52. IWK

Internationales Wissenschaftliches Kolloquium
International Scientific Colloquium

PROCCEDINGS | 10 - 13 September 2007

FACULTY OF COMPUTER SCIENCE AND AUTOMATION

COMPUTER SCIENCE MEETS AUTOMATION

VOLUME I

Session 1 - Systems Engineering and Intelligent Systems

Session 2 - Advances in Control Theory and Control Engineering

Session 3 - Optimisation and Management of Complex Systems and Networked Systems

Session 4 - Intelligent Vehicles and Mobile Systems

Session 5 - Robotics and Motion Systems

TECHNISCHE UNIVERSITÄT
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Bibliografische Information der Deutschen Bibliothek
Die Deutsche Bibliothek verzeichnet diese Publikation in der deutschen Nationalbiografie; detaillierte bibliografische Daten sind im Internet über **http://dnb.ddb.de** abrufbar.

ISBN 978-3-939473-17-6

Impressum

Herausgeber:	Der Rektor der Technischen Universität Ilmenau Univ.-Prof. Dr. rer. nat. habil. Peter Scharff
Redaktion:	Referat Marketing und Studentische Angelegenheiten Kongressorganisation Andrea Schneider Tel.: +49 3677 69-2520 Fax: +49 3677 69-1743 e-mail: kongressorganisation@tu-ilmenau.de
Redaktionsschluss:	Juli 2007
Verlag:	Technische Universität Ilmenau/Universitätsbibliothek Universitätsverlag Ilmenau Postfach 10 05 65 98684 Ilmenau www.tu-ilmenau.de/universitaetsverlag
Herstellung und Auslieferung:	Verlagshaus Monsenstein und Vannerdat OHG Am Hawerkamp 31 48155 Münster www.mv-verlag.de
Layout Cover:	www.cey-x.de
Bezugsmöglichkeiten:	Universitätsbibliothek der TU Ilmenau Tel.: +49 3677 69-4615 Fax: +49 3677 69-4602

Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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52nd Internationales Wissenschaftliches Kolloquium
Technische Universität Ilmenau
10 – 13 September 2007

I. JAWISH

The Improvement of Traveling Responses of a Subway Train using Fuzzy Logic Techniques

* Advances in Control Theory and Control Engineering

Keywords : Metro Network , ATO- Automatic Train Operation , Fuzzy predictive controller(FPC) , PI - Like FC, FIS-Fuzzy Inference System , Traveling mode , Traveling response, Riding comfort.

Abstract

It's well known that the conventional PID controllers are fixed–gain feedback controllers,they can't compensate the parameter variations in the plant and can't adapt changes in the environment. In our case , the classical PID controllers of the automatic train operation system start or stop a train by reacting to markers that show how far the vehicle is from a station. Because the controllers are rigidly programmed, the ride may be jerky; the automated controller will apply the same brake pressure when a train is, say ,100 meters from a station,even if the train is going uphill or downhill. Moreover, depending on the difference between the actual and set point speeds, the drive motor is to be accelerated or retarded by increasing or decreasing the operating voltage not considering the actual train traveling mode (e.g., Slow, Moderate,Fast), i,e., not taking into account the kinetic energy of the entire moving parts of the train.

In this paper we are concerned with a specific aspect of Fuzzy-ATO , when the conversion of speed differences into a “Traveling response” is to take place in accordance with the actual train “Traveling mode”. Using MATLAB 7.0.2 \ SIMULINK & Fuzzy TOOLBOX software and environment, a PI-like fuzzy controller FC for a speed control of dc traction motor model is designed. The designed FC has a Mamdani Model with two inputs: the linguistic variables ”Speed deviation” , and ‘Traveling mode’.The FC output is considered for the linguistic manipulated variable ’Traveling response’.Furthermore, 21 IF-THEN fuzzy rules is put up together, and the Max-Min inference mechanism is used in the rule evaluation process.The final step in the fuzzy logic controller design is to combine the fuzzy outputs into a crisp output , the Center of Gravity (COG) method is used in our application due to better results it gives,while the Integral action of the FC is taken separetely. Finaly,the influence of “Traveling mode” on the “Traveling response” at different “Speed deviation“ has been investigated. The simulation results show has a sufficient performance of the train speed fuzzy control system using the designed PI-Like fuzzy controller.

