The New Method for Optical Channel Drop Filter with High Quality Factor Based on Triangular Photonic Crystal Design

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ABSTRACT
We have designed a new type of optical channel drop filter (CDF) based on two dimensional triangular lattice photonic crystals. CDF operation is based on coupling to the photonic crystal waveguide. The proposed structure is optimized to work as a CDF for obtaining the CDF characteristics and band structure of the filter the finite difference time domain (FDTD) method and plane wave expansion (PWE) method are used respectively. Dropping efficiency at 1550nm and quality factor (Q) of our proposed structure are 96.36 % and 282.7, respectively. The quantities of quality factor and transmission efficiency are suitable for optical applications.

KEYWORDS: Channel drop filter, FDTD method, Photonic crystal, Wavelength.

1. INTRODUCTION
Photonics crystal, are nano-sized periodic structures and devices that control manipulate the flow of light that are either dielectric or metal - dielectric that will affect the direction of the electromagnetic wave, by creating allowed and forbidden energy bands. Basis of photonic crystals based on internal change in refractive index to more or less within a crystal [1]. By creating unrighteousness (point line) in a periodic structure may guide the light propagation through the optical forbidden band (PBG) is performed; This particular behavior leads to the detection of almost all types of Photonics crystal (PhC) is based on active and passive components. Structures based on Photonics crystals (PhCs) that enables researchers to design small-scale tools [2, 3, 4]. In recent years, much of the PhC are designed based on optical instruments, such as multiplexer[5], demultiplexer[6], dipole radiation separators [7], power separators [8], switches (9), the pass filters [11, 10], non-pass filters [12], oriented couple markers [13] and drop filter [drip] in the channel [14] is one of the key factors to select single or multiple wavelength channels of optical filters drop in the channel.

2. DESIGNING CDF
As shown in Figure 1 can be seen, the basic structure is used to design the filter is a
two-dimensional hexagonal lattice $26 \times 19$ of silicon rods with failure coefficients $n_{si} = 3.46$ and with air field $n_{air} = 1$. In this study, the ratio of rod radius to the lattice constant ($a$) is approximately 0.2. The normalized frequency of the first photonic band gap is equal to $0.5548 \leq a/\lambda \leq 0.5930$, as shown in Fig (2 - b), which corresponds to 1.026 mm to 1.097 mm wavelength range. According to Fig (2 - b), the second photonic band gap is equal to $0.4403 \geq a/\lambda \geq 0.27285$, which corresponds to 1.383 mm to 2.231 mm wavelength range. In TE mode, photonic band is according to Fig (2 - a), which normalized frequency of the photonic band gap is equal $0.8584 \geq a/\lambda \geq 0.8215$, which corresponds to 0.7094 to 0.7413 micrometers wavelength range.

In this structure, forbidden band for normalized frequency is from $0.27285 \ a/\lambda$ to $0.4403 \ a/\lambda$ and normalized high frequency $0.5548 \ a/\lambda$ to $0.593 \ a/\lambda$ is for TM polarization.

3. SIMULATION
A Gaussian pulse signal enters from the input section (Input), and its output is manifested by a Time monitor in output1 and output2. Normalized transmission spectra computed through fields Fourier transform (FFT); as well Fourier transform is given by the two-dimensional FDTD method. In Figure 3 the normalized transmission spectra for both outputs in parts of Output1 and Output2 in CDF are shown as blue and green lines, respectively. As can be seen, ability of spectral selection...
was improved considerably; which efficiency of 96.36% dropping can be obtained at 1550nm wavelength resonator; and quality factor of dropping is 272.8, also. Such values (Q) are sufficient for optical communication applications 1550nm and 1530nm. Figure (4 - a) and Figure (4 - b) draw model of intensify and non-intensify electric field, 1530 nm and 1550nm respectively.

Fig. 3. The normalized transmission spectra for the two outputs in CDF
In intensify wavelength ($\lambda = 1550nm$), the wave crossing electric field is located at output2, whereas, in non-intensify wavelength ($\lambda = 1530nm$), signal will be sent straight to output1.

4. CONCLUSIONS
CDF two-dimensional photonic crystals presented and reviewed which can be obtained at $\lambda = 1550nm$ by the FDTD method at the triangular silicon lattice rod with a drop efficiency of 96.36% and the quality factor of 272.8; this is an important advantage of the proposed CDF than reported CDFs in the field. In this paper it was shown that there is flexibility in optical crystal. Such structures provide virtual applications for optical integrated circuits based on PhCs and other nano-photonics structures.

REFERENCES
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A New Design of Photonic Crystal Filter and Power Splitter Based on Ring Resonators

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ABSTRACT
Here, we propose an optical filter and an optical power splitter based on two-dimensional photonic crystal all circular ring resonators. These structures are made of a square lattice of silicon rods with the refractive index $n_1=3.464$ surrounded by air (with refractive index $n_2=1$). First, we have designed the filter and by using that, we designed a power splitter. The transmission efficiency and Quality factor for both, an optical filter and an optical power splitter, respectively, are more than 90% and 1000. Resonant modes of the all-circular ring resonator with their corresponding degenerated poles and the transmission spectra are calculated using the PWE, and 2D-FDTD methods respectively.

KEYWORDS: Filter, Photonic crystal, power splitter, Ring resonator

1. INTRODUCTION
Photonic crystals (PhCs) composed of periodic dielectric materials dielectric or metallo-dielectric nanostructures, have been intensively studied in the past decade, because they possess many unique properties to control the propagation of electromagnetic (EM) waves [1]. As a result of this periodicity, the transmission of light is absolutely zero in certain frequency ranges which is called as Photonic Band Gap (PBG) [2-4]. PCs are classified mainly into three categories according to its nature of structure periodicity, that is, One Dimensional (1D), Two Dimensional (2D), and Three Dimensional (3D) PCs. The geometrical shape of 1DPCs, 2DPCs and 3DPCs [1]. The ability to control and manipulate the spontaneous emission by introducing defects in PCs, and related formation of defect state within PBG has been used for designing the optical devices for different applications that are directed towards the Integration of photonic devices [5]. photonic crystal ring resonators (PCRR) can be considered as a new type of linear defects which their size is determined by the desired resonant wavelength. In recent years many optical devices are made based on PCRRs such as multiplexers [6], de-multiplexers [7], power splitters [8], and add-drop filters [9], channel-drop filters [9-11] and so on. In this paper, our goal is design power splitter. The calculations of band structure are done using PWE method.
and the power transmission spectrum, resonance frequency and corresponding quality factors and add-drop filter are calculated using the 2D-FDTD method.

2. NUMERICAL RESULT AND ANALYSIS

To design a power splitter, we have designed the filter and by using that, we designed a power splitter. The basic structure is used to design the proposed filter and power splitter, by square lattice constant of silicon bars is surrounded by air. The refractive index of silicon is 3.46 and the refractive index of air is 1. First, we will examine the structure of the filter, and then we analyze the power splitter. Lattice constant for both the structure is equal to 494.5 nm and dielectric rods radius for both structures, is 95 nm. Ring structure used in both of these devices filter and power splitter, as is shown in Figure 1.

![Figure 1. Ring structure used in both of these devices filter and power splitter.](image)

In four ears ring, there are four scatters and for enhanced device performance that we have designed them with these rings, are used. Ring rods are darker, 15% in the x, z directions have been displaced from their places, and central rod ring correct in the middle of the ring is located. The number of rods for our proposed filter in the x and z directions are respectively, 22 and 20. Our filter structure, only has a one photonic band gap be in TM mode. The normalized frequency bandgap, is equal to $0.288 \leq a/\lambda \leq 0.426$. Which has a finite wavelength, $1.16 \leq \lambda \leq 1.717$. Figure 2 shows the band structure of our proposed filter.

![Figure 2. Shows band structure of our proposed filter](image)

This structure has three main parts. An input waveguide is vertical, and a ring resonator and an output waveguide is to form horizontal. Light is entered from the vertical waveguide and intensifies in the ring resonator and is entered to horizontal waveguide, and output is calculated by method FDTD. Figure 3 shows our proposed filter.
In addition, in Figure 4, the normalized spectrum transmission filter is based on our ring resonators.

The transmission efficiency of this filter is equal to 95% and the quality factor of this filter is equal to 3905.2. Now using this filter structure, we have designed a power splitter. Figure 5 is the structure of the proposed power splitter.

The number of rods for our proposed power splitter in the x and z directions are respectively, 33 and 20. This structure has three waveguides and two ring resonators. Vertical waveguide is between the 2 resonators, and two horizontal waveguide as being a previous filter. Light is entered from the central waveguide between the two rings, and exits by two other waveguide, which shows A and B. Figure 6, the normalized spectrum power splitter is our proposed.
According to Figure 6, the transmission efficiency of this power splitter for both outputs is equal to 100% and the quality factor for both outputs is equal to 1030.6. Figure 7 shows the electric field distribution in photonic crystal ring resonator for Wavelength of 1.55.

Figure 7 shows the electric field distribution.

3. CONCLUSIONS
In this paper, first we design an optical filter based on photonic crystal ring resonator. The transmission efficiency of this filter is equal to 95% and the quality factor of this filter is equal to 3905.2. Then using this filter structure, we have designed a power splitter. The transmission efficiency of this power splitter for both outputs is equal to 100% and the quality factor for both outputs is equal to 1030.6. According both, an optical filter and an optical power splitter, we can use of these structures for optical integrated circuits.

REFERENCES

Modeling a Bank ATM with Two Directions
Places Timed Petri Net (TPN)

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ABSTRACT
A Bank ATM is including controller, card authorization system and a teller unit. This paper explains how this parts connects together. In this paper will be used of a new mode place in Petri nets. More systems usually have a complex constructs. ATM will be simulated use of new mode place at this study. The Main part of this model is used of T.S.Staines model[1]. We discuss how a simple model of T.S.Staines model be used for new model in this study. At this work will be added money teller unit that was discussed in T.S.Staines model. Each main components of the system are identified and built using Petri Nets. The final Model is live and exhibits repetitive, consistent behavior. The work presented here is continue of last work and can be further developed.

1. INTRODUCTION
A bank ATM built of computerized machinery composed of difference classes of objects: Display Unit, Communication component, Printer, Keypad and etc. for good working must be all these components synchronize with another component. Each of those simple transactions in reality is composed of several steps. Some transaction such as communication and authorization are controlled remotely from the ATM. Various diagrams can be used to model this system like the Activity Diagram, Sequence Diagram, Communication diagram or State Diagram of the UML 2 [2]. To properly understand the system being explored the notion of synchronization of events and objects are of fundamental importance. For Real Time behavior complex mechanisms, redundancy and time must be considered. There is also a problem with diagram consistency if too many diagrams are used. The bank ATM can be considered to be a soft Real - Time system which requires some form of performance analysis. Even though there are numerous methods that can be used for analysis, often it is better to keep to one method rather than end up with a collection of methods .There are formal techniques like: Real Time Logics, Duration Calculus, Process Algebras and Formal languages [3]. Usually there is no visual depiction of the system. It is possible to have a formally correct system exhibiting unwanted behavior if this is incorrectly modeled. For a bank ATM, there are many possible events and states. Understanding this system is highly dependent on dynamic modeling. A person’s natural thought process must naturally focus on the interaction between the system’s structure and events not on keeping models consistent. This can be achieved through the use of Petri Nets. Some of the most common classes of Petri
Nets are Timed Petri Nets, Stochastic Petri Nets, Generalized Stochastic Petri Nets and colored Petri Nets. Timed Petri Nets have been used successfully to model network ATM switching. Special firing times and timing issues have been used in these cases. Transitions can have deterministic or exponential firing times [4]. High level Petri Nets have been used to describe intelligent network switching. A Petri Net can perform some form of choice using defined conditions. Timed Petri Nets, Stochastic Petri Nets and Generalized Stochastic Petri Nets are special classes that can be used for the design of real time systems and embedded systems [5]. Petri Nets can be used in a three-view model: path-view, map-view and resource view [6]. This is useful for performance engineering of concurrent software. These models like TCPN (Timing Constraint Petri Nets) can be used for schedulability analysis of real time system specifications. Most of the work done with Petri Nets does not usually take a complete system into consideration from a highly detailed point of view. Also it is not usual for these models to cater for redundancy. This paper shows how many other details and mechanisms can be included in the Petri Nets being used. These mechanisms were built using the Petri Net theory. These mechanisms or constructs cannot be easily replicated using other methods.

2. RELATED WORK
This model for bank ATM has 4 main parts. Refer to Fig. 1. These are:

i) The Bank ATM machine
ii) Credit card authorization server
iii) Money teller unit
iv) An ATM Controller
v) Money teller unit

The ATM machine, the ATM Controller and credit card authorization with money teller unit work together synchronic. We describe briefly the work carried out:

i) Events and states were identified by 4 main parts. E.g. for the ATM possible events are: Customer Arrives, Insert Card, Insert Pin, Validate Pin, peek money, save money and others.

ii) These events were used to build four Timed Petri Nets, one of them for ATM Machine, second for the ATM Controller, other for the Card Authorization System and latest for teller unit.

iii) Many additional mechanisms were added to the basic Petri Nets to make their behavior more realistic.

iv) The Petri Nets were tested in isolation for all parts for any kind of errors. v) At the end four Petri Nets model for all parts were connected to produce the final system model.

vi) The full system Petri Net model was tested and simulated to derive results used for performance analysis. Three first parts are used of T.S.Staines model. For use of them need to simple model of them instead full model. This simple model must be of work like to full model.
2.1 T.S.STAINES’S SIMPLE MODEL

Fig. 2. Shows this simple model. Processing result for simple model almost equal with processing result full model. The final model resulted in Timed Petri Net. This was used to obtain performance results. Two types of transitions were used:

I) time transitions  
ii) Immediate transitions

The final results appear for performance results in Table 1.

