

## Research Article

# Application and Development of Enhanced Chaotic Grasshopper Optimization Algorithms

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Received 30 December 2017; Revised 23 March 2018; Accepted 8 April 2018; Published 23 May 2018

Academic Editor: Gaetano Sequenzia

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In recent years, metaheuristic algorithms have revolutionized the world with their better problem solving capacity. Any metaheuristic algorithm has two phases: exploration and exploitation. The ability of the algorithm to solve a difficult optimization problem depends upon the efficacy of these two phases. These two phases are tied with a bridging mechanism, which plays an important role. This paper presents an application of chaotic maps to improve the bridging mechanism of Grasshopper Optimisation Algorithm (GOA) by embedding 10 different maps. This experiment evolves 10 different chaotic variants of GOA, and they are named as Enhanced Chaotic Grasshopper Optimization Algorithms (ECGOAs). The performance of these variants is tested over ten shifted and biased unimodal and multimodal benchmark functions. Further, the applications of these variants have been evaluated on three-bar truss design problem and frequency-modulated sound synthesis parameter estimation problem. Results reveal that the chaotic mechanism enhances the performance of GOA. Further, the results of the Wilcoxon rank sum test also establish the efficacy of the proposed variants.

## 1. Introduction

Optimization is a term which refers to the selection of the best option amongst the given set of alternatives. Examples of optimization processes are everywhere such as in business, human resource management, challenging engineering design problems, transportation, profit making propositions, and industrial applications. Optimization can be done for the maximization of any proposition or minimization of any proposition. In engineering problems particularly, the use of maximization is for efficiency maximization, classification accuracy maximization, and revenue or profit maximization, and on the other hand, minimization can be performed for cost, loss, risk, and execution time of any engineering process. Apart from these classifications of optimization, another classification of the optimization problem can be done on the basis of constraints. An optimization problem without any constraints is called unconstrained optimization; similarly another type is constrained optimization with linear and nonlinear

constraints. Another classification can be done on the basis of the objective of the optimization; when an optimization problem aims towards a single objective, it is called the single objective optimization problem, and similarly when it aims towards multiobjectives, the same is called the multiobjective optimization problem [1]. A recent trend is to employ metaheuristic optimization algorithms to solve challenging problems of the real world. The term metaheuristic refers to problem-independent higher level heuristic mechanism [2]. In recent years, applications of metaheuristic algorithms in engineering problems have been reported. The successful and effective implementation of these algorithms on real applications has attracted the attention of researchers to work in this direction.

The metaheuristic optimization approaches can be subdivided into three categories:

- (1) Evolutionary computing-based algorithms [3–5]
- (2) Physics law-based algorithms [6–8]
- (3) Swarm intelligence-based algorithms [9–16]

## Research Article

# Assessment of Transient Stability through Coherent Machine Identification by Using Least-Square Support Vector Machine

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Received 23 December 2017; Revised 20 March 2018; Accepted 29 March 2018; Published 10 May 2018

Academic Editor: Elio Chiodo

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Transient stability assessment (TSA) of the power system is a crucial issue with escalating demands and large operational constraints. Real-time TSA allows for deciding and monitoring of the relevant preventive/corrective control actions depending on the dynamic behavior of the system components. To assess this, coherency of generating machines is to be found. After determination of the coherent machines, any corrective or preventive action can be initiated by the system operator to maintain stability of the system during occurrence of any severe contingency. The Transient Severity Index (TSI) introduced in this paper has proven to be an interesting alternative for determining generator coherency. Furthermore, the numerical values of this index are employed to construct a supervised learning-based classifier and the ranking method with the help of system load and generation as input features. This framework employs the support vector machine (SVM) to perform the ranking of the generators based on severity and classify them into vulnerable and nonvulnerable machines. The results are validated on the IEEE 10-generator, 39-bus test (New England) system. It is observed that the proposed index and the supervised learning engine give satisfactory results and both are aligned with the published approaches.

## 1. Introduction

Modern power network is emerged from the vertically integrated structure to the deregulated unbundled structure. This transformation enables consumers and generators to participate in the competitive business environment. Issues of power quality, reliability, risk, and security become prominent in this environment. High power demand has made an essential criterion to maintain the power system secure under the stressed operating conditions. Transient stability (T/S) of the power system is an important denominator and defined by the CIGRE committee [1] as “the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact.” Stability studies can be subdivided into two categories: the first one is assessment and the second one is control. Ensuring T/S under any unforeseen

contingency is a challenge for a system operator. This fact initiated the research in the direction of assessment methods along with preventive control methods for ensuring system stability.

