuzzy variables associated with each parameter. If possible, use at least one variable and its time derivative. Although it is possible to use a single, instantaneous error parameter without knowing its rate of change, this cripples the system's ability to minimize overshoot for a step inputs.
4. Create FL membership functions that define the meaning (values) of Input/Output terms used in the rules.
5. Create the necessary pre- and post-processing FL routines if implementing in S/W, otherwise program the rules into the FL H/W engine.
6. Test the system, evaluate the results, tune the rules and membership functions, and retest until satisfactory results are obtained.

3.1.2 Applying fuzzy logic to Elevator control system

In this system destination details are obtained before a passenger load into the car through a numeric keypad located in the floor we can use these additional knowledge when applying fuzzy logic controller and the elevator with highest priority value will be assigned for the given request.

3.2 Fuzzification and Fuzzy Reasoning

Each fuzzy system is realized in the form of fuzzy rules as in the following example**:**
Rule 1: If X is A1 and Y is B1 then Z is C1 Rule 2: If X is A2 and Y is B2 then Z is C2 Where X and Y are variables of the condition part, and Z is the variable of the action part. A1, B1 and C1 are fuzzy parameters characterized by membership functions. The condition parts of control rules make use of measurements which are usually real numbers. e.g. x0 and y0 are matched to their corresponding fuzzy variables by determining their membership values.

Suppose that X = x0 and Y = y0, the reasoning is derived as follows:
• Define the linguistic variables as described in fuzzification section.
• Compute firing levels by mathematical interpretation of these rules, as follows:

_1 = A1 (x0) _ B1(y0)
_2 = A2 (x0) _ B2(y0)

Where x0, y0 are actual inputs to the system and A1, A2, B1, B2 are fuzzy sets and _1, _2 are firing levels. Inputs are now fuzzified and embedded in the firings of each rule.

• Apply Mamdani inference mechanism [3] to get individual out fuzzy sets for each rule and a final consequence set. Mathematically,

C'1= _1 _ C1
C'2= _2 _ C2

Where C'1 , C'2 are individual output fuzzy sets for each rule and C is the final consequence set.

3.2.1 Membership Functions

In order to build membership functions (MF) it is needed to identify the ranges where each base variable is spread out.

Waiting time = distance to request + no. of stops x 3

Riding time=distance to destination + no. of stops x 3

Since waiting time and riding time is evaluated with above mentioned formula range of the membership function depend on the maximum number of floors in the building. As in this system there are 6 floors maximum number of distance to arrival/destination is 5 floors. Also maximum number of stops is 5. As maximum number of passenger for the lift is 20, the range for number of passengers is from 0 to 20. Destination call area weight and hall call area weight values represent its direction as well. So the range of weight is between 0 to 1400kg. The priority request is determine by the floor that has the highest number of people as shown in appendix B figure iii .The car moves to the floor that has the highest number of passengers.

3.4 Rule Base

Depending on the fuzzy inputs and the rule bases, the output fuzzy set, `priority' is computed using an inference scheme. Several inference schemes are available like Mamdani, Sugeno etc. For the present simulator, the Mamdani scheme has been adopted. In this application each rule has a single input mapped to a single output to avoid complexities involved by considering all the inputs in a single rule.

There are different rules to achieve different objectives as described below.

1) If waiting time short then priority is high.
2) If waiting time is medium then priority is medium.
3) If waiting time is long then priority is small.
4) If riding time short then priority is high.
5) If riding time is medium then priority is medium.
6) If riding time is long then priority is small.
7) If loading is small then priority is high.
8) If loading is medium then priority is medium.
9) If loading is high priority is small.
10) If hall call area is close priority is high.
11) If hall call area is positively far priority is medium.

12) If hall call area is negatively far priority is small.
13) If destination call area is close priority is high.
14) If destination call area is positively far priority is medium.
15) If destination call area is negatively far priority is small.
16) If number of passengers waiting is more priority is high.

Every rule has a weight (a number between 0 and 1), which is applied to the number given by the antecedent. Generally this weight is 1 and so it has no effect at all on the implication process. From time to time system may want to weight one rule relative to the others by changing its weight value to something other than 1.