Table 1: Processing results for 8 runs of the T.S.Staines simple model

<table>
<thead>
<tr>
<th>Run No</th>
<th>PIN</th>
<th>Total cards taken invalid</th>
<th>PIN</th>
<th>Total cards taken valid</th>
<th>Inserting PIN</th>
<th>Timeouts transaction selection</th>
<th>Transaction timeout</th>
<th>Total ATM controller timeouts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>326</td>
<td>349</td>
<td>97</td>
<td>11</td>
<td>11</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>330</td>
<td>350</td>
<td>94</td>
<td>11</td>
<td>11</td>
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<td>3</td>
<td>335</td>
<td>348</td>
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<td>4</td>
<td>330</td>
<td>347</td>
<td>95</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Fig. 2. A simple T.S.Staines model

2.2 NEW DEFINE PLACE

For teller unit we need to various new components. This components design in Petri nets. One of them is new defining place that must be having below characteristics:

i) Ability to store positive token

ii) Ability to store negative token
In basic Petri nets all places had positive or zero token ($M \geq 0$). If number of token at places reached under zero (be negative), place of this token was inactive. But new define places must be have negative token (bidirectional token). For negative place can be used mode in [7]. But negative place don’t allow for positive token. HPsim or other simulators usually can’t work for bidirectional token. Fig. 3. Shows a basic Petri nets place and transitions. In this nets P1 haven’t any token, so T2 is disabling, but P0 have 1 token therefore T1 is enable.

Fig. 4. shows a Petri nets with bidirectional place and basic transitions .in this nets P0 haven’t any token, so T1 is disable , but $\pm P1$ have 1 token therefore T2 is enable. In fig 4. T2 is always enabling, but T1 is disabling if P0’s token be zero. Because HPsim can’t simulate bidirectional token place, we use of positive token place with offset token e.g. token’s place set to 10000 (as offset), at the end of simulate if token number for that place be less than 10000 (e.g. 9500) say token is negative ($9500 - 10000 = -500$) and if be more than 10000 (e.g. 10270) say token is positive ($10270 - 10000 = 270$).

Fig. 4. A simple bidirectional Petri nets

2.3 RANDOM NUMBERS
At this work for payer unit we need to Petri net model for generate random number. Fig. 5. shows this model. T2 gets constant time firing delay, but T1 gets a firing time interval 5 – 10s, so token number of P1 at the end of simulation is a random number Between 5 – 10s.

Fig. 5. A Petri net for generate random
2.4 FINAL SYSTEM
After each component worked successfully as planned the complete system was assembled. Assembly was simply done by using connection channels. Basically and bidirectional places and transitions were used instead of the dummy places and transitions used for testing. Counters (places) were added to this to be able to get performance results from the Petri Net being used. Simulation was used to derive performance results this implies that the final model needed to be analyzed in detail. Refer to Fig. 7. The functioning of the model was successful.

2.4 CHOICE POINTS
Using the idea in Fig. 6 it is possible to add a choice point for the Petri Net. In Fig. 6. There are 0.3333 probability the $T_1$, $T_2$ or $T_3$ fires. Thus we use conflict or choice to simulate random conditions. This design can use for not equal probability.
Fig. 8. Complete system timed Petri net consisting of an ATM, ATM controller and Card authorization and money Teller unit
3. RESULTS
Fault tolerant and recovery mechanisms that function correctly have been created. These mechanisms are important for complex systems being a hybrid of hardware and software parts. Timing and performance analysis can be obtained from the models. The final model with the counter places comes close to a generalized stochastic Petri Net which is a special class of a Timed Petri Net. There is also an element of nondeterminism because of conflicting transitions or transitions enabled simultaneously.

Table 2. Processing results for 8 runs of the complete system Teller unit

<table>
<thead>
<tr>
<th>Run No</th>
<th>Coffer Customers</th>
<th>Money for save</th>
<th>Customers</th>
<th>Money for remove</th>
<th>No change</th>
<th>Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td></td>
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<tr>
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<td>31</td>
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<tr>
<td>4</td>
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<tr>
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<td>-1482</td>
<td>27</td>
<td>38</td>
<td>13</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The data in Table 2 consists of a summary of 8 simulation runs of one hour each for the model in Fig. 8. Detailed performance analysis was carried out on the model. The values obtained are also quite close to a real scenario e.g. in 1 hour use the system. This is quite realistic. The final results appear in Fig. 9. By changing the time values of the transitions it is possible to achieve totally different results as desired.

4. CONCLUSION
From the results obtained it is shown that added complex mechanisms have been successfully added to normal Timed Petri Nets. It is noticeable that even though the system modeled here initially looks simple there are many intricacies that are often overlooked.

Figure 9. Performance results for the full model

It is possible to refine the Petri Nets developed using reduction methods to simplify the model. These reduction methods enable the Petri Net developed to be simplified in detail. The problem is that many simulation tools do not support higher level constructs and new define places (as bidirectional place). This is why many of these constructs were not used here. These types of diagrams could be used for detailed analysis and design of complex information systems with synchronous and synchronous message passing. These diagrams help to identify possible system. There are also drawbacks with Petri Nets. If the system is complex it is possible to have too many states to control. With new software for Petri net
simulator we will can design simplify model with high realistic.

5. REFERENCES
Lead-Lag Controllers Coefficients Tuning to Control Fuel Cell Based on PSO Algorithm

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ABSTRACT

One of the most important Fuel cells (FCs) is Proton Exchange Membrane Fuel Cells (PEMFCs). The output voltage of this FC depends on current loads. This paper tries to introduce, implement and control the voltage of PEMFC, during load variations. The output voltage of fuel cell should be constant during load variation. To achieve this goal, a controller should be designed. Here, the Lead-Lag controller is used which its coefficients are optimized based on PSO algorithms. In order to use this algorithm, first this problem has to be formulated as an optimization problem, including objective function and constraints, and then to obtain the most desirable controller, PSO method is used to solve the problem. Simulation results for various loads in the time domain are performed and the results show the capability of the proposed controller. Simulations show the accuracy of the proposed controller performance to achieve this goal.

KEYWORDS: PEMFC, Fuel cell, Controller Design, PSO algorithm.

INTRODUCTION

Proton exchange membrane fuel cells (PEMFCs) include a cathode and an anode, and a leading proton between the anode and cathode is like an electrolyte. Hydrogen gas (H2), which is obtained from the methanol (CH3OH), is inserted into the end of the anode blade (negative electrode), and also oxygen or air at the end of the positive electrode of the cell (cathode) [1].

To produce electrical energy from the fuel cell, it is essential that the output voltage of cell kept constant for different loads to supply high quality power to the loads. But fuel cell output voltage changes for different loads. In order to keep the fuel cell voltage constant, using a controller is vital. The simplest type of controller which can be used is a LEAD-LAG controller.

In reference [1], a type of fuzzy controller to control the fuel cell output voltage is proposed. In order to control the voltage and current of the fuel cell, in reference [2] BP and RBF networks are used. The speed and accuracy of the proposed algorithms in reference [2] for this system are desirable. In reference [3], artificial neural networks are used to control the temperature of the fuel cell. To achieve good and efficient control, reference [4] utilized an optimized neural controller with Cerebella Model Articulation Controller (CMAC). In reference [5], a reinforcement learning adaptive controller for this system is presented, which adjusts controller coefficients online during load variations.

Studied fuel cell, is of the multiple fuel cells, but it is assumed that the anode and cathode mass has been compressed in anode and cathode as a fuel cell [6]. Any of the proposed methods are used to control
Norradin Ghadimi: Lead-Lag Controllers Coefficients Tuning to Control Fuel Cell Based on PSO Algorithm

only one parameter of the fuel cell, which in the methods, fuzzy or neural network are used. Some of these systems initially detect and then control the system, that in turn this will make slow the control task and in some cases causing long transient response. In the reference [5], a controller, which also has an adaptive PID controller, output results depend heavily upon initial conditions.

In this paper, first PID controller problems are expressed in reference [5], and shown by simulations, and in correction of that a simple Lead-Lag Controller to control fuel cell voltage has been utilized. Except that the controller design has not been achieved through trial and error method, however, to obtain these coefficients, PSO is used. Initially, the problem has been formulated as an optimization problem and then solved using the PSO algorithm and optimal results for proposed controller coefficients are obtained. This system is simulated in MATLAB software.

I. STUDIED SYSTEM

To study the dynamic model of the fuel cell, firstly, the general schematic, structure and function of the fuel cell should be studied. The schematic system of the fuel cell that will be studied in this paper is shown in Fig. 1. The mass of the anode and cathode in the figure is considered as a sole compression of anode and cathode [6].

In this paper, the dynamic model of the fuel cell is considered according to the reference [1]. The output voltage of the fuel cell is obtained by subtracting the voltage drops from the regressive voltage. Equation (1) shows how to calculate the fuel cell output voltage [6], [7] and [8].

\[ V_c = n(E_{\text{reversible}} - V_{\text{act}} - V_{\text{ohmic}} - V_{\text{con}}) \] (1)

Where, \( V_c \) is the accumulated fuel cell output voltage in volts, \( n \) is the existing cells in the accumulated fuel cell, \( V_{\text{act}} \) is the voltage drop resulting from anode and cathode activity in volts, \( V_{\text{ohmic}} \) is the ohmic voltage drop in volts, which is a certain amount of resistance in the transfer of electrons and protons in the electrolyte between the anode and cathode. \( V_{\text{con}} \) is resulting from the mass transfer of oxygen and hydrogen. \( E_{\text{reversible}} \) in equation (1) is calculated through the following equations [1] and [9].

\[ E_{\text{reversible}} = 1.229 - 0.85 \times 10^{-3} (T - 298.15) + 4.3085 \times T \times \ln(PH_2 + 0.5 \ln(PO_2)) \] (2)

Where, \( T \) is the cells temperature in Kelvins, \( PH_2, PO_2 \) are effective partial pressure (atm) of hydrogen and oxygen gases respectively that can be calculated by the following equation.

\[ PO_2 = P_a - P_{H_2O}^{\text{sat}} - P_{\text{channel}} \exp \left( \frac{0.291}{T} \right) \] (3)

\[ PH_2 = 0.5 P_{H_2O}^{\text{sat}} \left( \exp \left( \frac{1.635}{T} \right) \right) \] (4)

Where, \( P_a \) and \( P_e \) are the anode and cathode inlet pressure in atmospheres, \( A \) is the effective electrode area in \( cm^2 \), \( i \) is the current of each cell in amperes, \( P_{H_2O}^{\text{sat}} \) is the amount of saturated steam pressure that its value depends on the fuel cell. \( P_{\text{channel}}^{N_2} \) is the partial pressure of \( N_2 \) in the cathode gas flow channels in atmospheres which can be calculated by the following equation.
\[ P_{ch}^{\text{channel}} = \frac{0.79}{0.21} P_{O_2} \] (5)

All amounts used in this article, are the same data available in the reference [1].

II. PARTICLE SWARM ALGORITHM

A. INTRODUCING PSO ALGORITHM

The intelligent methods search different parts of the solution space to find the solution of the optimization problem. So they can provide an appropriate solution for a particular problem in an acceptable time, but one cannot be sure that the obtained solution is an absolute optimum point for the problem. The most important advantage of this algorithm is that they do not need auxiliary conditions such as derivatives and boundary conditions and the only criteria used is the objective function.

PSO algorithms are inspired by the social behavior related to the animal categories such as bird flock and fish group. Individuals in the population are called a particle. Each particle is the potential solution for the optimization problem trying to search the best position in a multi-dimensional space. Each particle is determined with two vectors in the search space, i.e. position vector \( X = [X_1, X_2, ..., X_d] \) and velocity vector \( V = [V_1, V_2, ..., V_d] \). Between searches particles, each particle corrects itself using its current speed and previous experience and neighboring particles experience. The best position of the ith particle, which has been found so far, \( PB = [Pb_1, Pb_2, ..., Pb_n] \) is called the particle best and the best position in the whole particles \( GB = [Gb_1, Gb_2, ..., Gb_n] \) is called the global particle.

In any iteration, velocity values and all positions will be updated. In any iteration the velocity of ith particle is updated using equation (6). The figures of this update are shown in Fig 2.

\[ V_{i}^{k+1} = \omega V_{i}^{k} + c_1 r_1 (PB_i^{k} - X_i^{k}) + c_2 r_2 (GB_i^{k} - X_i^{k}) \] (6)

After that, the speed of all particles has been updated; particles with new speed moving to the new positions using the equation (7).

\[ X_{i}^{k+1} = X_i^{k} + V_i^{k+1} \] (7)

Fig. 2. updating of particles in PSO

Which \( c_1 \) and \( c_2 \) are the acceleration coefficients, \( r_1 \) and \( r_2 \) are the random values with normal distribution in the range of (0,1). \( X_{id} \) is the current position of particle, \( PB_i \) is the best individual position of each particle in the previous iterations, \( GB \) is the best global position of particles in previous iterations and the coefficient \( \omega \) is the inertia coefficient. Usually in the algorithm implementation, the value of inertia coefficient is set during learning and, generally, is decreased linearly from the value of unity to near the zero according to the equation (8).

\[ \omega = \omega_{\text{max}} - \frac{\omega_{\text{max}} - \omega_{\text{min}}}{\text{iter}_{\text{max}}} \text{iter} \] (8)

Which \( \text{iter}_{\text{max}} \) is the maximum number of iterations and \( \text{iter} \) is the number of current iteration. The velocity of velocity vector \( V_i \) (velocity vector) in each dimension is limited in the range of \([-V_{\text{max}}, +V_{\text{max}}]\) to reduce the probability of leaving the search space by particle. PSO
algorithm is performed with the following steps:

Step 1) (Initialize): put iteration \( k = 0 \) and \( n \) particles with initial position \( x^0 = [x_1^0, x_2^0, ..., x_d^0] \) and initial velocity \( v^0 = [v_1^0, v_2^0, ..., v_d^0] \) which are generated randomly. Calculate the objective function \( f(x^0) \) for each particle, If no constraint is violated, put \( PB^0 = x^0 \) and select, among all particles, a particle with the lowest objective function and put it equal to \( GB^0 \), otherwise, the initial generation of particles will be repeated.