I- Introduction

Electrical transportation means have become a part of modern life in developed countries. Subway trains are the famous one, since they offer an intensifier and fast access of passengers to the desired destination , contribute in saving and increasing efficient energy consumption , reducing traffic jam and air pollution.

In Syria a lot of joint projects have been carried out at domestic and international studies institutions. The common subscriber of such studies reveals the necessity to use large public transportation means, and to enhance the electrical ones , in particular, electrical trams and buses, and the underground tube. The intention to establish a Metro Network in a big Syrian cities (e.g., Damascus and Aleppo) are now strongly adopted by the Ministry of Transportation .

Metro Networks demand a considerable amount of electrical energy, which is consumed by: electric traction motors; escalators operation systems; control; measuring, monitoring (SCADA); lighting; conditioning and other needs. Meanwhile, the traction motors consume ~ 85% of the total supplied electric energy. Therefore, it's an important issue to improve the techno-economical performance indices of such distinguishable public transport means by implementing advanced control paradigms, and introducing developed equipment .

An alternative approach to the control of any process is to investigate the control strategies employed by the human operator. One of the most successful example of implementation fuzzy logic technology was the application of a predictive fuzzy control to automatic subway train operation system in Metro Sendai-Japan, which outperformed both human operator and conventional automated PID controllers. The purpose of this system is to obtain automatic operation on a par with that of skilled operator; specifically this means multi-purpose operation that balances several requirements such as riding comfort, stopping accuracy, and energy conservation. This automatic train operation system is called Fuzzy-ATO. The speed over which the ATC (automatic train control) operates the emergency brake to maintain safety is called critical speed .The speed between stations is controlled so as not to exceed the speed limit, then at the next station the train is stopped accurately at the stop position through automatic application of driving control and a brake control command (notch) [1]. Such Fuzzy-ATO has beat an automated version on the riders'comfort , shortened riding times and even achieved a 10 percent reduction in the trains' energy consumption.

It's well known that the conventional PID controllers are fixed–gain feedback controllers,they can't compensate the parameter variations in the plant and can't adapt changes in the environment. In our case , the classical PID controllers of the automatic train operation system start or stop a train by reacting to markers that show how far the vehicle is from a station. Because the controllers are rigidly programmed, the ride may be jerky; the automated controller will apply the same brake pressure when a train is, say ,100 meters from a station,even if the train is going uphill or downhill. Moreover depending on the difference between the actual and set point speeds, the drive motor is to be accelerated or retarded by increasing or decreasing the operating voltage not considering the actual train traveling mode (e.g., Slow, Moderate,Fast), i,e., not taking into account the kinetic energy of the entire moving parts of the train.

In this paper we are concerned with this specific control issue , when the conversion of speed differences between the actual and set point speeds into a “Traveling response” is to be taken in accordance with the actual train “Traveling mode”. Consequently, the drive traction motor should be accelerated or retarded with respect to a new different values of operating voltage then as in a conventional case.

II- Basic definitions ,and structures of the Fuzzy Logic Controllers

1- *Fuzzy controllers* (FC) are a class of knowledge based controllers using artificial intelligence techniques with origins in fuzzy logic. In the structure definition of a FC it is necessary to define the inputs and outputs (linguistic variables) of the control system , in terms of fuzzy sets, the number of linguistic labels(terms)and the respective membership functions for each , the design of fuzzy control rules ,the type of fuzzy inference system FIS, and finally the defuzzification methods .

