

M.TECH. THESIS ABSTRACT 2012

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Power & Control

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Title : *Four Quadrant operation and Closed Loop Speed Control of Brushless DC Motor with Torque Ripple Reduction*
Author(s) : *Madarapu Thulasiram*
Roll No : *10104053*
Supervisor(s) : *Das Shyama Prasad*

Abstract:

After much research and developments in the fields of magnetic materials their application to electric motor drives has increased to a significant extent. AC motors with permanent magnet rotors are available as brushless DC motors (BLDCM) for both domestic and industrial applications. With the advancements in power electronics, the control of Brushless DC machine has become more flexible for variety of applications. Thus BLDCMs are penetrating the market of home appliances and automotive applications in recent years because of their compact size, simple construction, higher power density, high efficiency, good heat dissipation, reliability, good over loading capability, silent operation and low maintenance. The present work is aimed at modeling, simulation, closed-loop speed control, and torque ripple reduction of BLDCM drive for possible applications in aerospace, wind turbines, hybrid/electric vehicles, lifts, hoists, cranes, winders and reels. The response of the drive to step change in speed and torque, and speed and torque reversals is studied. It is observed that the drive performance is satisfactory both under transient and steady-state conditions. One of the main disadvantages of BLDCM drive is high torque ripples when compared with inverter fed induction motor drives. In the present work, a torque ripple reduction method is proposed, which minimizes the torque ripple of BLDCM drive. A PC based closed-loop speed control of BLDCM with torque ripple reduction is implemented, and it is tested under no-load and loaded conditions. The performance of the drive is found satisfactory. Both simulation and experimental results obtained from with and without the torque ripple reduction technique are compared

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Title : *Identification Of Harmonic Sources And Optimal Placement Of Filters For Harmonics Mitigation*
Author(s) : *Bhaumik Sayak*
Roll No : *10104085*
Supervisor(s) : *Singh Sri Niwas*

Abstract:

Synchrophasor technology has brought the revolution in the field of power system engineering. It enables to measure the phasor values of voltage and current of a wide spread network with high accuracy. The application and scope of synchrophasor technology in mitigation of power system harmonics is explored in this work. Issue related to power system harmonics has become a major concern due to significant penetration of power electronics devices in power system. A complete solution to power system harmonics involves identification of harmonic sources and proper planning of filters to suppress the harmonics. In this thesis, a method, based on harmonic voltage phasor measurements, has been proposed to identify locations and sizes of multiple harmonic sources present in the system. Information on direction of active and reactive harmonic power flow have been utilized for identification purpose. The proposed method has been tested on an 18-bus system to show its effectiveness. To collect the harmonic voltage measurement data economically, a strategy for optimal placement of harmonic measurement units has been proposed. An index method followed by binary particle swarm optimization has been used to minimize the number of devices as well as maximize the measurement redundancy. The suitability of the approach has been verified on six IEEE standard systems. Once location and harmonic current injection spectrum of all the harmonic sources are known, optimal planning of harmonic filters becomes the next objective in this thesis. Optimal planning of passive tuned filter has been suggested by a two-step indexing method. Cost of filters and overall performances of filters have been taken into account during planning process. Due to some inherent demerit of passive filters, active filters have come up as an alternative solution to harmonic problems. A method for determining optimal locations and sizes of shunt active filters has also been proposed in this work. Locations are selected based on index values whereas particle swarm optimization has been employed to find optimal current injection spectrum. Both the filter placement methodologies have been tested on 18 bus system and found to be satisfactory.

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Title : *Cellular Neural Networks: Applications in Power Systems*
Author(s) : *Meena Manesh Kumar*
Roll No : *Y7027223*
Supervisor(s) : *Singh Sri Niwas*

Abstract

Artificial Neural Networks (ANNs) have wide range of applications in power systems. Traditionally many authors have used back propagation neural networks in power system stability, load forecasting, On Line Tap Changing (OLTC) and many other problems in the power systems. Tradition neural networks have few drawbacks like more error and high computation time, etc. With the increase in renewable energy sources connected to power grids better identification tools are needed for power system voltage -profile prediction, optimal transfer tap setting for VAR control, etc. Considering all the drawbacks a new approach is presented to make power system computations fast and more reliable. In Cellular Neural Networks (CNNs) computation is fast as it is a parallel processing tool. For training and testing of the CNN load-flow programs are run and various data according to nature of buses and nature of problem statement are collected. Results of CNN shows that parallel computing makes application of ANN in power system operations more reliable and fast. A comparative study of CNN and BPNN in various power system application is tested on standard IEEE 6-bus and 14-bus systems.

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Title : *Adaptive Load Shedding Strategy for Improving Power System Frequency and Voltage Stability*
Author(s) : *Praveen Kumar Reddy C*
Roll No : *10104024*
Supervisor(s) : *Srivastava S C; Chakrabarti Saikat*

Abstract

Large disturbances in interconnected power system networks, sometimes, cause the system to experience instability due to imbalance between generation and load. The instability may be angular instability, voltage instability, frequency stability, and/or a combination of these. Stabilizing controls may not always bring back the system to a normal state and requires emergency controls to be exercised. The effectiveness of emergency control schemes, in a power system, can be accomplished only with the availability of the real time dynamic states of the system. This thesis has focused on only load shedding, as one of the emergency control schemes, to regain the system stability. The thesis proposes two emergency load shedding schemes to ensure frequency and voltage stability using wide area phasor measurements. In the first scheme, a two stage load shedding is proposed assuming that the phasor measurements are available at all the buses. In the first stage, the load shedding amount is computed to ensure frequency stability and locations are decided based on the voltage dips at the load buses. In the second stage, a Voltage Collapse Proximity Indicator (VCPI) has been utilized for deciding the location and amount of the load shedding to ensure the voltage stability. In the second scheme, a single stage load shedding strategy has been proposed based on the load frequency sensitivities using phasor measurements only at the generator terminals. The proposed two schemes are able to bring the system frequency and bus voltages to within acceptable limits. The effectiveness of the proposed schemes is demonstrated on the 9-bus WSCC and the 39-bus New England test systems.