Step 2) Update the iteration parameter \( k = k + 1 \).

Step 3) Update particles velocity using the equation (6).

Step 4) Update particles position using the equation (7).

Step 5) Update the best particle (BP):

If \( f(x^k) < f(x^{k-1}) \), therefore put \( PB^k = x^k \)
otherwise put \( PB^k = PB^{k-1} \)

Step 6) Update the best particle among the particles (GB): \( f(GB^k) = \min\{ f(PB^k) \} \)

If \( f(GB^k) < f(GB^{k-1}) \) hence put \( GB^k = GB^k \)
otherwise \( GB^k = GB^{k-1} \).

Step 7) Program termination criteria: if the number of iterations is more than the maximum number of predetermined iterations the program will stops, and otherwise return back to step 2.

B. Using PSO to adjust control parameters

Despite many developments in control systems and their applicability, simple controllers in systems are still considered desirable controllers [12]. In most cases, compensators in power systems are lead-lag controllers. These controllers could be implemented easily in analog and/or digital systems. In this study, lead-lag controllers are used to control the voltage of proton exchange membrane fuel cell. The overall controller schematic is shown in Fig. 3.

Parameters which should be controlled in the controller area \( T_p, T_c, K_p \), it is clear that the transient state of the system in load changes depends on these coefficients of controller. Controller design methods here could not be implemented, since the system is fully nonlinear system, therefore these methods have not efficient performance in this system.

Fig. 3. Block diagram of the proposed controller to control fuel cell voltage

In order to design controller using PSO algorithm for this system based on the curve of the wind changes, we consider the worst conditions, and controller is designed for these conditions. Fig. 4 shows the worst considered changes in this system in voltage 20v.

Fig. 4. Bad conditions of load current considered for the studied system

Now, the problem must be formulated as an optimization problem and then be solved. Choosing an objective function is the main part of this optimization problem. Because the choice of objective functions may completely change how the particles will move. In our optimizing problem, here, we use the error signal.
\[ J = \int_{0}^{t = t_{sim}} |v_{out} - v_{ref}| dt \]  
\[ (9) \]

Where \( t_{sim} \) is the simulation time during which the objective function is calculated. It should be noted that the more the objective function is smaller the more the solution is optimum. Each optimization problem is expressed under a number of constraints which in this problem, constraints are expressed as follows.

\[
\text{Minimize } J \text{ subject to} \]
\[ T_p^\text{min} \leq T_p \leq T_p^\text{max} \]
\[ T_z^\text{min} \leq T_z \leq T_z^\text{max} \]
\[ K_p^\text{min} \leq K_p \leq K_p^\text{max} \]
\[ (10) \]

Where, \( T_p, T_z \) is within the interval \([0.01 \ 50]\) and \( K_p \) is in the interval \([0.01 \ 5]\).

In the optimization problem, the number of particles, particles dimensions and the number of iterations have been selected 30, 3 and 60, respectively. After the optimization results are determined as follows.

\[ T_p = 0.34515, T_z = 0.1165, K_p = 0.5578 \]
\[ (11) \]

SIMULATION RESULTS

In this section, simulation results are performed for five different conditions, and output results obtained using proposed controller is compared with a controller in reference [5].

C. SIMULATION RESULTS WITH REFERENCE CONTROLLER IN [5]

In reference [5], a controller is proposed based on reinforcement learning adaptive algorithm. This controller changes lead-lag coefficients online manner. If the varying steps get long, it is likely to reach a not more satisfied solution. But, if these variations are low, in these conditions, the algorithm needs to find an appropriate initial value for lead-lag coefficients. Fig.5 shows anode and cathode gas pressure, load current, output voltage and the reference voltage with initial conditions expressed in Eq (9).

\[ K_p = 1, K_i = 1, K_d = 0.1 \]
\[ (12) \]

Fig. 6 shows appropriately the output voltage and reference voltage with initial conditions expressed in Eq (12). And fig. 6 shows the output voltage and the reference voltage with initial conditions expressed in Eq (13). According to the results it is obvious that output voltage depends on the initial conditions, since results are different from each other.

\[ K_p = 15, K_i = 1, K_d = 0.2 \]
\[ (13) \]
Norradin Ghadimi: Lead-Lag Controllers Coefficients Tuning to Control Fuel Cell Based on PSO Algorithm

Fig. 6. Output voltage of load and reference voltage with PID coefficients in Eq (12)

Fig. 7. Output voltage of load and reference voltage with PID coefficients in Eq (13)

D. SIMULATION RESULTS WITH PROPOSED CONTROLLER

Simulation results using obtained coefficients proposed algorithm expressed in Eq (11) are shown in Figs. (8-10). Fig. 8 shows anode and cathode gas pressures, load current, output voltage and reference voltage. Output load voltage and reference voltage are shown in fig. 9, and according to the figure it is clear that results are improved and are better than the previous modes. Created peaks in this mode are lower than the previous coefficients. Also, the error between the output and reference voltages is shown in fig. 10 which shows the high efficacy of the proposed algorithm.

Fig. 8. Anode and cathode gas pressures, load current, output voltage and reference voltage with proposed controller

Fig. 9. Output voltage and reference voltage with proposed controller

Fig. 10. The error between output and reference voltages
E.  COMPARISON WITH GA CONTROLLER

In this section Results of proposed controller will be compared with GA algorithm controller [13]. Simulation results using obtained coefficients proposed algorithm using GA controller and proposed controller are shown in Figs. (11). Zooming on peak value at t=155s shows that the proposed PSO based controller is better than pervious GA based controller. With PSO based controller, the maximum peak and settling time value are less than GA based controller.

![Comparison with GA based algorithm](image)

**Fig.11. Result comparison with GA based algorithm**

**CONCLUSION**

In this paper, a controller based on PSO Algorithm and lead-lag controller was suggested to control the fuel cell output voltage. The controller has been chosen because it is simple and resolves the problem of the previous controller and its performance is higher than previous controllers. PSO algorithm was utilized to design the lead-lag controllers and has the most optimum state. In solving this problem, first the problem is formulated as an optimization problem which its objective function was defined in the time domain and then solved using PSO algorithms. And the most optimum mode for lead-lag coefficients were determined using this algorithm.

Proposed controller could improve the transient state of current and voltage. This claim within the different states of loads was verified using simulation in MATLAB software in a time domain system.

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Temperature Effect on THz Quantum Cascade Lasers

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ABSTRACT

A simple semi-phenomenological model, which accurately predicts the dependence of threshold current for temperature of Resonant-phonon three well quantum cascade laser based on vertical transitions is offered. We found that, the longitude optical phonon scattering of thermally excited electrons is the most important limiting factor for thermal performance of high frequency THz QCLs. In low frequency region, parasitic current increases the threshold current. Based on our model the use of materials with higher longitude optical phonon energy such as InGaAs/GaAsSb and decreasing the lower laser level lifetime can increase the maximum performance temperature. Our observations may can be used to understand the notion of the effects of thermal electrons on reduction of laser performance.

KEYWORDS: Quantum cascade lasers, longitude optical phonon, intersubband transitions, Parasitic current.

1. INTRODUCTION

Quantum cascade lasers (QCLs) are semiconductor lasers based on intersubband transitions in multi quantum well heterostructures, which rely on epitaxial growth techniques [1]. They are very versatile mid-infrared sources for the realization of Ultrasensitive and selective sensors for spectroscopic applications in the fields of environmental monitoring, industrial processes, security and military [2].

Terahertz quantum-cascade lasers (THz QCLs) now provide spectral coverage from $v = 1.2 – 5 \, THz$ with optical pomilliwatt in the tens of milli-Watt range, and are poised to become one of the most important types of terahertz radiation source [3]

So far among all existing designs, the three-well resonant phonon based THz QCLs, originally proposed by Luo et al. [4], have demonstrated the best temperature performance [5]. The major effect of temperature rising on laser performance as follows:

Low temperature performance of THz QCLs is a major problem. The temperature affects inter and intrasubband lifetimes by the Bose-Einstein factor. Although this is fortunately a weak coupling, the effective upper state lifetime decreases with increasing temperature affecting inversely the threshold current density. The atomic-like joint density of states is beneficially
since this will avoid direct temperature broadening of the linewidth. However, the linewidth is collision broadened by the ultra-short inter and intrasubband lifetimes. Linewidth broadening has a detrimental effect on the gain cross section and increases the non-resonant intersubband losses; both reduce the threshold current density. Furthermore, the temperature increases the backfilling and consequently the larger non-resonant losses will increase the threshold current density.

Improving the maximum operating temperatures of THz QCLs still further is highly attractive for a range of technological applications. This is made inherently more difficult in the THz frequency range than in the mid-infrared (MIR) due to the smaller photon energy (typically less than 20 meV). At higher lattice temperatures (and, hence, higher electron temperatures), it becomes more difficult to achieve selective injection and depopulation of the upper and lower laser levels. Additionally, since the photon energy is less than the LO phonon energy (36 meV in GaAs) in the THz frequency range, at sufficiently high electron temperatures, thermally activated LO phonon .

The maximum operating temperature demonstrated to date, without a magnetic field, is 186 K [6] for pulsed operation and 117 K for CW operation [7]. With an applied magnetic field of 20–30 T, THz QCLs can operate at higher temperatures, with \( T_{\text{max}} \approx 225 \text{K} \) demonstrated for 3-THz devices [8].

Several theoretical models have been employed to understand the details of charge transport and optical gain within THz QCLs, based on various approaches such as density matrix (DM) [9], non-equilibrium Green function [10], and Monte Carlo (MC) techniques [11]. We are going to provide a model to explain the decrease of gain at higher temperatures. We present a simple semi-phenomenological model, which accurately predicts the threshold current dependence for 3QW QCL design with a vertical (the lower and upper laser levels located in the same well) lasing transition. This study may lead to a better understanding of the notion of the effects of thermal electrons on reduction of laser performance.

2. THEORETICAL MODEL

The electron can lose its energy by colliding with other electrons, emitting photons, emitting optical and acoustical phonons, and by interacting with interface surface and impurities. It seems that, the LO phonon scattering of thermal electrons is the main factor of low performance. Accordingly, this is because of the fact that when the temperature of electrons is increased, instead of photon emission and leaving the upper level they emit LO phonons.

The population inversion in a two level system is described by the following equation

\[
    n_2 - n_1 = \frac{J_{\text{eff}} (\tau_{21} - \tau_1)}{e} 
\]

\( \tau_1 \) is the electron lifetime in the lower laser level (in our case, it is determined by resonant tunneling into the injector and subsequent optical phonon scattering), \( \tau_{21} \) is the electron scattering time from state 2 to state 1 (which is determined by optical phonon scattering of thermal electrons in state 2 and \( J_{\text{eff}} = J - J_{\text{par}} \). The threshold current for this laser is given as follows:
\[ J_{th} = J_{par} + \alpha_{tot} \left( \frac{\varepsilon_0 \hbar c n_{\text{eff}}}{4\pi e} \right) \left( \frac{\delta \nu}{\nu_0} \right) \left( \frac{L_{\text{per}}}{z} \right) \left( \frac{1}{\tau_{21} - \tau_i} \right) \]  

(2)

Where \( \alpha_{tot} \) are the total optical losses in the laser, \( n_{\text{eff}} \) is the optical dipole moment for the laser transition, \( \delta \nu \) is the full-width at half-maximum (FWHM) of the laser transition at frequency \( \nu_0 \), and \( L_{\text{per}} \) is the length of one period. Equation (2) can be rewritten in typical units used in experiments as

\[ J_{th} = J_{par} + 31.5 \alpha_{tot} \left( \frac{\delta \nu}{\nu_0} \right) \left( \frac{L_{\text{per}}}{z} \right) \left( \frac{1}{\tau_{21} - \tau_i} \right) \]  

(3)

In the above equation, length, time and total optical losses are written in nanometer, picoseconds and cm\(^{-1}\) units.

When the energy separation between the upper and lower laser levels is less than the LO-phonon energy, and the electron density in state 2 is low so that the Fermi energy is much smaller than \( K_B T \), we can approximate the electron scattering time from state 2 to state 1 as follows:

\[ \frac{1}{\tau_{21}} = \frac{1}{\tau_{21,0}} + \frac{1}{\tau_{21,\text{hot}}} \]  

(4)

Where, \( \tau_{21,0} \) is the upper level lifetime at 0K, and \( \tau_{21,\text{hot}} \) is the lifetime of electrons in level 2 which can emit optical phonons and relax to level 1. In order to obtain the above equation we used the assumption \( \tau_{21,0} > \tau_{21,\text{hot}} \).

Using Eq. (4) and (3) the temperature dependence of threshold current obtained as

\[ J_{th} = J_{par} + \frac{B}{\tau_1} \left( \frac{1}{\tau_{21,\text{hot}}} \right) \left( \frac{1}{\tau_{21,0}} \right) \left( \frac{1}{\tau_i} \right) \left( \frac{\hbar c}{K_B T} \right) \]  

(5)

Where \( B = 31.5 \alpha_{tot} \left( \frac{\delta \nu}{\nu_0} \right) \left( \frac{L_{\text{per}}}{z} \right) \).