Defuzzification method , i.e., transformation of the fuzzy control statement into specific control actions since the controlled process takes only crisp values as inputs , we have to use a defuzzifer to convert a fuzzy systems , set to a crisp value .In case of implementing Mamdani fuzzy models, there are two common means of doing this the Center of Gravity (COG) , and Mean of Maximum (MOM)[2],[3].

2- The Fuzzy Inference System (FIS)

FIS is a computational framework based on the concepts of *fuzzy sets*, *fuzzy if- then rules* ,and *fuzzy reasoning* .The basic structure of FIS consists of three conceptual components: a *rule-base* ,which contains a selection of *fuzzy rules* ;a *database* (or dictionary) ,which defines the *membership functions* used in the fuzzy rules ; and a *reasoning mechanism*, which performs the inference procedure upon the rules and given facts to derive a reasonable output or conclusion[4] .

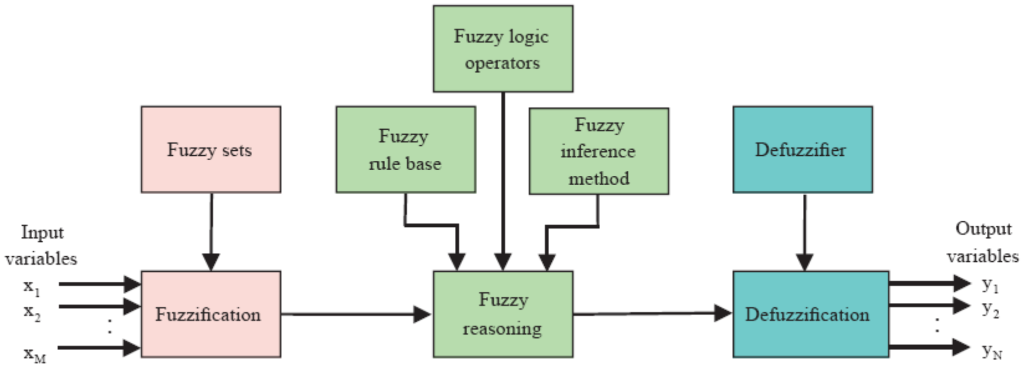

Figure.1 The Block Diagram of a typical Fuzzy Controller

3- Structures of a PID-Like Fuzzy logic Controllers

FLC can be derived from the original classical PID mathematical model [5],[6],[7],[8]:

$$u(t)=K_P\ e(t)+Ki\ \int e(t)dt + K_d\ de/dt \qquad (1)$$

or in discrete form:

$$u(k) = K_P\ e(k)+Ki\ \sum e(m) + K_d\ \Delta e(k),\ \ m=0,..,k \qquad (2)$$

The increment of the output signal is :

$$\Delta\ u(k) = u(k) - u(k-1)\ ,\ \text{then} \qquad (3)$$

$$\Delta u(k) = K_P\ \Delta e(k)+Ki\ e(k)+ K_d\Delta^2 e(k) \qquad (4)$$

Depending on the choice made in the design phase we can have different types of FLCs : P, PI, PD, or PID .Usually, the universes of discourse of the controller variables are normalized in the [-1,0,+1] or in the [0,+1] domains. Associated to each linguistic variable is a scaling factor. Scaling factors of the FC enable the use of normalized universes of discourse and play a role similar to that of the gain coefficients in conventional controllers. The Block diagram of a typical Fuzzy Controller is shown in Figure.1

III-Design Steps of the subway train fuzzy speed control system

In this section we shall illustrate how a PI -like fuzzy controller for a speed control of dc traction motor is constructed . The recommended FC has a Mamdani Model with two inputs: the linguistic variables "Speed deviation" , and 'Traveling mode'.The FC output is considered for the linguistic manipulated variable 'Traveling response', while the Integral action of the FC has been taken separetely. We now continue the design of the FC in details [9] :

1) Converting the control objectives Into Linguistic Variables and Fuzzy Sets

The control differences between the actual traveling rates corresponds directly to the set -point and actual speeds of the drive motor . A '**Speed deviation**' linguistic variable is thus required. To allow differentiated evaluation ,seven fuzzy sets are defined for the 'speed deviation' variable. They are 'very negative', 'negative', 'slightly negative ' ,'zero' , 'slightly positive ','positive' ,and 'very positive' (Fig.2) The second linguistic variable '**Traveling mode'** is represented as the second FC input .It encompasses the 'Slow' ,'Moderate 'and 'Fast' fuzzy sets (Fig.3).