In the past, various methods have been applied by researchers to assess system stability. Stability analysis-oriented research is mainly based on the evaluation of the violation of the limit of power system quantities and the behavior of the generator under contingency conditions. Some methods [2–5] proposed for stability assessment in the latest literature were based on risk or probabilistic, pattern recognition, and time domain simulation (TDS) techniques. TSA is directly concerned about the large disturbance. A risk-based methodology was proposed in [2–4]. A probabilistic small-disturbance stability analysis (PSSA) method with uncertainties was proposed by Preece and Milanović [2]. In this approach, the probability density functions (PDFs) were designed for the damping of the critical oscillatory electro-mechanical modes by modeling the stochastic variation

# Identification of Generator Criticality and Transient Instability by Supervising Real-Time Rotor Angle Trajectories employing RBFNN

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## Abstract

Identification of transient stability state in real-time and maintaining stability through preventive control technology are challenging tasks for the large power system while integrating deregulation constraints. Widely employment of the phasor measurement units (PMUs) in power system and development of wide area management systems (WAMS) gives a relaxation to monitoring, measurement and control hurdles. This paper focuses on two research objectives; the first is transient stability assessment (TSA) and second is selection of the appropriate member for the control operation in unstable operating scenario. A model based on the artificial machine learning and PMU data is constructed for achieving both objectives. This model works through prompt TSA status with radial basis function neural network (RBFNN) and validates it with PMU data to determine the criticality level of the generators. To reduce the complexity of the model a transient stability index (TSI) is proposed in this paper. A RBFNN is used to determine the transient stability aspects like stability status of system, coherent group and criticality rank of generator and preventive control action, following a large perturbation. PMUs measure post-fault rotor angle values and these are used as input for training RBFNN. The proposed approach is demonstrated on the IEEE 10-generator 39-bus, 16-generator 68-bus and 50-generator 145-bus test power system successfully and the effectiveness of the approaches is discussed.

*Keywords:* Coherency identification; PMU; Preventive control action; RBFNN; Rotor angle stability; Transient instability detection & control; Dynamic stability assessment.

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## 1. Introduction

An interconnected power system consists of generating units (which are primarily controlled by governing system), transmission lines, loads, compensating units and HVDC lines. In recent years, the generation units are added swiftly in existing system to fulfill the escalating demands. However, transmission network expansion planning for matching this generation level is yet taking baby steps. Due to this, the transmission lines are operating

# Intelligent Grey Wolf Optimizer - Development and Application for Strategic Bidding in Uniform Price Spot Energy Market

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## Abstract

Restructuring of power system has enabled generating companies to sell the power in energy markets. To avail maximum profit, every generating company frame strategies and bid in competitive energy markets. Prediction of rival behavior and information of future energy price is a major difficulty, while exercising the profit making strategies. A powerful optimization tool is required to handle the profit maximization process in dynamically changing market; keeping this fact in consideration, a new variant of grey wolf optimizer (GWO) named as intelligent grey wolf optimizer (IGWO) is proposed. This variant employs two mathematical frameworks first an efficient sinusoidal truncated function and another one is oppositional based learning concept for ensuring the better exploration and exploitation properties. The accuracy of IGWO is tested and compared with other contemporary algorithms on 22 benchmark functions. Once proved, the proposed algorithm is applied for framing bidding strategy in uniform and dynamically changing market conditions. The results of IGWO are compared with GWO, oppositional-GWO (OGWO) and PSO. The rivals behaviors are modeled through normal distribution of the bids and two cost models are prepared. Further, Monte Carlo simulations are performed. It is observed that profit obtained from IGWO is more from OGWO, GWO and PSO for both a single trading hour and a trading day. A considerable amount of profit can be earned by a generation company by employing proposed methodology.

*Keywords:* Bidding strategies, Electricity market, Market clearing price, Monte carlo simulation, Grey wolf optimization.

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## 1. Introduction

In competitive electricity market, Generating Companies (Gencos) participate in energy trading on the basis of framed bidding strategies. These strategies are helpful for a company as they can have impact on profits; in addition to that these strategies also drive market

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April 13, 2018

## Research Article

# Structured Clanning-Based Ensemble Optimization Algorithm: A Novel Approach for Solving Complex Numerical Problems

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Received 18 August 2018; Revised 10 October 2018; Accepted 4 November 2018; Published 9 December 2018

Academic Editor: Azah Mohamed

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In this paper, a novel swarm intelligence-based ensemble metaheuristic optimization algorithm, called Structured Clanning-based Ensemble Optimization, is proposed for solving complex numerical optimization problems. The proposed algorithm is inspired by the complex and diversified behaviour present within the fission-fusion-based social structure of the elephant society. The population of elephants can consist of various groups with relationship between individuals ranging from mother-child bond, bond groups, independent males, and strangers. The algorithm tries to model this individualistic behaviour to formulate an ensemble-based optimization algorithm. To test the efficiency and utility of the proposed algorithm, various benchmark functions of different geometric properties are used. The algorithm performance on these test benchmarks is compared to various state-of-the-art optimization algorithms. Experiments clearly showcase the success of the proposed algorithm in optimizing the benchmark functions to better values.

## 1. Introduction

With the ever increasing demand for new and better utility-driven technologies, the challenges surrounding them are becoming more and more complex. These optimization problems were traditionally solved using classical deterministic methods [1], which were often quite efficient in finding the solutions. But the ever increasing complexity of these problems has made these classical techniques quite unreliable for various real-world engineering problems. Here, various metaheuristic optimization [1] algorithms prove to be quite successful. Often inspired by nature, these algorithms makes use of various stochastic [2] techniques for finding the solution. These metaheuristics are higher-level heuristics that try to find a partial solution called heuristic representing a sufficiently good solution to the optimization problem [3–6]. The presence of randomness drives the algorithms towards promising regions of the search space. Simplicity of use, high reliability, and high

flexibility has made these algorithms quite popular in last few years [7].