Experimental data for threshold and parasitic current is obtained in [12]. The frequency values of these lasers are 2.3, 2.7, 3.1, 3.5 and 3.8 THz. Fig.1 shows the experimental values of threshold current for some THz QCLs with different frequencies which are obtained as a heat sink temperature.

![Fig. 1. The threshold current obtained in various heat sink temperatures for some THz QCLs with different frequencies [12].](image)

We can obtain the values of \( B/\tau_1 \) and \( \tau_i/\tau_{21,\text{hot}} \) through fitting the above equation with experimental data and compare them with theatrical values obtained in [13, 14].

3. RESULT AND DISCUSSION

3.1. Parasitic current

Parasitic current appears when electrons go through some unwanted channel. This current appears in all bias voltages; however, in this section we focus on parasitic current, which occurs due to electron tunneling from the active region. In
fact, this occurs when the energy of the electron rises to a specific value. We show this current in Fig.2 schematically. When the energy of the electron reaches to this point, the instability appears in the current-voltage graph of the laser. At this point, the second derivative of the current-voltage curve vanishes.

\[
J_{\text{par}} = eN \frac{(\Delta_{12}/\hbar)^2\tau_1}{2(1+(\Delta_{12}/\hbar)^2\tau_1^2)}
\]

Where \( \Delta_{12} \) is the anticrossing energy between levels 1 and 2 at the parasitic alignment, \( N \) is the doping density, \( \tau \) is the phonon emission time in the upper injector state (state 2), and \( \frac{1}{\tau_1} = \frac{1}{2\tau} + \frac{1}{T_2^*} \), where \( T_2^* \) is a pure dephasing time.

If the Schrödinger-Poisson method is used for calculating anticrossing energy, the following values can be resulted in parasitic current, which are in a good agreement with the experimental data given in [12].

<table>
<thead>
<tr>
<th>( v(TMz) )</th>
<th>2.3</th>
<th>2.7</th>
<th>3.1</th>
<th>3.5</th>
<th>3.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta_{12} )</td>
<td>1.08</td>
<td>0.94</td>
<td>0.79</td>
<td>0.74</td>
<td>0.68</td>
</tr>
<tr>
<td>( J_{\text{par (cal)}} )</td>
<td>1025</td>
<td>879</td>
<td>701</td>
<td>640</td>
<td>566</td>
</tr>
<tr>
<td>( J_{\text{par (exp)}} )</td>
<td>991±54</td>
<td>827±53</td>
<td>623±70</td>
<td>508±70</td>
<td>462±70</td>
</tr>
</tbody>
</table>

As it can be seen, parasitic current, have higher values in lower frequencies and increase the threshold current.

### 3.2. LO PHONON SCATTERING

If the temperature of electron equals with heat sink, we get the best fit with \( \frac{B}{\tau_1} \approx 305.23 \), and \( \frac{\tau_1}{\tau_{21,\text{hot}}} \approx 3.19 \); however, there is a little difference with theoretical \( \left( \frac{B}{\tau_1} \approx 144, \frac{\tau_1}{\tau_{21,\text{hot}}} \approx 2.7 \right) \) value obtained for this parameters in [13,14].

This is due to the equality assumption of electron temperature with heat sink temperature. In fact, this assumption is not valid, and there is a temperature difference of the range 50 to 100 between electron and lattice. Fig.3 shows the results abstained from fitting equation (5) with experimental data. A temperature difference of 50 degrees between the electron and the heat sink was considered. As it can be seen, there is a good accordance between represented model and experimental data. The values of parameters, \( \frac{\tau_1}{\tau_{21,\text{hot}}} \approx 2.832 \) are in good agreement with the theoretical value of this parameter.
Using equation (4), the maximum performance temperature can be given as

$$T_{\text{max}} \approx \frac{E_{\text{LO}} - \hbar \nu}{K_B \ln(\frac{\tau_1}{\tau_{21,\text{hot}}})}$$  \hspace{1cm} (7)$$

This relation for 2 THz laser results in $T_{\text{max}} \approx 250$ and for 4 THz laser results in $T_{\text{max}} \approx 182$. We see that this model gives an upper temperature bound for vertical 3 well QCLs. In order to improve the temporal performance of these lasers we can offer various solutions. In the first stage, we can reduce parasitic current. According to (6), the less anticrossing energy is, the less this current will be. In the second stage, we can use materials with lower $E_{\text{LO}}$ such as InGaAs/GaAsSb.

In order to obtain the equation (7) we have used the assumption $\tau_{21,0} > \tau_{21,\text{hot}}$. Now, if we neglect this assumption the maximum performance temperature will be

$$T_{\text{max}} \approx \frac{-E_{\text{LO}} + \hbar \nu}{K_B \ln[(1 - \frac{\tau_1}{\tau_{21,0}}) \frac{\tau_{21,\text{hot}}}{\tau_1}]}$$  \hspace{1cm} (8)$$

In Fig. 4 the effect of a lower laser lifetime on maximum temperature has been shown.

We see that a little variation in these parameters can increase $T_{\text{max}}$ drastically.

The LO phonon emission rate reduces drastically in diagonal transition. Hence, in this section we apply this model to a THz QCLs with the vertical transition with performance temperature of 186 k. The performance frequency of this laser is 3.9 THz and optical dipole moment is 5.9.

In the previous section we have seen that according to the definition, $B$ was proportional to $z^{-2}$; however, in this section we offer a new quantity $\mu = \frac{\tau_{\text{verse}}}{\tau_{\text{diag}}}$ and therefore, $B$ must be replaced by $Bu$. The phonon emision rate of thermal electrons in diagonal transitions is proportional to $z^{2}$ [16]. Thus, in previous model we replace $\frac{\tau_1}{\tau_{21,\text{hot}}}$ with $\frac{\tau_1}{\tau_{21,\text{hot}}} \cdot \frac{1}{\mu}$. $\tau_1$ and $L_{\text{per}}$ are same for both lasers. The data obtained with this model are compared with data given in [17]. As it can be found from the plot, there is a reasonable and satisfactory accordance between experimental and
maximum performance temperature can be more than 700 k.

Also the maximum performance according to this model is very high; but, other factors as low z increase the threshold current of these lasers.

![Fig. 5. The experimental and calculated threshold current for vertical THz QCL.](image)

**5. CONCLUSIONS**

Therefore, it can be concluded that for three well THz QCLs designed based on vertical transitions, the maximum performance temperature is limited by LO phonon scattering of thermally excited electrons. We can improve the maximum performance temperature using materials with higher $E_{LO}$ and decreasing the electron lifetime in the lower laser level with lifetime engineering.

In Diagonal transitions, LO-phonon scattering significantly reduces, so using this kind of transitions can be a useful alternative for constricting a THz QCL at room temperature.

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Robust Method for E-Maximization and Hierarchical Clustering of Image Classification

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ABSTRACT

We developed a new semi-supervised EM-like algorithm that is given the set of objects present in each training image, but does not know which regions correspond to which objects. We have tested the algorithm on a dataset of 860 hand-labeled color images using only color and texture features, and the results show that our EM variant is able to break the symmetry in the initial solution. We compared two different methods of combining different types of abstract regions, one that keeps them independent and one that intersects them. The intersection method had a higher performance as shown by the ROC curves in our paper. We extended the EM-variant algorithm to model each object as a Gaussian mixture, and the EM-variant extension outperforms the original EM-variant on the image data set having generalized labels. Intersecting abstract regions was the winner in our experiments on combining two different types of abstract regions. However, one issue is the tiny regions generated after intersection. The problem gets more serious if more types of abstract regions are applied. Another issue is the correctness of doing so. In some situations, it may be not appropriate to intersect abstract regions. For example, a line structure region corresponding to a building will be broken into pieces if intersected with a color region. In future works, we attack these issues with two phase approach classification problem.

KEYWORDS: Algorithm, models, mixture, segmentation.

I. INTRODUCTION

In recent years, the computer vision community has started to tackle more general, more difficult recognition algorithms using a number of techniques that have been developed over the years. Techniques that use the appearance of an object in its images, instead of its 3D structure, are called appearance-based object recognition techniques [1]. The current limitations of these techniques are that they expect the image to consist of, or be limited to, the object in question and that this object must be presented from the same viewpoint as the images used to train the system. Appearance-based techniques have been able to yield high recognition accuracy in limited domains. Appearance-based
techniques do not attempt to segment the image; this is both strength and a weakness of the approach. Region-based techniques [2] require pre-segmentation of the image into regions of interest. In most applications, the reliability of image segmentation techniques has been a problem for object recognition, but image segmentation algorithms [3] that use both color and texture can now partition an image into regions that, in many cases, can be identified as having the right colors and textural pattern to be a tiger or a zebra or some other object with a well-known color-texture signature. Related to this approach are algorithms that look for regions in color-texture space that corresponds to particular materials, such as human flesh [4]. A different set of color criteria and spatial region relationships can be used to find horses [5]. People’s faces have also been successfully detected using only gray-tone features and relying on heavily-trained neural net classifiers [6]. In fact, neural nets and support-vector machines have become an important tool in recognizing several different specific classes of imagery. CBIR has become increasingly popular in the past 10 years. In a publication [7] by Smeulders et al. More than 200 references are reviewed. On the web page of the Viper project, a framework to evaluate the performance of CBIR systems, about 70 academic systems and 11 commercial systems are listed. Prominent systems include VISUALSEEK [8], WebSEEK, [9], BLOBWORLD [2], and SIMPLIcity [10]. In the CBIR, only a small number of researchers have worked on retrieval via object recognition and many of these efforts have been limited to a single class of object, such as people or horses. The SIMPLIcity system extracts features by a wavelet-based approach and compares images using a region-matching scheme. It classifies images into categories, such as textured or non-textured, graphic or non-graphic. In [11] utilize a generative hierarchical model to automatically annotate images. In [12] classifies image regions as blobs and finds the relationship between blobs and annotations as a machine translation problem. In [12-14] described their model as machine translation. One problem with both of these approaches is the assumption of a one-to-one mapping between image regions and objects, which is not always true. Instead, some objects span multiple regions, and some regions contain multiple objects. For the same reason, these approaches cannot use context information to assist in recognition. Yet context is an important cue that is often very helpful. The fundamental difference between these approaches and ours is that they map a point in feature space to the target object, while we map a set of points in the feature space to the target. In the SIMPLIcity system, the authors recognized the problem with one-to-one mappings and solved it with an approach called “integrated region matching,” which measures the similarity between two images by integrating properties of all regions in the images. This approach takes all the regions within an image into account, which can bring in regions that are not related to the
target object. Our approach first discovers which regions are related to the target object and makes its decision based on those regions. Clearly there is no single feature suitable for all object recognition tasks. A robust system should be able to combine the power of many different features to recognize many different objects. In [10], the feature set is determined empirically by the developer. Our system learns the best weights for combining different features to recognize different objects. For the most part, generic object recognition efforts have been standalone. There is not yet a unified methodology for generic object class recognition or for concept class recognition. The development of such a methodology is the subject of our research. In Section II we formalize this approach, in Section III we describe our experiments and results, and an extension of this approach aiming at recognizing object classes with different appearances.

2. FORMALIZING THE APPROACH
Initialization phase of the EM-variant approach, each object is modeled as a Gaussian component, and the weight of each component is set to the frequency of the corresponding object class in the training set. Each object model is initialized using the feature vectors of all the regions in all the training images that contain the particular object, even though there may be regions in those images that do not contribute to that object. From these initial estimates, which are full of errors, the procedure iteratively re-estimates the parameters to be learned. The iteration procedure is also supervised by the label information, so that a feature vector only contributes to those Gaussian components representing objects present in its training image. The resultant components represent the learned object classes and one background class that accumulate the information from feature vectors of other objects or noise. With the Gaussian components, the probability that an object class appears in a test image can be computed. This part describes the EM-variant approach and illustrates its use with color and texture regions. We are given a set of training images, each containing one or more object classes, such as grass, trees, sky, houses, zebras, and so on. Each training image comes with a list of the object classes that can be seen in that image. There is no indication of where the objects appear in the images. We would like to develop classifiers that can train on the features of the abstract regions extracted from these images and learn to determine if a given class of object is present in an image.