The linguistic variable required for the manipulated variable is termed **'Traveling response"** and it consists of seven fuzzy sets . They are : 'Strong braking ', 'braking ','slight braking','constant speed', 'slight acceleration ' ,'acceleration' and 'strong acceleration' ,the shape of the Membership Functions is the same as of "Speed deviation " .

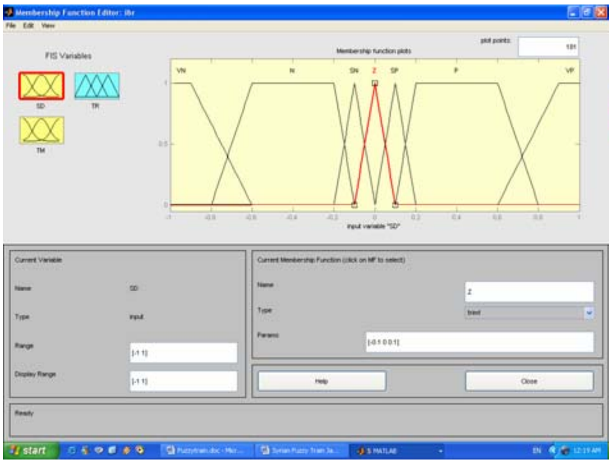

Fig.2 Membership Functions of Speed Deviation

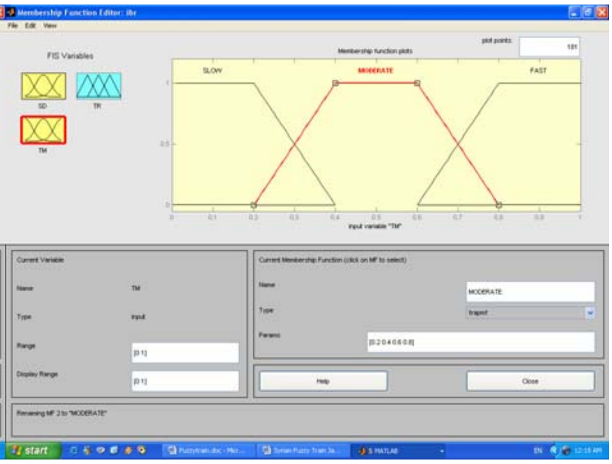

Fig.3 Membership Functions of Traveling mode

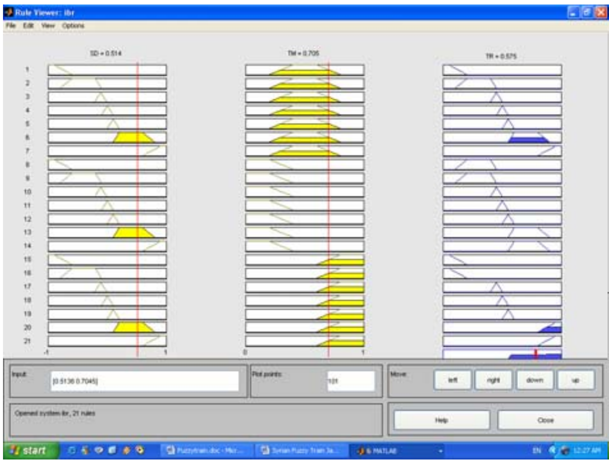

Fig.4 Th fuzzy rules viewer

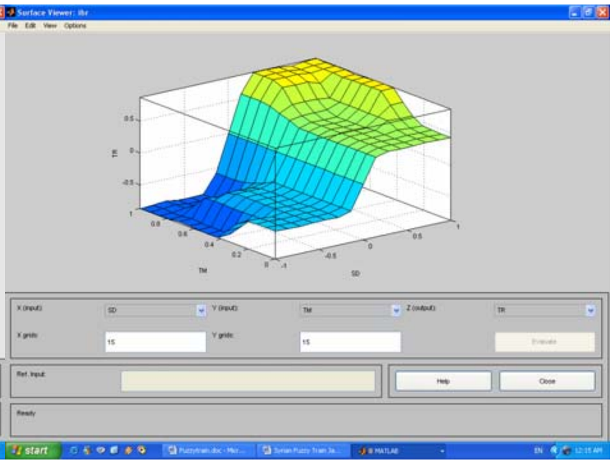

Fig.5 The fuzzy controller Surface

2) Deriving the fuzzy inference Rules from the Control Objectives

The conversion of speed differences into traveling responses is to take place in accordance with the selected traveling mode .The following rules are associated with the one –to-one conversion in the ‘moderate’ traveling mode:

Rule1: IF speed deviation very negative And traveling mode moderate THEN travelling response strong braking
Rule2: IF speed deviation negative And traveling mode moderate THEN traveling response braking
Rule3: IF speed deviation slightly negative And travelling mode moderate THEN travelling response slight braking
Rule4: IF speed deviation zero And traveling mode moderate THEN traveling response constant speed