Among these algorithms, many are based on multiagent paradigms. These include various evolutionary algorithms [8] inspired by the evolutionary mechanisms found in nature. These algorithms [9–15] use various mechanisms like crossover, mutation, and selection for solving the optimization problems. Among the most popular metaheuristic, GA [9] was proposed by Holland in 1970s. It represents the information in the form of genetic representation as bits and performs evolutionary processes like selection, mutation, and crossover on it. Other population-based algorithms utilize swarm intelligence-based mechanisms [16–20] to solve the optimization problem. These algorithms make use of information distributed in the individual participants of the swarm. The lack of any central control structure makes it vital for the distributed information to be shared amongst the individuals of the swarm. The interaction between these individuals leads to

# A Compact Coplanar Waveguide Fed Wideband Monopole Antenna for RF Energy Harvesting Applications

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**Abstract**—For energy harvesting applications a new design of a coplanar waveguide (CPW) fed monopole antenna is presented. It covers almost all useful band ranges from 900 MHz–9.9 GHz (Radio, GSM, ISM, UWB bands). It also provides band reject characteristics for the range 3.1 GHz–5.6 GHz (HIPERLAN, C-Band, and W-LAN) to avoid interference from this range. The new design is based on the modification of coplanar waveguide (CPW) structure and optimizing the gap between patch and CPW ground for covering the ultra wideband (UWB) range and other useful ranges (Radio, GSM and ISM). Bandwidth enhancement and impedance matching for UWB range have been obtained by chamfering the corners, cutting two slots in CPW ground and dual stubs. The new design incorporates a parasitic patch above the antenna patch for tuning the desired band rejection. The entire design has been optimized at various stages during its evolution. The structure is compact in size  $50 \times 40 \times 1.6 \text{ mm}^3$ . It may also be used for mobile, military and satellite applications.

## 1. INTRODUCTION

### 1.1. RF Energy Harvesting and Its Demands on Antenna Specifications

In the field of wireless communication the emerging technologies need compact and miniature devices. Such devices have small batteries that need to be charged well in time. Day by day increase in the usage of data demands that the batteries be charged frequently. A possible solution is that the batteries are charged automatically by any technique (for example by energy harvesting technique). RF energy is present in the ambient practically everywhere. Therefore research is being conducted throughout the world to harvest this energy. Any RF energy harvesting module will draw RF energy from an available source and convert it into usable energy for a given application. Most common source is the ambient. A RF energy harvesting module is the combination of a receiving antenna, RF-DC converter circuit and impedance matching circuit. Such a combined structure (device) has been named as RECTENNA by the researchers [1–4]. So a miniaturized structure of antenna is needed to capture energy and to feed it to the rectifying block of RECTENNA. For maximizing energy output of the antenna the input should be maximized. However, at any given place, the environment will have limited RF energy per unit area. Therefore for given dimensions, the energy capturing area of the antenna should be as large as possible. In the ambient RF energy is present in various frequency bands such as 900 MHz–2 GHz (Band for radio & television applications, GSM), 2.1 GHz–2.6 GHz (ISM band for various applications) and 3.1 GHz–10.6 GHz (ultra wideband for satellite applications) [5]. Narrow band systems such as WLAN (3.1 GHz–4.4 GHz), HIPERLAN (5.1 GHz–5.3 GHz), C-BAND (4.4 GHz–5 GHz) may provide interference. The rectifying block should incorporate a band reject filter to stop these narrow bands. Additionally a band reject filter may have to be included after the rectifying diodes to suppress internal

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*Received 12 October 2017, Accepted 1 December 2017, Scheduled 12 January 2018*

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# Design and experimental investigations on six-stroke SI engine using acetylene with water injection

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Received: 23 February 2018 / Accepted: 24 May 2018  
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## Abstract

In the present study, a four-stroke cycle gasoline engine is redesigned and converted into a six-stroke cycle engine and experimental study has been conducted using gasoline and acetylene as fuel with water injection at the end of the recompression stroke. Acetylene has been used as an alternative fuel along with gasoline and performance of the six-stroke spark ignition (SI) engine with these two fuels has been studied separately and compared. Brake power and thermal efficiency are found to be 5.18 and 1.55% higher with acetylene as compared to gasoline in the six-stroke engine. However, thermal efficiency is found to be 45% higher with acetylene in the six-stroke engine as compared to four-stroke SI engine. The CO and HC emissions were found to be reduced by 13.33 and 0.67% respectively with acetylene as compared to gasoline due to better combustion of acetylene. The NO<sub>x</sub> emission was reduced by 5.65% with acetylene due to lower peak temperature by water injection. The experimental results showed better engine performance and emissions with acetylene as fuel in the six-stroke engine.