2.1 Single-Feature Case
Let T be the set of training images and O be a set of m object classes. Suppose that we have a particular type a of abstract region and that this type of region has a set of \( n^a \) attributes which have numeric values. Then any instance of region type a can be represented by a feature vector of values \( r^a = (v_1, v_2, \ldots, v_{n^a}) \). Each image I is represented by a set \( F^a_I \) of type a region
feature vectors. Furthermore, associated with each training image \( I \in T \) is a set of object labels \( O_I \), which gives the name of each object present in \( I \). Finally, associated with each object \( o \) is the set \( R^o_a = \bigcup_{I \in O_I} F^a_I \), the set of all type \( a \) regions in training images that contain object class \( o \). Our approach assumes that each image is a set of regions, each of which can be modeled as a mixture of multi-variate Gaussian distributions. We assume that the feature distribution of each object \( o \) within a region is a Gaussian \( N_o(\mu_o, \sum_o) \), \( o \in O \) and that the region feature distribution is a mixture of these Gaussians. We have developed a variant of the EM algorithm to estimate the parameters of the Gaussians. Our variant is interesting for several reasons. First, we keep fixed the component responsibilities to the object priors computed over all images. Secondly, when estimating the parameters of the Gaussian mixture for a region, we utilize only the list of objects that are present in an image. We have no information on the correspondence between image regions and object classes. The vector of parameters to be learned is:

\[
\lambda = (\mu_{o1}^a, ..., \mu_{om}^a, \mu_{bg}^a, \sum_{o1}^a, ..., \sum_{om}^a, \sum_{bg}^a)
\]

(1)

where \( \{\mu_{oi}^a, \sum_{oi}^a\} \) are the parameters of the Gaussian for the \( i \)th object class and \( \{\mu_{bg}^a, \sum_{bg}^a\} \) are the parameters of an additional Gaussian for the background. The purpose of the extra model is to absorb the features of regions that do not fit well into any of the object models, instead of allowing them to contribute to, and thus bias, the true object models. The label \( bg \) is added to the set \( O_I \) of object labels of each training image \( I \) and is thus treated just like the other labels. The initialization step, rather than assigning random values to the parameters, uses the label sets of the training images. For object class \( o \in O \) and feature type \( a \), the initial values are:

\[
\mu_{o}^{a} = \frac{\sum_{r \in R_{o}^{a}} r^{a}}{|R_{o}^{a}|}
\]

(2)

\[
\sum_{o}^{a} = \frac{\sum_{r \in R_{o}^{a}} (r^{a} - \mu_{o}^{a})(r^{a} - \mu_{o}^{a})^{T}}{|R_{o}^{a}|}
\]

(3)

Note that the initial means and covariance matrices most certainly have errors. For example, the Gaussian mean for an object in a region is composed of the average feature vector over all regions in all images that contain that object. This property will allow subsequent iterations by EM to move the parameters closer to where they should be. Moreover, by having each mean close to its true object, each such subsequent iteration should reduce the strength of the errors assigned to each parameter. In the E-step of the EM algorithm, we calculate:

\[
p(r_a^a | o, \mu_o^a(t), \sum_o^a(t)) = \begin{cases} 0 & \quad \text{otherwise} \\ \frac{1}{(2\pi)^{a/2}} e^{-\frac{1}{2}(r^{a} - \mu_o^a)^T \sum_o^a(t)^{-1}(r^{a} - \mu_o^a)} & \quad \text{otherwise} \\ \frac{1}{(2\pi)^{a/2}} e^{-\frac{1}{2}(\sum_o^a(t))} & \quad \text{otherwise} \end{cases}
\]

(4)
\[
p(o \mid r^a, \lambda(t)) = \frac{p(r^a \mid 0, \mu_o^a(t), \sum_j a(t)) p(o)}{\sum_{j \in a} p(r^a \mid j, \mu_j^a(t), \sum_j a(t)) p(j)}
\]

where

\[
p(o) = \frac{|I \mid o \in O_i|}{|T|}
\]

Note that when calculating \( p(r^a \mid 0, \mu_o^a(t), \sum_j a(t)) \) in (4) for region vector \( r_a \) of image I and object class \( o \) and when normalizing in (5), we use only the set of object classes of \( O_i \), which are known to be present in I. The M-step follows the usual EM process of updating with \( \sum_0 a \):

\[
\mu_o^a(t + 1) = \frac{\sum_{r^a} p(o \mid r^a, \lambda(t)) r^a}{\sum_{r^a} p(o \mid r^a, \lambda(t))}
\]

\[
\sum_0 a(t + 1) = \frac{\sum_{r^a} p(o \mid r^a, \lambda(t)) [r^a - \mu_o^a(t + 1)] [r^a - \mu_o^a(t + 1)]'}{\sum_{r^a} p(o \mid r^a, \lambda(t))}
\]

After multiple iterations of the EM-like algorithm, we have the final values \( \mu_o^a \) and \( \sum_0 a \) for each object class \( o \) and the final probability \( p(o \mid r^a) \) for each object class \( o \) and feature vector \( r^a \). Now, given a test image I we can calculate the probability of object class \( o \) being in the image I given all the region vectors are \( a \) in me:

\[
p(o \mid F_i^a) = f\{ p(o \mid r^a) \mid r_a \in F_i^a \}
\]

where \( f \) is an aggregate function that combines the evidence from each of the type-a regions in the image. We use max and mean as aggregate functions in our experiments.

### 2.2 Multiple-Feature Case

Since our abstract regions can come from several different processes, we must specify how the different attributes of the different processes will be combined. For the EM-variant, we have tried two different forms of combination:

1. Treat the different types of regions independently and combine only at the time of classification:

\[
p(0 \mid \{ F_i^a \}) = \prod_a p(0 \mid F_i^a)
\]

2. Form intersections of the different types of regions and use them, instead of the original regions, for classification.

In the first case, only the specific attributes of a particular type of region are used for the respective mixture models. If a set of regions came from color segmentation, only their color attributes are used, whereas if they came from texture segmentation, only their texture coefficients are used. In the second case, the intersections are smaller regions with properties from all the different processes. Thus an intersection region would have both color attributes and texture attributes.
3. RESULTS
We tested the EM-variant approach on color segmentations and texture segmentations. The test database of 860 images was obtained from two image databases: creatas.com and our ground truth database. The images are described by 18 keywords. The keywords and their appearance counts are listed in Table 1. We ran a set of cross-validation experiments in each of which 80% of the images were used as the training set and the other 20% as the test set. In the experiments, the recognition threshold was varied to obtain a set of ROC curves to display the percentage of true positives vs. false positives for each object class. The measure of performance for each class was the area under its ROC curve, which we will henceforth call a ROC score. Figure 1 illustrates the ROC curves for each object, treating color and texture independently. Figure 2 illustrates the results for the same objects, using intersections of color and texture regions. Table 2 lists the ROC scores for the 18 object classes for these two different feature combination methods. In general, the intersection method achieves better results than the independent treatment method, a 6.4% performance increase in terms of ROC scores. This makes sense because, for example, a single region exhibiting grass color and grass texture is more likely to be grass than one region with grass color and another with grass texture. Using intersections, most of the curves show a true positive rate above 80% for a false positive rate 30%. The poorest results are on object classes “tree,” “grass,” and “water,” each of which has a high variance, for which a single Gaussian model is not sufficient. Our EM-variant approach, described in Section II, assumes that the feature distribution of each object within a region is a Gaussian. So it has difficulty modeling objects having a high variance or multiple appearances, for which a single Gaussian model is not sufficient. Therefore a justifiable extension of the EM-variant approach is to model the feature distribution of each object as a mixture of Gaussian, instead of a single Gaussian. To compare this extension to the EM-variant approach described in Section II for recognizing objects having multiple appearances, we used the same set of 860 images, but relabeled them with 10 general object classes to replace the 18 more specific classes used in that work. For example, the former classes “tree trunk”, “cherry tree”, and just plain “tree” were merged to form a single “tree” class. The set of 10 classes used were mountains, stadiums, beaches, arctic scenes, water, primates, African animals, sky, grass, and trees. The mapping relationships from the old labels to the new labels are listed in Table 3. We applied both the EM-variant and EM-variant extension to this new labeled image set using color and texture features. The features were combined via region intersections. The EM-variant extension uses a Gaussian mixture to approximate the distribution of each object. While general Gaussian parameters are used for the original EM-variant, aligned Gaussian parameters, in which the covariance matrixes are diagonal matrices, are adopted for the EM-variant extension.
There are two reasons for this decision. The first one is the system efficiency. If there are \( m \) objects to learn, the original EM-variant performs the iterations for the convergence of a \((m + 1)\)-component Gaussian mixture in which \( m \) Gaussians components are for the objects and one is for the “background”. For the EM-variant extension, a region is modeled as a mixture of object models denoted by the outer mixture, which in turn are modeled as Gaussian mixtures denoted by the inner mixtures.

<table>
<thead>
<tr>
<th>Key word</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mountains</td>
<td>30</td>
</tr>
<tr>
<td>Orangutan</td>
<td>37</td>
</tr>
<tr>
<td>Track</td>
<td>40</td>
</tr>
<tr>
<td>Tree trunk</td>
<td>43</td>
</tr>
<tr>
<td>Football field</td>
<td>43</td>
</tr>
<tr>
<td>Beach</td>
<td>45</td>
</tr>
<tr>
<td>Prairie grass</td>
<td>53</td>
</tr>
<tr>
<td>Cherry tree</td>
<td>53</td>
</tr>
<tr>
<td>Snow</td>
<td>54</td>
</tr>
<tr>
<td>Zebra</td>
<td>56</td>
</tr>
<tr>
<td>Polar bear</td>
<td>56</td>
</tr>
<tr>
<td>Lion</td>
<td>71</td>
</tr>
<tr>
<td>Water</td>
<td>76</td>
</tr>
<tr>
<td>Chimpanzee</td>
<td>79</td>
</tr>
<tr>
<td>Cheetah</td>
<td>112</td>
</tr>
<tr>
<td>Sky</td>
<td>259</td>
</tr>
<tr>
<td>Grass</td>
<td>275</td>
</tr>
<tr>
<td>Tree</td>
<td>361</td>
</tr>
</tbody>
</table>

Table 1: EM-variant Experiment Data Set Keywords and Their Appearance Counts

Figure 1. ROC curves for the 18 object classes with independent treatment of color and texture.

Figure 2. ROC curves for the 18 object classes using intersections of color and texture regions.
Table 2. ROC scores for the two different feature combination methods: 1) independent treatment of color and texture and, 2) intersections of color and texture regions.

<table>
<thead>
<tr>
<th>New label</th>
<th>Old label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staindium(44)</td>
<td>Track(40, football field(43)</td>
</tr>
<tr>
<td>Beach(45)</td>
<td>Arctic(56)</td>
</tr>
<tr>
<td>Water(76)</td>
<td>Primate(116)</td>
</tr>
<tr>
<td>Primate(116)</td>
<td>Mountains(30)</td>
</tr>
<tr>
<td>African animal</td>
<td>Boulder(76)</td>
</tr>
<tr>
<td>Grass(321)</td>
<td>Zebra(56), lion(71), cheetah(112)</td>
</tr>
<tr>
<td>Tree(378)</td>
<td>Sky(259)</td>
</tr>
<tr>
<td>Mountains(56)</td>
<td>Prairie grass(53), grass(272)</td>
</tr>
<tr>
<td>Orangutan(37)</td>
<td>Tree trunk (43), cherry tree(53), cherry tree(361)</td>
</tr>
<tr>
<td>Grass(272)</td>
<td></td>
</tr>
<tr>
<td>Track(40)</td>
<td></td>
</tr>
<tr>
<td>Football field</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Mapping of the more specific old labels to the more general new labels. The first column is the new labels and the second column lists their corresponding old labels. The number of images containing each object class is shown in parentheses.

Suppose that the outer mixture has \( (m+1) \) components and that the outer EM algorithm converges after \( i \) iterations. The inner mixtures require re-estimation for each of the \( I \) iterations. If the number of components of the inner Gaussian mixtures is \( m' \), then there are \( i \times m \) \( m' \)-component inner Gaussian mixtures plus one \( (m + 1) \)-component complex outer mixture to calculate, which is much heavier work than that of the original EM-variant. The aligned Gaussian parameters are chosen for the EM-variant extension to relieve the system burden. The other objective of using aligned Gaussian parameters is to reduce the number of parameters to learn. Suppose the feature vectors are \( d \)-dimensional. For each Gaussian component, there are \( d^2 \) parameters for the covariance matrix, \( d \) for the mean, and 1 for its probability. Thus
with general Gaussian parameters, the original EM-variant has \((m+1) \times (d^2 + d + 1)\) parameters to learn. Using general Gaussian parameters with the EM-variant extension, there are \((m + 1) \times [m' \times (d^2 + d + 1) + 1]\) parameters to learn, and the number is roughly \(m'\) times of that of the original EM-variant. Having more parameters means a higher likelihood of over fitting unless a large number of training samples are provided. Therefore, we chose aligned Gaussian parameters for the EM-variant extension, and the number of parameters reduces to \((m + 1) \times [m' \times (2 \times d + 1) + 1]\).

We performed a series of experiments to explore the effect of the parameter \(m'\), the number of components of the inner Gaussian mixtures, on the performance. The ROC scores of experiments with different value of \(m'\) are shown in Figure 3. In the figure, the ROC score of the original EM-variant is also plotted for comparison. It shows that when \(m'\) is less than 4, the performance of the EM-variant extension is worse than the EM-variant and this suggests that for this particular task, using a mixture of a few Gaussians with the aligned Gaussian parameters to model an object is not as good as just using a single Gaussian with the general Gaussian parameters. When \(m'\) increases, the performance of the EM-variant extension outperforms the original EM-variant. The ROC scores settle at a level between 85% and 86% when \(m'\) is greater than 10, which is about 2.4% higher than that of the original EM-variant. It is worth mentioning that having a fixed \(m'\) is not the best solution. Although the major trend shows that the higher the value of \(m'\), the better the performance, a bigger \(m'\) does not always lead to a better performance, since the quality of the clustering also plays an important role here. It is better to have a smart clustering algorithm to adaptively calculate \(m'\) for different objects and to discover the optimal clusters. This task is challenging and deserves more research by itself. The ROC scores for individual objects for the original EM-variant and the EM-variant extension with \(m'\) set to 12 are listed in Table 4. The average score on the ten labels for the original EM-variant with single Gaussian models was 82.6%; while the average score for the EM-variant extension was 86.0%. Furthermore, if only the labels of combined classes are considered, the EM-variant extension approach achieved a score of 83.1%, about 5% higher than that of the EM-variant approach, which achieved a score of 78.2%.

### Table 4: ROC Scores for EM-variant with single Gaussian models and EM-variant extension with 12-component Gaussian mixture for each object.