Rule5: IF speed deviation slightly positive And traveling mode moderate THEN traveling response slight acceleration
Rule6: IF speed deviation positive And traveling mode moderate THEN traveling response acceleration

Rule7:1F speed deviation very positive And traveling mode moderate THEN traveling response strong acceleration

The production rules for "Slow" Traveling mode are the same as for ‘Moderate‘ , the only two differences are that for the first rule the consequence should be ‘Braking ‘ instead of ‘Strong Braking" ,and for the seven rule: ‘Acceleration’ instead of ‘Strong Acceleration” . Furthermore,the production rules for"Fast" traveling mode is different to the ‘Moderate‘ one, in that not only very negative or positive speed deviations , but also normal ones cause ‘Strong Braking’ or ‘Strong Acceleration’, i.e. to alter the consequenses of second and six rules of ‘Moderate‘ travelling mode , respectively. Now we have 21 IF-THEN fuzzy rules which are to put up together,the AND operator is selected

as the aggregation operator , the Max-Min inference mechanism is used in the rule evaluation process , and OR as the accumulation operators. The final step in the fuzzy logic controller design is to combine the fuzzy outputs into a crisp output , the Center of Gravity (COG) method is used in our application due to better results it gives . Finaly ,the PI-like FC has been designed ,the fuzzy rules viewer,and thedesigned FC Surface are shown in Figs.4,and 5,respectivly.