**Keywords** Acetylene fuel · Six-stroke engine · Exhaust heat recovery · Water injection · Engine performance

## Abbreviations

SI	Spark ignition
CO	Carbon monoxide
HC	Hydrocarbon
NO <sub>x</sub>	Nitrogen oxides
CO <sub>2</sub>	Carbon dioxide

LPG	Liquefied petroleum gas
CA	Crank angle
TDC	Top dead center
NDIR	Non-dispersive infrared radiation
MEP	Mean effective pressure
FC	Fuel consumption
BP	Brake power
BTE	Brake thermal efficiency

Responsible editor: Philippe Garrigues

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## Nomenclature

$W_{net}$	Net work (watt)
$V_{disp}$	Displacement volume (m <sup>3</sup> )
$N$	Speed (RPM)
$n_s$	Number of crank revolution
$P$	Power (Watt)
$T$	Torque (N-m)

## Introduction

Today, the world is facing a crisis of fossil fuel and environmental degradation. The spark ignition (SI) engines used in transportation as well as in small power generation running on conventional fossil fuels are emitting pollutants such as HC, CO, CO<sub>2</sub>, and NO<sub>x</sub>. The global warming is particularly

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# Exploring the musculoskeletal problems and associated risk-factors among brick kiln workers

Brick kiln  
workers

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Received 17 May 2018  
Revised 18 July 2018  
Accepted 1 October 2018

## Abstract

**Purpose** – Prolonged working in repetitive and awkward postures can result in musculoskeletal disorders among workers involved in labour-intensive jobs like those of brick kiln workers. Unlike other labour-intensive sectors, workers in this particular sector have a lack of awareness about musculoskeletal problems. Therefore, the purpose of this paper is to explore musculoskeletal issues and associated risk-factors among brick kiln workers.

**Design/methodology/approach** – A questionnaire survey was conducted among 217 male and 111 female workers aged between 17 and 53 years. They were employed in traditional brick kiln units situated in Rajasthan, India. Postures were analysed by Rapid Upper Limb Assessment and Rapid Entire Body Assessment methods. Binary logistic regression was used to find the association between musculoskeletal problems and risk-factors.

**Findings** – For the mould evacuating task, wrist (76.2 per cent) and lower back (56 per cent) issues were the most frequently reported musculoskeletal problems, while in spading task, lower back (62.4 per cent) and shoulder (57.7 per cent) problems were prominent. Musculoskeletal symptoms in one or more body regions were associated with personal and work-related factors including the type of task and experience.

**Research limitations/implications** – Kiln workers are exposed to high musculoskeletal and postural risks, particularly in spading and mould filling tasks. To reduce these risks, ergonomic interventions are needed.

**Originality/value** – It is recognised that the musculoskeletal health of brick kiln workers is a cause for concern. The present study provides the evidence of the prevalence of musculoskeletal symptoms experienced by brick kiln workers and the association of symptoms with various risk-factors, which has not been addressed in previous studies.

**Keywords** Logistic regression, Musculoskeletal disorders (MSDs), Brick kiln, Risk-factors

**Paper type** Research paper

## 1. Introduction

The clay brick making process requires a large number of repetitive manual activities which are continuously performed in awkward postures (Trevelyan and Haslam, 2001). In India, fired clay bricks are produced in traditional kilns which fall under the category of unorganised small-scale industries (Bandyopadhyay and Sen, 2016; Sett and Sahu, 2014).

The authors declare no conflict of interest. There is no specific funding from any provider source for this study. The authors would like to thank all the experts for their valuable suggestions in questionnaire development. The authors would also like to acknowledge the enormous support of kiln workers, managers and owners during the present study.



**Article Type:** Original

**Complete Title:** Identifying musculoskeletal issues and associated risk factors among clay brick kiln workers

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**Short Running Title:**

MUSCULOSKELETAL ISSUES AMONG BRICK KILN WORKERS

**Received: May 23, 2018**

**Accepted: September 26, 2018**

**Advance publication: October 19, 2018**

## Abstract

The present study is aimed to investigate the musculoskeletal issues and association of risk-factors with these problems among manual brick kiln workers. A modified Nordic Questionnaire was administered among 376 traditional brick kiln workers to collect data. Logistic regression was used to determine the association between musculoskeletal problems and risk-factors. Majority of workers (76.19%) involved in mould evacuating task reported wrist issues whereas lower back issues were reported by 62.35% of spading task workers. Age was a factor associated with musculoskeletal symptoms in the majority of the body regions. Gender was significantly associated with lower back (OR=3.71, CI:1.51–9.11) MSDs. Spading task was associated with the wrist (OR=2.42, CI:1.03–5.66), and lower back (OR=3.97, CI:1.75–8.98) problems. Mould filling was a contributing factor for the wrist (OR=4.27, CI:1.81–10.09) and knee (OR=6.88, CI:2.40–19.70) issues. MSDs in wrist (OR=12.22, CI:4.82–30.98) and fingers (OR=3.57, CI:1.23–10.36) were significant in mould evacuating workers. Workers having less than five years of experience were less prone to the neck (OR= 0.03, CI: 0.00–0.72) and upper back (OR = 0.08, CI:0.01–0.76) MSDs. For prevention of problems, ergonomic interventions such as workers' training, use of protecting aids, modification in hand tools and work practices are needed.

**Keywords:** brick kiln; ergonomics; logistic regression; musculoskeletal disorders; MSDs; risk factors.



## Impact of posture and upper-limb muscle activity on grip strength

Rahul Jain, Makkhan Lal Meena, Manoj Kumar Sain & Govind Sharan Dangayach

To cite this article: Rahul Jain, Makkhan Lal Meena, Manoj Kumar Sain & Govind Sharan Dangayach (2018): Impact of posture and upper-limb muscle activity on grip strength, International Journal of Occupational Safety and Ergonomics, DOI: [10.1080/10803548.2018.1501972](https://doi.org/10.1080/10803548.2018.1501972)

To link to this article: <https://doi.org/10.1080/10803548.2018.1501972>



Accepted author version posted online: 19 Jul 2018.