<table>
<thead>
<tr>
<th>Object</th>
<th>EM variant (%)</th>
<th>EM Variant extension(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>African</td>
<td>71.8</td>
<td>86.1</td>
</tr>
<tr>
<td>animal</td>
<td>80</td>
<td>82.9</td>
</tr>
<tr>
<td>Arctic</td>
<td>88</td>
<td>93.2</td>
</tr>
<tr>
<td>Beach</td>
<td>76.9</td>
<td>67.7</td>
</tr>
<tr>
<td>Grass</td>
<td>94.0</td>
<td>96.3</td>
</tr>
<tr>
<td>Moutainios</td>
<td>74.4</td>
<td>86.7</td>
</tr>
<tr>
<td>Primate</td>
<td>91.9</td>
<td>84.8</td>
</tr>
<tr>
<td>Sky</td>
<td>95.2</td>
<td>98.4</td>
</tr>
</tbody>
</table>
Shahin Shafei, Tohid Sedghi Robust Method for E-Maximization and Hierarchical Clustering of 

| Stadium   | 70.7 | 76.6 |
| Tree      | 82.9 | 87.1 |
| Water     |      |      |
| Mean      | 82.6 | 86   |
| Mean of   | 78.2 | 83.1 |
| Combined  |      |      |
| Class     |      |      |

![Table](table.png)

**Figure 3.** The ROC scores of experiments with different value of the parameter, m', the component number of Gaussian mixture for each object model.

**4. CONCLUSION**

We have developed an algorithm to recognize classes of objects and concepts in outdoor scenes. We have developed a new method for object recognition that uses whole images of abstract regions, rather than single regions for classification. A key part of our approach is that we do not need to know where in each image the objects lie. We only utilize the fact that objects exist in an image, not where they are located. We have designed an EM-like procedure that learns multivariate Gaussian models for object classes based on the attributes of abstract regions from multiple segmentations of color images. The objective of this algorithm is to produce a distribution for each of the object classes being learned. It uses the label information from training images to supervise EM-like iterations.

**REFERENCE**


AUTHORS

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Ultra Wideband Fabric-Based Slot Antenna on Human Body for Medical Application

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ABSTRACT

In this paper a new UWB textile slot antenna has been designed with high precision. This work aimed to make closer steps towards real wearability by investigating the possibilities of designing wearable UWB antenna where textile materials are used for the substrate as well as the conducting parts of the designed antenna. The antenna is composed of three textile layers: the top and bottom are conducting layers and the third layer is a textile dielectric layer and sandwiched between these two conducting layers. The developed antenna offers flexible, light-weight and bendable properties, and can be easily incorporated into clothing using a simple iron-on adhesive process. The iron-on process allows for the fabric to be washed without losing its adhesion. The antenna shows better than 13 dB return loss and peak gain 5±2 dB over FCC UWB from 3.1 to 10.6 GHz. The antenna’s overall size is 5mm×5mm.

KEYWORDS: fabric antenna, UWB, slot antenna, textile substrate, medical application.

INTRODUCTION

Using textiles for antenna development is an attractive option for many applications. Chief among these is the growing field of body area networks for narrow and ultra wideband applications. The key considerations for wearable electronics are to be lightweight, flexible, small size, inexpensive, able to withstand damage from obstacles (robust), and comfortable to wear [1-3]. Since the Federal Communications Commission (FCC) in 2002 approved the commercial use of frequency bands from 3.1 to 10.6 GHz for Ultra-wideband (UWB) systems, UWB antennas received more and more attention with the advancement of communication technology [4-6]. Since 1997, wearable telecommunication systems have become popular topics in research institutions. Numerous papers have been published about the design, fabrication and applications of wearable antennas and systems [7-13]. Moreover, full success can be achieved only when the antenna and all related components are entirely converted into 100% textile materials where the use of embedded textile components guarantees washing of the electronic suit and accordingly reuse of it.

The use of textiles for wearable applications offers a low-cost, flexible solution when compared to rigid antennas. This flexibility becomes even more important when large arrays are required.
In this paper, we present the design process of a UWB slot antenna for use in wearable applications with detailed discussion about the concept, simulation. The organization of this summary paper is as follows. Sections II discuss the materials that have been used to accomplish the wearable antenna design. In Section III, we present the single element slot antenna, successive design steps, and a set of comparative results of the proposed antenna. The conclusion is given in Section IV.

TEXTILE MATERIAL SELECTION

The most important properties of textile materials that are mobilized in wearable applications are flexibility to conform to the body, comfort to touch, and softness. The antenna was designed using the triple-nickel-silver nylon rip stop conductive textile from Swift Textile Metalizing. The electrical resistance of this material is less than 0.05Ω/square and conductive layer is 0.12mm thick. This material offers the best surface conductivity. As a substrate material, we focused on the nylon Cordura dielectric with permittivity of 2.05 and loss tangent of 0.025. The thickness of the dielectric layer is 0.57mm, thus providing a flexible, lightweight alternative to thick textile or foam substrates. The fabric is coated on one side with nonconductive hot melt adhesive which make the attachment process easier by ironing the conducting fabric onto the surface of flannel fabric substrate material. The proposed conducting fabric can be washed as well as its ability to resist temperature up to 200°C.

ANTENNA DESIGN

In general, the design and construction of the UWB planer monopole antenna consist of a circular parch to be placed at the top of the fabric substrate material, a microstrip/coplanar waveguide (CPW) feed line and a circular slot beneath the fabric substrate material. Using the properties for each textile layer, a slot antenna is designed which operates with bandwidth 5.5:1. This antenna was designed in Ansoft’s HFSS and is shown in Fig. 1.

The return loss of the antenna is calculated and shown in Fig. 2 as a function of the patch radius \( R_2 \) and slot radius \( R_1 \). The maximum bandwidth is achieved when \( R_1 = 24 \text{mm} \) and \( R_2 = 14.5 \text{mm} \). Additionally, the antenna performance with a CPW and microstrip feed is compared and return loss of the antenna vs. frequency with each feed line is shown in Fig 3. The antenna showed better performance with microstrip feed.

Fig. 1. UWB fabric slot antenna with microstrip feed.
are listed in Table I. With these dimensions, the simulated design produced good impedance matching with a reflection coefficient being below -13 dB all over the bandwidth from 2 to 11 GHz (140%) as shown in Fig 4.

**TABLE I: OPTIMIZED DIMENSIONS OF THE UWB SLOT ANTENNA**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>L</th>
<th>Wa</th>
<th>R1</th>
<th>R2</th>
<th>w</th>
<th>La</th>
</tr>
</thead>
<tbody>
<tr>
<td>(size) mm</td>
<td>50</td>
<td>50</td>
<td>24</td>
<td>14.5</td>
<td>2</td>
<td>4.5</td>
</tr>
</tbody>
</table>

**Fig.4.** Return loss of the UWB slot antenna with optimized dimensions.

The E-plane and H-plane radiation patterns for this antenna are presented in Fig. 5 at discrete frequencies of 5 GHz, 7 GHz and 9 GHz. The peak gain of the proposed antenna versus frequency in the main beam direction is shown in Fig. 6. It has a maximum gain of 5±2 dB within 3-11 GHz.

**Fig.2.** Return loss of the antenna vs. (a) radius of the slot, (b) radius of the patch.

**Fig.3.** Comparison of the antenna return loss with microstrip and CPW feed.

The optimized dimensions of the proposed wearable textile UWB antenna with microstrip feed
I. CONCLUSION

In this paper, we have proposed a UWB wearable slot antenna using fully textile materials. The antenna was fed by microstrip line and CPW line for comparison and was shows that microstrip had better performance. The antenna provides more than 140% bandwidth with compact size and flexible materials. It has a maximum gain of 5±2 dB within 3-11 GHz and better than -13dB return loss over 2-11 GHz.

REFERENCES


Modified Harmony Search Algorithm Based Unit Commitment with Plug-in Hybrid Electric Vehicles

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ABSTRACT

Plug-in Hybrid Electric Vehicles (PHEV) technology shows great interest in the recent scientific literatures. Vehicle-to-grid (V2G) is an interconnection of energy storage of PHEVs and grid. By implementation of V2G dependencies of the power system on small expensive conventional units can be reduced, resulting in reduced operational cost. This paper represents an intelligent unit commitment (UC) with V2G optimization based on Modified Harmony Search Algorithm (MHSA). MHSA was conceptualized using the musical process of searching for a perfect state of harmony, just as the optimization process seeks to find a global solution that is determined by an objective function. Intelligent UC with V2G optimization in power system is presented in this paper. Since the number of PHEV in V2G is relatively high, UC with V2G optimization problem is more complex than the basic UC.

A case study based on conventional 10-unit test system is conducted to facilitate the effectiveness of the proposed method. Results show a significant amount of cost reduction with integration of V2G in UC problem. Comparison of the results with those obtained by Particle Swarm Optimization shows the effectiveness of the proposed method.

KEYWORDS: Unit Commitment (UC), Vehicle-to-Grid (V2G), Improved Harmony Search Algorithm, Plug-in Hybrid Electric Vehicle (PHEV).

1. INTRODUCTION

The power and energy industry in terms of economic importance is one of the most important sectors in the world since nearly every aspect of industrial productivity and daily life are dependent on electricity [1].

Unit commitment (UC) and generation scheduling problem involves on/off status as an integer programming and generators production levels as a nonlinear programming for use in meeting the forecasted demand for a given time horizon [2] -[3]. The optimal schedule should minimize the system production costs during the study time horizon while satisfying power system constraints including load demand, spinning reserve requirements, and the physical as well as operational constraints of each individual unit [2], [4].

Being a large scale, non-convex and mixed-integer non-linear combinatorial optimization problem, several solutions techniques have been proposed in literature to Solve UC optimization problem. Exactly
optimal solution can be achieved by exhaustive enumeration but it is very time consuming, while priority list which results fast solution that sometimes lead to a non-optimal outcome [5]. Dynamic programming (DP) and Mixed Integer Programming (MIP) are other techniques for unit commitment problem that needs more computational costs [6]-[7]. Lagrangian relaxation (LR) methods [8]-[9] focus on finding an appropriate coordination technique for generating feasible primal solutions, while minimizing the duality gap. The main drawback of the LR method is the difficulty encountered in obtaining feasible solutions.

Being a very complicated optimization problem, different heuristic optimization algorithms have been applied to solve UC problem. Different heuristic techniques have been addressed in the literature, like Genetic Algorithm (GA) [10]-[11], Ant Colony (AC) [12], Tabu Search (TS) [13], Particle Swarm Optimization (PSO) [14] as well as Simulated Annealing (SA) [15]. To achieve more improvement to the existing unit commitment solution techniques the hybrid models such as fuzzy dynamic programming [16], genetic-based artificial neural network [17], hybridization of Lagrangian relaxation and genetic algorithm (LRGA) [18], and simulated annealing genetic algorithm (SAGA) [2] are proposed.

The main focuses of Vehicle-to-Grid (V2G) researchers have been on interconnection of energy storage of vehicles and grid [19]-[21]. The economic benefits of V2G integration into the market has been considered in these studies. However, success of V2G technology greatly depends on the efficient scheduling of PHEVs in the restricted parking lots [1]. An intelligent scheduling of V2Gs and conventional generating units can reduce operation cost of the power system and increase the reliability as well as security.

Geem et al. in [22] developed a harmony search algorithm (HSA) as a meta-heuristic approach that was conceptualized using the musical process of searching for a perfect state of harmony. Compared to the earlier meta-heuristic optimization algorithms, HSA imposes fewer mathematical requirements that can be easily adopted for various types of engineering optimization problems [23]. Recently different application of HSA has been addressed in the literature that demonstrate the potential of HSA in solving complex power system problems [24-26]. An improved harmony search algorithm (IHSA) was proposed in [27] to improve the performance and accuracy of the traditional HSA.

In this paper, unit commitment with vehicle-to-grid (UC–V2G) that was addressed in [1] is optimized with IHSA where UC–V2G involves intelligently scheduling conventional units and large number of PHEVs. It reduces operation cost of the power system effectively. In addition to fulfilling a large number of practical constraints, the optimal UC–V2G should meet the forecast load demand calculated in advance, parking lot limitations, state of charge of gridable vehicles, charging–discharging efficiency, spinning reserve requirements, etc. at every time interval such that the total operation cost and emission are minimal [1].

The optimization of UC–V2G is a combinatorial optimization problem with both binary and continuous variables. The number of combinations of generating units and gridable vehicles grows exponentially
in UC–V2G problems. UC–V2G optimization problem is more complex than typical UC of conventional generating units, as number of variables in UC–V2G is much higher than typical UC problems, and both cost and emission are minimized in the objective function of UC–V2G [1].

The proposed IHSA based solution approach minimizes the operation cost of the power system for UC-V2G. Moreover, spinning reserve and reliability of power systems are enhanced. The IHSA is applied to a widely used 10-unit test system. Comparing the simulation results from this study with those obtained by PSO reported in [1] reveals that the HSA is a more effective technique from the operation costs aspects.

This paper is organized as follows: Section II provides the mathematical formulation of the UC-V2G problem. Section III presents the proposed optimization technique and its application to solve UC problem. Section IV conducts the numerical simulations and presents a comparison with PSO. Finally, concluding remarks are discussed in section V.

2. PROBLEM FORMULATION

Unit commitment involves determining generating outputs of all units from an initial hour to satisfy load demands associated with a start-up and shut-down schedule over a time horizon. The objective function is to find the optimal schedule such that the total operating costs can be minimized while satisfying the load demand, spinning reserve requirements as well as other operational constraint [25].

Objective Function

Usually large cheap conventional units are used to satisfy base load demand of a power system. Most of the time, large units are therefore on however they have slower ramp rates. On the other hand, small units have relatively faster ramp rates. Besides, each unit has different cost characteristics that depend on the amount of power generation, fuel type, generator unit size, technology and so on. In UC-V2G problems, the main challenge is to schedule small expensive units to minimize cost, and to improve system reserve and reliability. PHEVs of V2G technology will reduce dependence on small/micro expensive units. But the number of PHEVs in V2G are much higher than small/micro units. Therefore profit, spinning reserve, reliability of power systems varies on scheduling optimization quality [1].