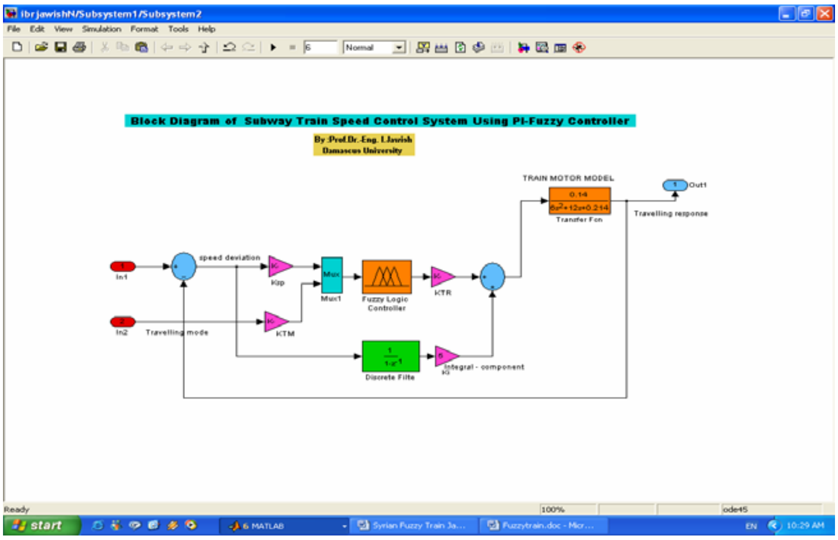

Fig.6 Block Diagram of the Train Speed fuzzy Control System

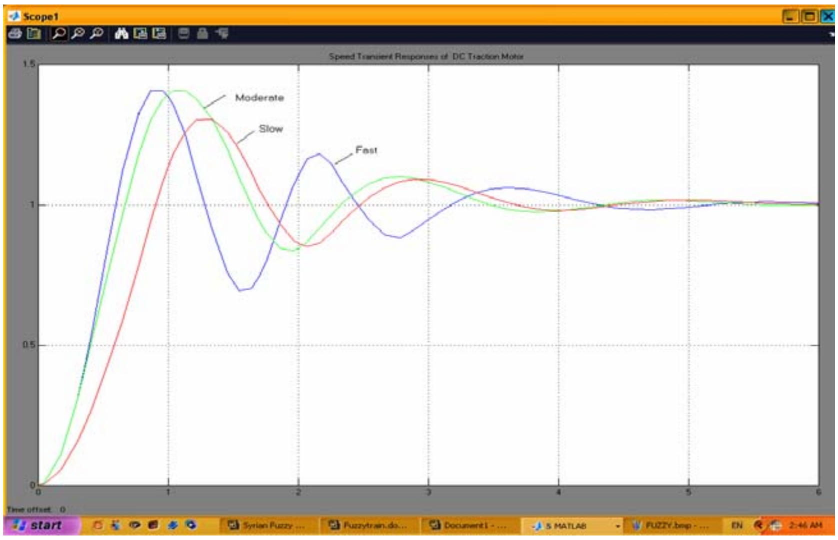

Figure 7. Speed Traveling Responses at different Traveling Modes
Slow = 10km/h,Moderate=50 km/h,Fast=90 km/h

IV-Computer Simulation Results

Using MATLAB 7.0.2 \ SIMULINK & Fuzzy TOOLBOX software and environment , we now use the computer simulation to demonstrate the behavior of the Subway Train Speed Control System using PI- like FC .

The mathematical model of of the traction dc traction motor for the purpose of simulation was adopted from [10]:

$$G_m(s) = \omega(s)/u(s) = 0.14/ 6s^2 + 3.4s+ 0.214 \qquad (5)$$

The designed and invesigated Subway Train Speed Control System using PI- Fuzzy is depected in Figure.6 .

The speed traveling responses to a step-unit at different traveling modes is shown Figure 7. Analyzing the transient curves of the train fuzzy control system we can conclude that the designed PI-Like fuzzy controller has a sufficient performance

V- Conclusion

In this paper we have investigated the influence of the train traveling mode on the speed traveling response , which must be taken into considaration .In view of the fact that the kinetic energy is proportional to the square value of the actual train speed the amount of this energy might be more or less than the calculated nominal one(at moderate mode) , in such case applying the same value of strong acceleration or braking at slow mode is worthless, saving electrical energy ,and enhancing riding comfort . On the other side , at the fast traveling mode, even medium deviations in speed demands a strong acceleration or braking to overcome the increment of train inertia, saving travel time, and improving traceability .

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Authors:

Prof. Dr.-Eng., Ibrahim Jawish
Damascus University
+963-11,Damascus,Syria
Phone: +963-11-3121214
Fax: : +963-11-3320326
E-mail: ibrahim-jawish@fulbrightweb.org