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**Publisher:** Taylor & Francis & Central Institute for Labour Protection – National Research Institute (CIOP-PIB)

**Journal:** *International Journal of Occupational Safety and Ergonomics*

**DOI:** 10.1080/10803548.2018.1501972



## **Impact of posture and upper–limb muscle activity on grip strength**

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**SHORT TITLE:** “Grip strength in manual working”

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### **Abstract:**

**Purpose:** The current research was carried out to determine the grip strength (GS) with change in posture and upper–limb muscle activity of manual workers and find out the impacts of these changes.

**Methods:** For the current research, 120 male and 80 female participants were selected and GS was assessed using digital hand grip dynamometer in various conditions.

**Results:** The outcomes showed that male participants had higher GS as compared to female participants. Maximum GS was found in standing posture with the fixed forward shoulder in 45°, elbow at 90° and neutral position of wrist and forearm for all participants.



# International Journal of Occupational Safety and Ergonomics

ISSN: 1080-3548 (Print) 2376-9130 (Online) Journal homepage: <http://www.tandfonline.com/loi/tose20>

## Pulling force prediction using neural networks

Rahul Jain, Makkhan Lal Meena, Manoj Kumar Sain & Govind Sharan Dangayach

To cite this article: Rahul Jain, Makkhan Lal Meena, Manoj Kumar Sain & Govind Sharan Dangayach (2018): Pulling force prediction using neural networks, International Journal of Occupational Safety and Ergonomics

To link to this article: <https://doi.org/10.1080/10803548.2018.1443899>



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**Publisher:** Taylor & Francis & Central Institute for Labour Protection – National Research Institute (CIOP-PIB)

**Journal:** *International Journal of Occupational Safety and Ergonomics*

**DOI:** 10.1080/10803548.2018.1443899



## **Pulling force prediction using neural networks**

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**SHORT TITLE:** “Pull force prediction using ANNs”

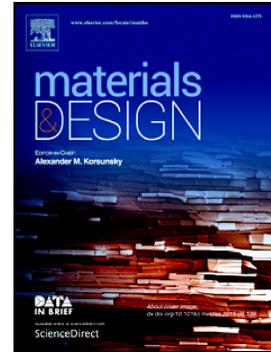
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## Accepted Manuscript

Polymer-metal-polymer (PMP) multilayer transparent electrode for organic optoelectronics

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PII: S0264-1275(18)30493-3  
DOI: doi:[10.1016/j.matdes.2018.06.026](https://doi.org/10.1016/j.matdes.2018.06.026)  
Reference: JMADE 3996  
To appear in: *Materials & Design*  
Received date: 30 October 2017  
Revised date: 11 June 2018  
Accepted date: 15 June 2018

Please cite this article as: Vikas Sharma, Himanshu Sharma, Rishi Vyas, Kanupriya Sachdev , Polymer-metal-polymer (PMP) multilayer transparent electrode for organic optoelectronics. Jmade (2018), doi:[10.1016/j.matdes.2018.06.026](https://doi.org/10.1016/j.matdes.2018.06.026)

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**Polymer-Metal-Polymer (PMP) Multilayer Transparent Electrode for  
Organic Optoelectronics**

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# Metallic Slit–Loaded Ring Resonator–Based Plasmonic Demultiplexer with Large Crosstalk

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Received: 29 August 2018 / Accepted: 12 November 2018  
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## Abstract

Photonics provides a key solution to limit the myriads of challenges offered by existing silicon technology. Here, we propose a simple 2-channel Plasmonic demultiplexer with Metal-Insulator-Metal (MIM) waveguide geometry. The demultiplexer is capable to separate two fundamental optical windows (i.e., 1310 nm and 1550 nm). An FDTD (finite difference time domain) method is used to investigate the structure numerically. The optical properties of the demultiplexer are also investigated. The performance of the proposed demultiplexer is measured using crosstalk and quality factor. The minimum value of crosstalk is  $-30$  dB and maximum quality factor is 60. The maximum transmission is limited to 45% due to large metallic losses. The proposed demultiplexer is ultra-compact in size and is capable to provide sub-wavelength confinement. It is suited for WDM applications and can pave a way to design the photonic integrated circuits.

**Keywords** Plasmonic · Demultiplexer · Metal-insulator-metal (MIM) · Crosstalk · Quality factor

## Introduction

Light waves can be used to transport information to distance apart with numerous merits like large bandwidth, high-speed immunity to interference [1]. The ever-increasing demand of data rate stems the need for multiplexing scheme [1–3]. In recent era, wavelength division multiplexing (WDM) or demultiplexing techniques have emerged as a key technology to effectively utilize the capacity of optical fibers. But, the advancements in technology demand miniaturization of components [3, 4]. The flow of optical signals in the dielectric waveguide is constrained to the diffraction limit; hence, the size of the device cannot be scaled beyond this limit [5, 6]. A new chip-scale technology (i.e., Plasmonics) plays a vital and critical role in the field of fast information transport [5]. It lends a hand to bridge the gap between high-speed Photonics and nano-sized