UC-V2G is a complex, large-scale optimization problem. The objective of the UC-V2G optimization problem is to minimize total operation cost, where the cost includes mainly fuel cost, start-up cost and shutdown cost.

Fuel Cost

The objective function of the conventional UC problem is a function that comprises the fuel costs of generating units, the start-up costs and shut-down costs of the committed units. The objective function in common form is formulated as:

\[
\text{Min} \sum_{i=1}^{N} \sum_{t=1}^{T} \left[ F_i (P'_i) u'_i + SUC_i u'_i (1-u'_i) \right]
\]

(1)

Where \( F_i (P'_i) \) is the cost function of the \( i \)th unit with generation output, \( P'_i \), at the \( t \)th hour. Usually it is a quadratic polynomial as follows:

\[
F_i (P'_i) = a_i + b_i \times P'_i + c_i \times (P'_i)^2
\]

(2)

Where: \( a_i, b_i \) and \( c_i \) are fuel cost coefficients. \( u'_i \) is the on/off status of unit \( i \) at \( t \)th time interval, \( u'_i = 0 \) if unit \( i \) is off, \( u'_i = 1 \) if it is on at \( t \). \( N \) is the total number of power generating units to be committed and
T is the time period (usually the number of hours ranging from 24 to 168 hours).

Start-up Cost
The start-up cost for restarting a decommitted thermal unit, which is related to the temperature of the boiler, is considered in the optimization model. The start-up cost is defined as follows:

\[
SUC_{it} = \begin{cases} 
HSC_i, & \text{if } T_i^D \leq MD_{i}^{\text{on}} \leq T_i^D + CST_i, \\
CSC_i, & \text{if } MD_{i}^{\text{on}} > T_i^D + CST_i, \\
\end{cases} \\
1 \leq t \leq T \\
i \in N
\]  

(3)

Where \(HSC_i\) and \(CSC_i\) are hot and cold start-up cost of ith unit respectively. \(T_i^D\) is the minimum down time of unit i, \(CST_i\) is a cold start time of the unit i and \(MD_{i}^{\text{on}}\) is the number of hours that ith unit has been on-line since it was turned on earlier.

Shut-down cost.
Shut-down cost is constant and the typical value is zero in standard systems.

Constraints of UC-V2G
The optimization problem is subjected to a number of system and unit constraints such as: power balance, spinning reserve capacity of generating units, unit ramp-up and unit ramp-down rate constraints, minimum up/down time limit as well as spinning reserve requirement. Initial condition also needed to be considered in scheduling problem.

V2G Constraints
PHEVs balance in UC-V2G.
Only predefined registered/forecasted PHEVs are considered for the optimum scheduling in UC-V2G. Total number of registered PHEVs is assumed fixed and it is considered that they are charged from renewable sources. All the vehicles discharge to the grid during a predefined scheduling period (24 h) [1].

\[ \sum_{i=1}^{T} N_{v_{2G}}(t) = N_{v_{2G}}^{\text{Max}} \]

(4)

Charging-Discharging Frequency
PHEVs are charged from renewable sources and discharge to the grid. Multiple charging–discharging facilities of gridable vehicles may be considered. It should vary depending on life time and type of batteries. For simplicity, charging–discharging frequency is one per day in this study [1].

State of Charge
Each vehicle should have a desired departure state of charge level [1].

Number of discharging vehicles limit
All the vehicles cannot discharge at the same time. For reliable operation and control, limited number of vehicles will discharge at a time. This constraint also applies for power transfer, current limit.

\[ N_{v_{2G}}(t) \leq N_{v_{2G}}^{\text{Max}}(t) \]

(5)

Efficiency
Charging and inverter efficiencies \( \xi \) should be considered.

System constraints

Initial Conditions
The initial conditions of generating units include the number of hours that a unit sequence has been on-line or off-line at an hour before the scheduling will be started.

Power balance constraints
Power supplied from committed units and selected PHEVs (some percentage of total vehicles) must satisfy the load demand and the system losses, which is defined by Eq. (6):

\[ \sum_{i=1}^{N} P_i(t) \mu_i(t) + P_v N_{v_{2G}}(t) = D(t) + \text{Losses} \]

\[ 1 \leq t \leq T \\
i \in N \]

(6)

Where, \(D(t)\) is the MW load demand at time t and \(P_v\) is capacity of each vehicle.

Spinning reserve requirement
Spinning reserve requirement (SRR) is usually a pre-specified amount or equal to the largest unit or a given percentage of the forecasted load demand. Spinning reserve of committed units is the total amount of real power generation available from all synchronized units minus the present load plus the losses. It must be sufficient enough to maintain the desired reliability of a power system. Spinning reserve constraint is given by Eq. (7) [25].

\[
\sum_{i=1}^{N} P_{i}^{\text{max}}(t)u_{i}(t) + P_{i}^{\text{max}} N_{i}(t) = D(t) + \text{SRR}(t)
\]

Where: \( \text{SRR}(t) \) is the SRR at time \( t \) (MW).

Unit constraints

Unit output limits
\[
P_{i}^{\text{min}}u_{i} \leq P_{i}(t) \leq P_{i}^{\text{max}}u_{i}
\]

Minimum up time limit
Minimum number of hours that a unit must be on-line since it has been turned on beforehand.
\[
MD_{i}^{\text{ON}} \geq T_{i}^{U}
\]

Where \( T_{i}^{U} \) is the minimum up time of unit \( i \).

Minimum down time limit
Minimum number of hours that a unit must be off-line since it has been turned off.
\[
MD_{i}^{\text{OFF}} \geq T_{i}^{D}
\]

Where: and \( MD_{i}^{\text{OFF}} \) is the number of hours that \( i \)th unit is off-line since it has been turned off.

Ramp rate limits
Minimum and maximum generating limits that bound the generating output of each unit in a particular hour can be varied within the range of unit power outputs due to unit ramp rate constraint.
\[
P_{i}^{r+1} - P_{i}^{r} \leq RUR_{i}, \quad 1 \leq t \leq T \quad i \in N
\]

Where: \( RUR_{i} \) and \( RDR_{i} \) are ramp-up rate limit and ramp-down rate limit of unit \( i \), respectively.

Prohibited operating zones
Each generator has its generation limit which cannot be exceeded at any time. Moreover, a typical thermal unit may have a certain limitation of steam valve operation, or a vibration in a shaft bearing, which may result in interference and discrete input–output performance-curve sections, called prohibited zones.

Therefore, in practical operation, adjusting the generation output of a unit must avoid all capacity limits and unit operations in prohibited zones. The feasible operating zones of a unit can be described as follows:

\[
\begin{align*}
P_{i}^{L} \leq P_{i} & \leq P_{i}^{L_{\text{upper}}} \\
P_{i}^{U_{i,j}} & \leq P_{i} \leq P_{i}^{L_{\text{lower}}} \\
P_{i}^{U_{i,j}} & \leq P_{i} \leq P_{i}^{L_{i,j}} \\
P_{i}^{U_{i,j}} & \leq P_{i} \leq P_{i}^{L_{i,j}} \\
\end{align*}
\]

Where: \( j = 2, \ldots, PZ_{i} \).

3. MODIFIED HARMONY SEARCH ALGORITHM

A. Harmony Search Algorithm

The harmony search algorithm was derived by adopting the idea that the existing meta-heuristic algorithms are found in the paradigm of natural phenomena. The algorithm was recently developed in an analogy with music improvisation process where music players improvise the pitches of their instruments to obtain better harmony [22]. The pitch of each musical instrument determines the aesthetic quality, just as the objective function value is determined by the set of values assigned to each decision variable [23].
Traditional HAS Steps of optimization procedure of traditional HSA are as follows [22], [25]:

Step 1. Initialize the optimization problem and algorithm parameters.

Step 2. Initialize the harmony memory (HM).

Step 3. Improvise a new harmony from the HM.

Step 4. Update the HM.

Step 5. Repeat steps 3 and 4 until the termination criterion is satisfied.

Initialization of the Optimization Problem and Algorithm Parameters

In this step the optimization problem is specified as follows:

Minimize $f(x)$

Subject to $x_i \in X_i$, $i = 1, 2, \ldots, N$

where $f(x)$ is the objective function; $x$ is a candidate solution consisting of $N$ decision variables ($x_i$); $X_i$ is the set of possible range of values for each decision variable, that is, $l_{x_i} \leq x_i \leq u_{x_i}$ for continuous decision variables where $l_{x_i}$ and $u_{x_i}$ are the lower and upper bounds for each decision variable, respectively; and $N$ is the number of decision variables. In addition, HS algorithm parameters that are required to solve the desired optimization problem are specified in this step. These parameters are the harmony memory size (HMS) or the number of solution vectors, harmony memory considering rate (HMCR), pitch adjusting rate (PAR), and termination criterion (maximum number of searches). HMCR and PAR are parameters that are used to improve the solution vector; both are defined in step 3.

Initialization of the Harmony Memory

In this step, the harmony memory (HM) matrix, shown in Eq. (14), is filled with as many randomly generated solution vectors as HMS and sorted by the values of the objective function, $f(x)$.

$$HM= \begin{bmatrix} x^1 \\ x^2 \\ \vdots \\ x^{HMS} \end{bmatrix}$$ (14)

Improvising New Harmony from the Harmony Memory

A new harmony vector, $x' = (x'_1, x'_2, \ldots, x'_N)$, is generated from the HM based on memory considerations, pitch adjustments, and randomization. For instance, the value of the first decision variable ($x'_1$) for the new vector can be chosen from any value in the specified HM range $(x^1 \cap x^{HMS})$. Values of the other decision variables ($x'_i$) can be chosen in the same manner. There is a possibility that the new value can be chosen using the HMCR parameter, which varies between 0 and 1 as follows:

$$x'_i \left\{ \begin{array}{ll} x'_i \in \{x^1, x^2, \ldots, x^{HMS}\} & \text{with probability } \text{HMCR} \\ x'_i \in X_i & \text{with probability } (1-\text{HMCR}) \end{array} \right.$$ 

The HMCR sets the rate of choosing one value from the historic values stored in the HM, and (1-HMCR) sets the rate of randomly choosing one feasible value not limited to those stored in the HM. For example, a HMCR of 0.9 indicates that the HS algorithm will choose the decision variable value from historically stored values in the HM with the 90% probability or from the entire possible range with the 10% probability. Each component of the new harmony vector, $x'=(x'_1, x'_2, \ldots, x'_N)$, is examined to determine whether it should be
Oveis Abedinia, Ali Ghasemi, Noradin Ghadimi: Modified Harmony Search Algorithm …

pitch-adjusted. This procedure uses the PAR parameter that sets the rate of adjustment for the pitch chosen from the HM as follows:

\[
\text{Pitch adjusting decision for } x'_i \leftarrow \begin{cases} 
\text{Yes with probability PAR} \\
\text{No with probability (1-PAR)} 
\end{cases}
\]

A PAR of 0.3 indicates that the algorithm will choose a neighboring value with 30% × HMCR probability. If the pitch adjustment decision for \( x'_i \) is Yes, the pitch-adjusted value of \( x'_i \) will be \( x'_i + \alpha \) where \( \alpha \) is the value of \( bw \times u(-1,1) \), \( bw \) is an arbitrary distance bandwidth for the continuous design variable, and \( u \) is a uniform distribution between −1 and 1.

Updating the Harmony Memory

In this stage, if the new harmony vector is better than the worst harmony vector in the HM in terms of the objective function value, the existing worst harmony is replaced by the new harmony. The HM is then sorted by the objective function value.

Termination Criterion

The computations are terminated when the termination criterion (maximum number of improvisations) is satisfied. Otherwise, steps 3 (improvising new harmony from the HM) and 4 (updating the HM) are repeated.

Improved Harmony Search Algorithm

The traditional HSA uses fixed values for both PAR and bw in which these values can only be adjusted at the initialization step (Step 1) and cannot be changed during new generations. The main drawback of this algorithm is that it needs much iteration to find an optimal solution. An improved Harmony Search Algorithm (IHSA) is then developed by Mahdavi et al. [28]. The IHSA has been successfully applied to various benchmarking and standard engineering optimization problems. Numerical results reveal that the IHSA can give better solutions compared to the traditional HSA and other heuristic or deterministic methods and also it is a powerful search algorithm for solving various engineering optimization problems [27].

The main difference between the IHSA and traditional HSA is in the way the PAR and bw values are adjusted. To improve the performance of the HSA and eliminate the drawbacks of fixed values of PAR and bw, the IHSA uses variable PAR and bw values in the improvisation step (Step 3). The PAR value changes dynamically with generation number and is expressed as follows [27]:

\[
PAR(gn) = PAR_{\text{Min}} + \frac{(PAR_{\text{Max}} - PAR_{\text{Min}}) \times gn}{NI}
\]

(15)

Where, \( PAR(gn) \) is pitch adjusting rate for each generation; \( PAR_{\text{Min}} \) is minimum pitch adjusting rate; \( PAR_{\text{Max}} \) is maximum pitch adjusting rate; \( NI \) is number of solution vector generations and \( gn \) is generation number

bw changes dynamically with generation number and is defined as (16):

\[
bw(gn) = bw_{\text{Max}} \exp(c \times gn)
\]

(16)

\[
c = \frac{\ln(bw_{\text{Max}})}{NI}
\]

(17)

Where, \( bw(gn) \) is bandwidth for each generation; \( bw_{\text{Min}} \) is minimum bandwidth and \( bw_{\text{Max}} \) is maximum bandwidth

B. Modified Harmony Search Algorithm

To achieved a good choice for simulating complex phenomena, sampling, numerical analysis in heuristic method needs random sequences with a long period and good uniformity. Chaos is a deterministic, random like process found in dynamical system, non-linear, which is non-converging, non-period and limited. The standard HSA algorithm has gained much
attention and widespread applications in different optimization fields. But, after becoming converged, the HSA algorithm loses its efficiency to search and then becomes stopped. Thus, new operators should be added to algorithm in order to increase its ability and flexibility for solving more complicated optimization problems. To cover this problem, we introduce MHSA that develop searching process by employing CLS into HSA.