3.5 Defuzzification

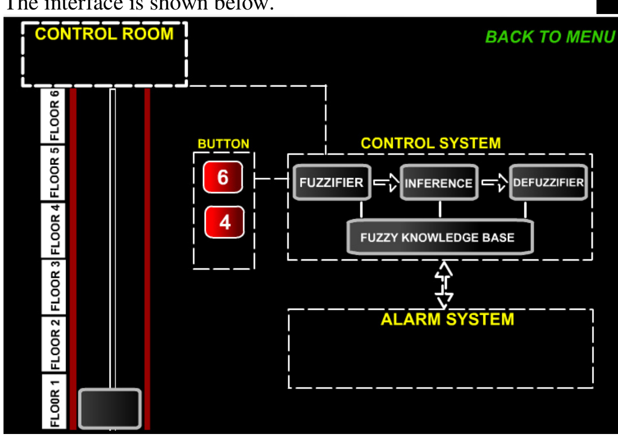
The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single number. As much as fuzziness helps the rule evaluation during the intermediate steps, the final desired output for each variable is generally a single number. However, the aggregate of a fuzzy set encompasses a range of output values, and so must be defuzzified in order to resolve a single output value from the set.

4. SYSTEM DESIGN

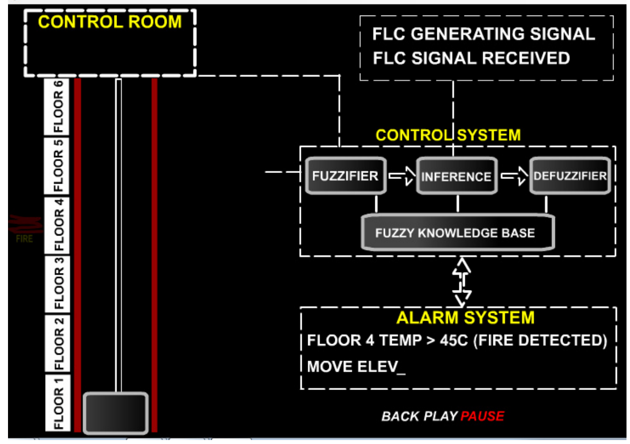
Simulator is developed using C#.Net. C#.Net is used to create the graphical user interface and calculate performance of the algorithm compared to conventional algorithms. Also calculating input parameters to fuzzy logic is done in the net application. The dynamic link library that was created C# to evaluate the fuzzy inputs and to give the output feed the output to the net application. In the simulator the following functionalities are implemented:

- Auto traffic generator
- Graph controller for test result analysis
- Elevator movement visualization average riding time.

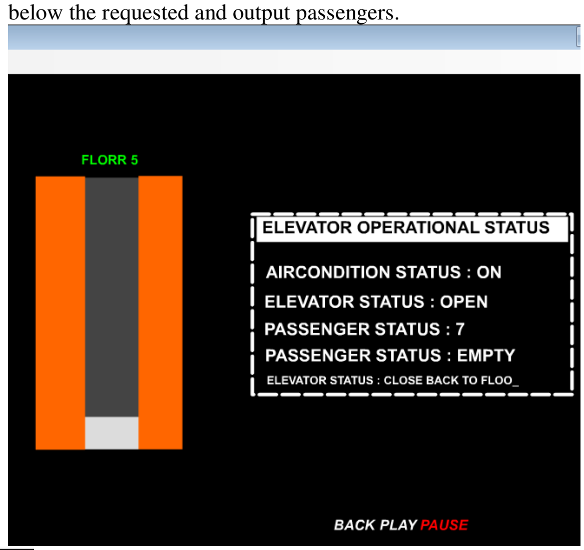
The interface is shown below.



This is the design of what is obtained from the system.



The inference engine infer that FLC is generating signal, from the signal received, the knowledge base deduced a temperature higher than 45 ^{0}c which is not suitable for the elevator, alarm system detected fire and car moved to floor below the requested and output passengers.



SUMMARY

was conceived as a better method for sorting and ndling data but has proven to be an excellent choice for ny control system applications since it mimics human ntrol logic. It can be built into anything from small, nd-held products to large computerized process control tems. It uses an imprecise but very descriptive language deal with input data more like a human operator. Fuzzy ic provides an inference structure that enables the man reasoning capabilities to be applied to artificial owledge-based systems. Fuzzy logic provides a means converting linguistic strategy into control actions and s offers a high-level computation.

6. CONCLUSION

Fuzzy Logic provides a completely different, unorthodox way to approach a control problem. This method focuses on what the system should do rather than trying to understand how it works. One can concentrate on solving the problem rather than trying to model the system mathematically, if that is even possible. This almost invariably leads to quicker, cheaper solutions. Once understood, this technology is not difficult to apply and the results are usually quite surprising and pleasing.

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Authors' Brief

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