electronic [6, 7]. Plasmonics is a new branch of nano-science that witnesses the interaction of electromagnetic energy with free electrons of metal at a sub-wavelength scale [6–8]. Plasmonics offers the inherent feature to conquer the fundamental diffraction limit and it is considered as an efficient platform to realize future photonic integrated circuits. Therefore, several optical solutions based on Surface Plasmon Polaritons (SPPs) were investigated theoretically and experimentally [9–12]. Recently, plasmonic-based plasmonic polarizer [13, 14], absorber [15], polarization rotators [16], polarization beam splitter [17], plasmonic microcavity [18] are proposed. The MIM (Metal-Insulator-Metal) waveguide geometry of SPP acts as a promising technique to realize on-chip optical/photonic components such as filters, demultiplexers, buffers, and sensors [19, 20]. The fascinating property of sub-wavelength confinement in MIM waveguide helps to offer ultra-small feature size. The dream of optical integrated circuits can come true with the use of plasmonic MIM waveguide [20–22]. The demultiplexer is an integral part of optical integrated circuits. Different plasmonic-based demultiplexers have also been proposed previously [23–26]. In this paper, we have utilized MIM waveguide geometry to design a compact plasmonics demultiplexer that will demultiplex 1.3 and 1.55  $\mu\text{m}$ . The performance of the demultiplexer is measured in terms of crosstalk and quality factor. A comparison of the performance of proposed device is also carried out in this paper.

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# Fano Resonance Excited All-Optical XOR, XNOR, and NOT Gates with High Contrast Ratio

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Received: 9 November 2017 / Accepted: 13 February 2018  
© Springer Science+Business Media, LLC, part of Springer Nature 2018

## Abstract

We have presented all-optical XOR, XNOR, and NOT gates using metal-insulator-metal (MIM)-coupled ring resonator. The performance of the device is evaluated by finite difference in time-domain (FDTD) method. The proposed gate utilizes a unique phenomenon of Fano resonance to excite logic OFF/ON state. Fano resonance has quite asymmetric resonance profile and the transmission spectrum of Fano profile abruptly drops to a minimum value at the resonance condition. Due to this unique resonance phenomenon, a large value of contrast ratio is obtained. The proposed XNOR gate offers a contrast ratio (C.R.) of 20.66 dB while XOR and NOT gates offer C.R. 12.8 and 18.8 dB respectively. The variation of contrast ratio is also studied against different input wavelength and it is reported that the obtained value of contrast ratio is an optimum value for the proposed structure. The device is compact sized with small dimension  $0.31 \lambda_0^2$ , where  $\lambda_0 = 1.55 \mu\text{m}$ . The proposed device opens up the avenues for designing on-chip optical gates in the field of high-speed optical communication networks.

**Keywords** XNOR, XOR, and NOT gates · FDTD method · Fano resonance · Contrast ratio

## Introduction

Recently, all-optical signal processing is being the area of intense research due to its potential application in replacing the low-speed electronics with high-speed photonics or optics. The basic end-to-end technology in fiber optic system is prone to optical-electrical-optical (O-E-O) conversion at the transmitter and receiver terminal [1]. The high latency is involved in this conversion which is a bottleneck in the high-speed optical system. This latency can be reduced if all-optical devices are involved in the communication system. In this regard, photonics and its devices have emerged as a key technology to facilitate the optical/photonics on-chip integrated circuits [2]. The myriads of challenges of O-E-O conversion can be combated using all-optical devices such as optical multiplexer/de-multiplexer (MUX/DEMUX) [3], optical filters [4], modulators and switches [5], and optical gates [6]. Among all these optical components, all-optical logic gates

play a vital role in optical computing, signal regeneration, and so on [7–9]. All-optical gates can be designed using several variants of optical-based solution, viz. semiconductor optical amplifiers (SOAs) [7, 8] and photonic crystals [9]. But, SOA-based solution offers a challenge in terms of operational speed of gates [7, 8]. Also, the nonlinearity associated with nonlinear materials demands high power requirement [8]. In recent years, the interest of researchers has been enthused by photonic crystal structures in designing and manufacturing optical logic gates because of its inherent merits in terms of high switching speed and the possibility to create optical integrated circuits using them [10, 11]. Recently, noble metals are also being used in realizing several optical devices and components [3–5, 12]. The interaction of electromagnetic energy with free electrons of metal lies in the realm of a new branch of optics called as Plasmonics [2]. The metal-insulator-metal/metal-dielectric-metal (MIM/MDM) waveguide geometry of Plasmonic waveguide has the unique feature to confine an optical signal far beyond the diffraction limit [2]. The fascinating features of Plasmonics help to exploit the unique optical properties that allow the manipulation of the flow of light or photons [2, 12, 13]. Recently, it is proposed with experimental and simulated results that electronics components like buffers, modulators, routers, and logic gates can be realized using MIM Plasmonic waveguide [2–5, 12, 13]. Fu. et al. have also realized all-optical XNOR, XOR, NOT, and OR logic

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# Plasmonics-Based Refractive Index Sensor for Detection of Hemoglobin Concentration

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Antonio d'Alessandro, and Mohammad Salim

**Abstract**—An ultra-compact plasmonics-based sensor is investigated which is excited by Fano resonance. The structure is numerically simulated by the finite-difference time-domain method. The sensor utilizes unique waveguide geometry named as metal-insulator-metal (MIM) waveguide geometry which has an intriguing feature to confine signal far beyond diffraction light. Thus, it is used to devise ultra-compact optical circuits. The MIM waveguide is coupled to a pair of elliptical ring resonators and the interaction between the resonators excites special mode which is known as Fano resonance mode. It is a unique phenomenon which exhibits asymmetrical resonance profile and supports ultra narrow line width. Because of its exciting feature, a large value of sensitivity = 1100 nm/RIU and figure of merit = 224RIU<sup>-1</sup> is obtained for the proposed sensor. The sensing performance of the device can be further enhanced by tailoring the geometrical parameters. The applicability of the device is also tested to detect the concentration of hemoglobin in blood. Thus, the device is well suited to design on-chip optical sensors.