Assume that our array of sensors controls the current $C_{ji+1}$ that is formulated based forcing of the pendulum, by rewritten it from $\cos(t)$ to something like:

$$
1 = \frac{g_{kbest}^{i+1}}{g_{best}^{k}}, \quad 0 < c_i' \leq 1
$$

(18)

Where, $g_{kbest}$ denotes best optimal value for $k$th iteration and $g_{best}$ represents the fine tuning necessary to achieve the desired sequence of gyrations. The CLS operator on the GSA algorithm can be summarized as follows:

Step 1: generate an initial chaos population randomly for CLS.

$$
X_{cl}^0 = \{x_{cl,0}^1, x_{cl,0}^2, ..., x_{cl,0}^i, ..., x_{cl,0}^N\}^{1 \leq j \leq T}
$$

$$
\text{cx}_j = [\text{cx}_j^1, \text{cx}_j^2, ..., \text{cx}_j^N]
$$

$\text{cx}_j^i = \frac{x_{cl,0}^i - P_{j,\text{min}}}{P_{j,\text{max}} - P_{j,\text{min}}}, \quad j = 1, 2, ..., Ng
$ (19)

Where, the chaos variable can be generating as follows:

$$
X_{cl}^0 = \{x_{cl,0}^1, x_{cl,0}^2, ..., x_{cl,0}^i, ..., x_{cl,0}^N\}^{1 \leq j \leq T}
$$

$$
x_{cl,0}^i = \text{cx}_j^i \times (P_{j,\text{max}} - P_{j,\text{min}}) + P_{j,\text{min}}, \quad j = 1, 2, ..., Ng
$$

(20)

Step 2: determine the chaotic variables

$$
\text{cx}_i = [\text{cx}_i^1, \text{cx}_i^2, ..., \text{cx}_i^N], \quad i = 0, 1, 2, ..., N_{\text{chaos}}
$$

$$
\text{cx}_{i,cl} = \text{base CLS} \quad j = 1, 2, ..., Ng
$$

$$
\text{cx}_i^j = \text{rand}(0)
$$

(21)

Where, $N_{\text{chaos}}$ is the number of individuals for CLS. $\text{CxiNg}$ is the $i$th chaotic variable. Rand() generate a random value in (0,1).

Step 3: mapping the decision variables

Step 4: convert the chaotic variables to the decision variables

Step 5: evaluate the new solution with decision variables.

4. PROPOSED ALGORITHM

UC-V2G is a mixed integer, non-linear optimization problem consisting of discrete and continuous variables.

In the proposed approach, each harmony vector has two fields for the conventional generating units and V2G scheduling. Harmony vector, $x',j'$ is constituted of \{Generating unit: An $N \times T$ binary matrix; Vehicle: An $T \times 1$ integer column vector\}. Binary HSA can easily handle the optimization problem of an $N \times T$ binary matrix for generating units because possible state of a generating unit is either 1 or 0 only [25]. On the other hand, basic HSA has the great abilities for the optimization of an $T \times 1$ integer column vector for PHEVs, as possible number of connected PHEVs varies from 0 to $N_{\text{Max}}^V(t)$ at hour $t$.

The flowchart of the proposed IHSAs for UC-V2G optimization problem is shown in Fig. 1. The details of proposed algorithm are explained in the following sections.

Initialize the optimization problem and algorithm parameters.

At the first step of the proposed algorithm, as discussed in the previous section, the optimization problem and HSA parameters, HMS, HMCR and PAR should be initiated.

Initialize the HM

Afterward HM, that is $N+1 \times T$ mixed integer matrix, as mentioned above, is initialized. For taking into account ramp rate of the $i$th hour, $P_{\text{min}}^i$ and $P_{\text{max}}^i$ of the...
conventional generating units in the \( t \)th hour are restricted using Eq. (11) and Eq. (12) as follows:

\[
P_{\text{max}}^{ij} = \min\{(P_{\text{max}}^{ij-1} + RUR^i), P_{\text{max}}^i\}
\]

\[1 \leq t \leq T \quad i \in N \quad (18)\]

\[
P_{\text{min}}^{ij} = \max\{(P_{\text{min}}^{ij-1} - RDR^i), P_{\text{min}}^i\}
\]

\[1 \leq t \leq T \quad i \in N \quad (19)\]

Improvisation of a new harmony from HM

At this step, as discussed in the previous section, new harmony vectors are improvised from the HM based upon memory considerations, pitch adjustments, and randomization. Number of new harmony vectors should be as the same as HMS. As shown in Fig. 1 three steps are considered for improvising new harmony from HM. Since the UC of conventional units problem and V2G scheduling are different, new harmony from HM is improvised for UC and V2G separately then these two are merged. Initially a new harmony is improvised from the matrix \((N \times T)\) called HMUC which represent conventional generating units, and then this process is performed for V2G using HMV2G. Finally these new matrixes are merged to build a new harmony vector that based on that scheduling is determined.

New harmony vectors are compared with harmony vectors in HM in terms of objective function value. New HM is updated by replacing weaker vectors of old HM with stronger vectors of the newly generated vectors. Result of this step is an updated HM that contains strongest vectors of both harmony vectors that were stored in HM and improvised vectors.

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**Fig. 1.** Flowchart of the proposed IHSA for UC-V2G optimization Problem
Modifying the HM

In this stage, a repairing mechanism is applied to HM that will check load demand, spinning reserve, min up/down time limits at all of the hours at the desired time horizon and V2G constraints. In this process, the harmony vectors that did not satisfy load demand or min up/down limit will be modified. For checking load demand and spinning reserve Eq. (7) will be considered such that the sum of the PMax of the committed units and \( P_{r,\text{Max}} \) of scheduled PHEVs should be more than sum of the forecasted demand and spinning reserve requirement. Other constraints are handled in this stage such that all of the optimization problem constraints are satisfied.

Economic Dispatch

UC associated with economic dispatch is a useful tool to find the most economical generation schedule. The economic dispatch determines the output of all online units with the objective function of minimum total operating costs at a given hour [25]. A lambda iteration method is used in this study to determine the optimal economic dispatch of the committed units along with PHEVs.

Fitness Calculation

In this step, based upon economic dispatch results and with consideration of start-up costs, the objective function is calculated for each harmony vector of HM.

Termination criterion

The proposed IHSA will be stopped when the termination criterion is satisfied; otherwise, the algorithm will go back to steps 3. In this study termination criterion is the maximum number of improvisations.

5. RESULTS AND DISCUSSION

A widely used 10-unit test system is considered for simulation with 50,000 PHEVs, which are assumed to be charged from renewable sources, so the results will be comparable with those obtained by PSO reported in [1]. Load demand of this test system is depicted in fig. 2 while generating unit’s characteristics of the 10-unit system are provided in Appendix.

Vehicles are charged from renewable sources and they discharge to the grid so that the total running costs are minimized while all of the system, unit and V2G constraints are fulfilled. Load demand and unit characteristics of the 10-unit system are collected from [25]. The spinning reserve requirement is 10% of the load demand, cold start-up cost is double of hot start-up cost, and total scheduling period is 24 h. Like other heuristic algorithms IHSA is stochastic and convergence depends on proper setting of parameter values. Table I provides the IHSA parameters.

Fig. 2. Load demand of 10-unit test system

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</tr>
</thead>
<tbody>
<tr>
<td>HMS</td>
<td>HMCR</td>
<td>PAR(_{\text{Max}})</td>
<td>PAR(_{\text{Min}})</td>
<td>BW(_{\text{Max}})</td>
<td>BW(_{\text{Max}})</td>
<td>NI</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>Load (MW)</td>
<td>0</td>
<td>200</td>
<td>400</td>
<td>600</td>
<td>800</td>
<td>1000</td>
<td>1200</td>
</tr>
<tr>
<td>Hour</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>14</td>
</tr>
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</table>

Table I

Improved harmony search algorithm parameters
Other parameters in optimization problem as follows: total number of vehicles = 50,000; maximum battery capacity = 25 kWh; minimum battery capacity = 10 kWh; average battery capacity, PV = 15 kWh; maximum number of discharging vehicles at each hour, $N_{Max}^{V2G}(t)$ = 10% of total vehicles; total number of PHEVs in the system, $N_{Max}^{V2G}$ = 50,000; charging−discharging frequency = 1 per day; scheduling period = 24 h; departure state of charge = 50%; efficiency= 85%.

The best solutions of the proposed IHSA with and without PHEVs are shown in Tables II and III, respectively.

Generation cost (fuel cost plus startup cost) is $563,977 when PHEVs are not considered in the 10-unit test system during 24-h (Table II). Generation cost is $553,985 when 50,000 PHEVs are considered in the same system (Table III).

Table IV provides the comparison of results of the proposed IHSA and those obtained by PSO in [1]. As the results demonstrate the proposed IHSA is a more powerful tool than PSO. The IHSA is more capable in finding the best schedule of both of UC and UC-V2G optimization problems.

The best solution of other deterministic and heuristic algorithms along with average of the solutions and worst solution are also provided in this table. As it can be seen IHSA is the best solution that guarantees high quality solution and not only results the best solution but also has the best average among the presented methods.

---

**TABLE II**

Schedule and dispatch of generating units for 10-unit test system without v2g

<table>
<thead>
<tr>
<th>Unit</th>
<th>Hours</th>
</tr>
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<tr>
<td>1</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24</td>
</tr>
<tr>
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<td>45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45</td>
</tr>
<tr>
<td>2</td>
<td>24 29 37 45 39 36 41 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45</td>
</tr>
<tr>
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</tr>
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</tr>
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<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
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<tr>
<td>6</td>
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<tr>
<td>8</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>9</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>10</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>V2G</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
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</table>

---

**TABLE III**

Schedule and dispatch of generating units and PHEVs for 10-unit test system with 50,000 PHEVs

<table>
<thead>
<tr>
<th>Unit</th>
<th>Hours</th>
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<tbody>
<tr>
<td>1</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24</td>
</tr>
<tr>
<td>1</td>
<td>45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45</td>
</tr>
<tr>
<td>2</td>
<td>23 28 34 37 35 39 44 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45 45</td>
</tr>
</tbody>
</table>

---

59


\textbf{TABLE IV}

Comparison of the total costs for different techniques

<table>
<thead>
<tr>
<th></th>
<th>DP</th>
<th>LR</th>
<th>EP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Best</td>
<td>Averaged</td>
<td>Worst</td>
</tr>
<tr>
<td>UC</td>
<td>565,825</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>UC-V2G</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GA</td>
<td>Best</td>
<td>Averaged</td>
<td>Worst</td>
</tr>
<tr>
<td>UC</td>
<td>565,825</td>
<td>N/A</td>
<td>570,032</td>
</tr>
<tr>
<td>UC-V2G</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

\textbf{CONCLUSIONS}

An intelligent UC-V2G optimization problem based on one of the most powerful heuristic algorithms, Improved Harmony Search Algorithm, has been proposed in this paper. Being a very complex optimization problem (since the number of PHEV in V2G is relatively high), UC-V2G optimization problem is more complex than the basic UC and needs more elaboration. Conventional 10-unit test system has been studied to show the effectiveness of the proposed method. Results show operation costs of the system can be effectively reduced with integration of V2G in UC problem. Comparing the results of IHSA with PSO demonstrates the high capability of the proposed method.

\textbf{TABLE A-1}

Generating unit's characteristics of the ten-unit system

<table>
<thead>
<tr>
<th>Unit no.</th>
<th>( p_{i}^{\text{max}} )</th>
<th>( P_{i}^{\text{min}} )</th>
<th>( a_{i} )</th>
<th>( b_{i} )</th>
<th>( c_{i} )</th>
<th>( T_{i}^{\text{on}} )</th>
<th>( T_{i}^{\text{off}} )</th>
<th>( HSC_{i} )</th>
<th>( CSC_{i} )</th>
<th>( CST_{i} )</th>
<th>IS</th>
</tr>
</thead>
<tbody>
<tr>
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<td>150</td>
<td>1000</td>
<td>16.19</td>
<td>0.00048</td>
<td>8</td>
<td>8</td>
<td>4500</td>
<td>9000</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>455</td>
<td>150</td>
<td>970</td>
<td>17.26</td>
<td>0.00031</td>
<td>8</td>
<td>8</td>
<td>5000</td>
<td>10000</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>130</td>
<td>20</td>
<td>700</td>
<td>16.6</td>
<td>0.002</td>
<td>5</td>
<td>5</td>
<td>550</td>
<td>1100</td>
<td>4</td>
<td>-5</td>
</tr>
<tr>
<td>4</td>
<td>130</td>
<td>20</td>
<td>680</td>
<td>16.5</td>
<td>0.00211</td>
<td>5</td>
<td>5</td>
<td>560</td>
<td>1120</td>
<td>4</td>
<td>-5</td>
</tr>
<tr>
<td>5</td>
<td>162</td>
<td>25</td>
<td>450</td>
<td>19.7</td>
<td>0.00398</td>
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<td>6</td>
<td>900</td>
<td>1800</td>
<td>4</td>
<td>-6</td>
</tr>
</tbody>
</table>
1. APPENDIX

The generating unit's characteristics of the ten-unit system are provided in Table A-1.

REFERENCES