**Index Terms**—Plasmonics, metal-insulator-metal (MIM), Fano resonance, sensitivity, figure of merit (FOM), hemoglobin.

## I. INTRODUCTION

RECENTLY, Fano resonance is garnering a great interest of researchers due to its exciting applications in the field of biological and chemical sensing [1], switching [2], Electromagnetically Induced transparency [3], generation of slow light [4], etc. Fano resonance was initially defined as a quantum mechanics phenomenon and is given by Fano [5]. It is defined as the interaction between two existing (direct and indirect) pathways of atomic excitations and the interaction give rise to an asymmetrical resonance profile [5]. Later, the phenomenon is also explained classically in some of the physical system [6]–[8]. The phenomenon is recently demonstrated in Plasmonics system which is excited by propagation of SPPs (Surface Plasmon Polaritons) along the metal/dielectric interface [9]. SPP is defined as the coupled state of incident photons and freely available surface electrons along the surface of the conductor. It is excited along the interface of two material having dielectric constants of

Manuscript received February 22, 2018; revised April 7, 2018; accepted April 7, 2018. Date of publication April 12, 2018; date of current version May 9, 2018. The associate editor coordinating the review of this paper and approving it for publication was Prof. Yu-Cheng Lin. (*Corresponding author: Rukhsar Zafar.*)

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Digital Object Identifier 10.1109/JSEN.2018.2826040

opposite sign [9]–[11]. The Plasmonics is the new branch of nanoscience which bridges the gap between high-speed photonics and ultra small-sized electronics and helps to bring photonics on-chip [10]. In previous years, Plasmonics is greatly used for exciting Fano resonance effect [4], [11], [12].

Fano resonance effect emerges due to the coupling and interference of a non-radiative or dark mode with bright or continuum of the radiative spectrum [13]–[15]. The Fano interference based resonance is quite distinct from the conventional Lorentzian shaped resonance because Fano resonance based systems do exhibit an asymmetrically shaped profile [12]–[15]. One of the most peculiar features of Fano resonance is an ultra large value of Quality factor which increases the photon lifetime in the resonator and leads to enhanced light-matter interaction with the MUT (material under test). This feature is best suited for sensing characteristics [12], [16]. Recently, He and Yang [16] demonstrates Fano line for application in nano-sensor. The performance of the sensor is quantified by its sensitivity which is measured as a change in resonance condition for per unit change in input parameter (i.e. refractive index). Zhao *et al.* [17] also has reported a tunable Fano resonance in asymmetric MIM waveguide for the large sensitivity of 718 nm/RIU. The sensitivity is a vital parameter of the sensor. However, the better accuracy of the sensor can be claimed with an ultra large value of FOM (Figure of Merit) [16]–[18]. Zhang *et al.* [19] investigated a compact Plasmonic nano-sensor with a large value of FOM. Therefore, FOM is reported as the most important quantifying parameter for enhanced accuracy and improved selectivity [18]–[24].

In this paper, the sensing characteristics of Plasmonics based RI sensor is investigated. The structure comprises of a MIM waveguide coupled to a pair of elliptical ring resonators. The coupling between resonators is maintained in such a manner that Fano resonance is excited with better sensing performance. The sensitivity and FOM are also studied for changing geometrical parameters of the structure. The large value of sensitivity and FOM opens the pathway to design highly sensitive on-chip sensors. Therefore, the structure is also investigated as a biological sensor to detect the concentration of hemoglobin level in human blood group.

## II. WAVEGUIDE GEOMETRY AND THEORETICAL ANALYSIS

Fig 1 (a & b) shows the 3D geometry and 2D layout of the proposed structure with the given parameters respectively. It comprises of MIM waveguide coupled to a pair of elliptical resonators with the following assumed parameters:  $R_1$ ,  $R_2$  is

# LIFE CYCLE COST ASSESSMENT OF DIFFERENT SEWAGE TREATMENT TECHNOLOGIES : A CASE STUDY

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**Abstract:** The need for the present study arose due to the increased demand for application of higher treatment technologies for reuse/recycle of sewage meeting water demand to maintain green stretch in urban areas. In this study a comparative Life Cycle Cost (LCC) analysis of secondary treatment methods such as ASP, MBBR and SBR has been carried out for a period of 20 years at different rates of interest by assessing some treatment plants of each technology. LCC of ASP plants was found to be lower as compared to the MBBR and SBR plants. LCC analysis of five disinfection treatments was also carried out for five options, namely, chlorination, ozonation, ultraviolet (UV) irradiation, hybrid disinfection A (Cl<sub>2</sub>/O<sub>3</sub>) and hybrid disinfection B (Cl<sub>2</sub>/UV). Chlorine disinfection process is found to be most cost effective compared to others. Both ozone and UV have a benefit that no residuals are left after treatment, hence do not pose any toxicity risk to aquatic organisms of the receiving waters. However, due to their relatively higher cost as compared to chlorine, these processes need optimization. Hybrid disinfection A (Cl<sub>2</sub>/O<sub>3</sub>) and hybrid disinfection B (Cl<sub>2</sub>/UV) strategies were evolved to avoid high doses of chlorine by adopting a two-step treatment. LCC of hybrid disinfection strategies was found to be lower as compared to Ozonation and UV treatment for 20 years at different rates of interest. On combining LCC cost of secondary and tertiary treatment, it was found that LCC of ASP followed by five disinfection strategies was more cost effective compared to similar combination with SBR and MBBR. These data would help in decision making for choosing appropriate technology for sewage treatment and reuse in the changing scenario.

**Key Words:** Life Cycle Cost; Sewage Treatment; ASP; MBBR; SBR; Tertiary Treatment; Hybrid Disinfection.

## 1. INTRODUCTION

As the population and its living standards increase, the need for water also increases. Waste Water treatment plays a vital role for fulfilling the demand of water. New norms of disposing the effluent have been introduced CPCB (2017) in which the standards for fecal coliform have been introduced first time in October 2017. Therefore tertiary treatment has become necessary for every treatment plant for disposing the effluent in metro and class I cities of India. As per Koul and John (2015), Life Cycle Cost analysis has evolved as one of the measures for determining the suitability for use of a particular type of wastewater treatment technology. Different treatment processes can be used for any particular type of wastewater generated from any source. Most of the times the efficiency or the degree of treatment for a treatment technology may be almost similar to other technology or the difference may not be much significant. In such cases, Cost analysis may come of use as to determine which treatment process can be preferred over other. Life Cycle Cost analysis helps to evaluate the cost of a treatment technology over its design period to help selection of the most suitable one. This is

particularly helpful in areas where selection of wastewater treatment technology may be restricted due to financial constraints. One tool to assess environmental impacts resulting from shifting from one design choice for WWT to another is by conducting Life Cycle Analysis (LCA) of all considered designs/systems. An LCA study considers all the environmental impacts associated with a product or system throughout its life cycle (i.e., from cradle to grave) (Pirani *et al.*, 2012). Life Cycle Costing (LCC) is used as decision-making tool while constructing any STP. The LCC results will be helpful for raising the funds when constructing a new plant with same technology (Bhoye *et al.*, 2016). The present study aims to carry out economic analysis of secondary and tertiary treatment technologies so that a cost effective option can be selected for the treatment of sewage in the changing scenario.

## 2. LOCATION OF WASTE WATER TREATMENT PLANTS AND DATA COLLECTION

The Activated Sludge Process, MBBR and SBR secondary treatment plants were considered in this study. The ASP

(12) PATENT APPLICATION PUBLICATION

(21) Application No.201811002382 A

(19) INDIA

(22) Date of filing of Application :19/01/2018

(43) Publication Date : 26/01/2018

(54) Title of the invention : TWO WHEELER VEHICLE TO PREVENT BACK ACHE FOR RIDER

(51) International classification

:B60N  
2/00

(31) Priority Document No

:NA

(32) Priority Date

:NA

(33) Name of priority country

:NA

(34) International Application No

:NA

Filing Date

:NA

(87) International Publication No

:NA

(61) Patent of Addition to Application Number

:NA

Filing Date

:NA

(62) Divisional to Application Number

:NA

Filing Date

:NA

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(57) Abstract :

Present invention relates to a two wheeler vehicle, designed so as to provide back comfort for a rider. More particularly, present invention relates to a two wheeler vehicle, which has a front rake of 55 degrees. The vehicle comprises of a swing arm modified so as to hold shockers above hub of the rear tire.

No. of Pages : 9 No. of Claims : 5

(12) PATENT APPLICATION PUBLICATION

(21) Application No.201811033875 A

(19) INDIA

(22) Date of filing of Application :09/09/2018

(43) Publication Date : 28/09/2018

(54) Title of the invention : DUAL-AXIS PARABOLIC SOLAR COOKER SYSTEM TO AUTOMATICALLY TRACK SUNLIGHT

(51) International classification	:H02J7/0073
(31) Priority Document No	:NA
(32) Priority Date	:NA
(33) Name of priority country	:NA
(86) International Application No	:NA
Filing Date	:NA
(87) International Publication No	:NA
(61) Patent of Addition to Application Number	:NA
Filing Date	:NA
(62) Divisional to Application Number	:NA
Filing Date	:NA

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- 18)ABHISHEK SHARMA

(57) Abstract :

A dual-axis parabolic solar cooker system to automatically track sunlight. The dual-axis parabolic solar cooker system to comprises light dependent resistors (LDRs),micro-controller unit, a plurality of stepper motors, solar panels, a power unit, lead screw, ball bearing, and couplers. The LDRs sense intensity of the sunlight received on the outer surface. The micro-controller unit computes the intensity of the sunlight to determine a direction of the sunlight and further initiates an actuation signal. The plurality of stepper motors are configured with the micro-controller unit to receive the actuation signal. The stepper motors hold a plurality of solar panels and utilize the received actuation signal to position the solar panels in a way to receive the sunlight from the direction having a maximum computed intensity of the sunlight. The plurality of stepper motors comprises front stepper motors, right stepper motors, rear stepper motors, and left stepper motors.

No. of Pages : 23 No. of Claims : 7