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Title : *Speed/Position Sensor-less Direct Torque Control of IPMSM Drive*
Author(s) : *Shandilya Mayank*
Roll No : *Y9104041*
Supervisor(s) : *Das Shyama Prasad*

Abstract

The emphasis of this thesis is to work upon different speed control techniques of Permanent Magnet Synchronous motor. Permanent magnet motor synchronous motors are increasingly being used in a variety of industrial applications where accurate positioning and speed control are required along with fast dynamic response of the drive. Various techniques for the speed control of synchronous motors have been proposed in past but out of which, only vector control and Direct Torque Control (DTC) are most popular and powerful techniques due to their simplicity and accuracy of control. The sensors in the close loop control of motor are crucial and expensive part of the system. In conventional drives DC tachogenerators are used for speed measurement. For rotor position feedback, Hall-sensor, Electromechanical Resolvers and digital encoders can also be used. In the present work the close loop speed sensor-less control of IPMSM is carried out and thus the system becomes more robust. The PI controllers are used for speed and torque and flux control loop. This method has the advantage of significantly lesser torque ripples with almost same settling time compared to conventional DTC. Normally Motor parameters are very important in the close loop dynamic control of IPMSMs. Different methods for measurement of motor parameters have been employed and the results found were in close approximation with all the methods, with some erroneous data ignored. The motor has also been run in Self Controlled mode and Open loop operation and is found stable in different load conditions. The basic theory of proposed method is presented. A mathematical model of proposed method is developed and the MATLAB Simulink ® model is used to verify the basic operation of the topology along with some experimental verification. The Control scheme gives satisfactory results

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Title : *Power System State Estimation Considering Real-time
Equivalents of the External Networks*
Author(s) : *Dongare Kapil Subhash*
Roll No : *10104033*
Supervisor(s) : *Saikat Chakrabarti*

Abstract

Today's power systems are heavily interconnected. During analysis, one such area may be considered as the internal area and the rest of the network as the external area. Internal area solution is dependent on topology information and measurement data of the external areas connected to it. But the area utilities are reluctant to share their network and operating data among themselves. Handling of such a large amount of data from different utilities in real-time is a difficult problem. This report presents a new technique to determine steady-state equivalent of an external power system network for use in real-time operation. Method involves use of measurement sensitivity analysis procedure, which determines the significant nodes of the external network such that, internal area solution is significantly dependent on the measurements at those nodes. Next step is to eliminate the nodes of the external area which comes out to be non-essential in sensitivity test. Algorithm has been developed to adjust of parameters of equivalent network for tracking the external area operating point for different loading conditions. This results in a dependable equivalent with excellent response at all operating points as well as for contingencies. Test results supporting the validity of the new method are presented

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Title : *Current Differential Protection of Transmission Line considering Parameter Uncertainties*
Author(s) : *Gangavarapu Sivanagaraju*
Roll No : *10104092*
Supervisor(s) : *Srivastava S C; Chakrabarti Saikat*

Abstract

The transmission lines play important role in transferring electrical energy from generating stations to distribution networks. Transmission lines require a well-designed protection and control scheme for secure and reliable operation of power system. Usually, the distance relays are used to protect the transmission lines in a power system. However, sometimes the distance relays mal-operate under dynamic conditions such as power swings and voltage instability. With the advent of the synchrophasor technology and advances in the communication system, current differential relays offer a more reliable protection system for the transmission lines. Current differential protection is relatively simple, offers high speed and sensitivity and is also immune to power swings and external faults. Various simulation studies require accurate model of the power system components including transmission lines. The synchrophasor measurements can be effectively used to obtain the component models. This thesis proposes a method to estimate the transmission line parameters using synchrophasor measurements, from Phasor Measurement Unit (PMU) as well as hybrid measurements, from PMU and SCADA system. It also proposes a method to estimate the transmission line parameter uncertainties under consideration of measurement inaccuracies and applied on the WSCC 9-bus and two area system. The results of the line parameter estimation are demonstrated on the WSCC 9-bus and the two area systems. The uncertainties in the line parameters are needed to set the bounds of the restrain region of the relay and to know the uncertainty in the power system state estimation. A new current differential protection scheme has been suggested for transmission line protection using synchronized measurements. The method utilizes the distributed parameter line model estimated earlier from the PMU measurements. The proposed current differential protection scheme has been tested on the two area system and results are compared with and without considering the line parameter uncertainties.

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Title : *A Half - Bridge Inverter Based Capacitive Power Transfer Circuit with Unity Power Factor Utility Interface*
Author(s) : *Shekhar Saurabh*
Roll No : *10104084*
Supervisor(s) : *Mishra Santanu Kumar;Joshi Avinash*

Abstract

Contactless power transfer technologies have been developed to provide convenient, safe and low maintenance power transfer from a stationary power source to a mobile or detachable load without wiring. It finds applications in biomedical implants, vehicles, battery chargers of portable devices, etc. Amongst the relevant technologies, Inductive Power Transfer (IPT) has been widely accepted with successful implementations in materials handling systems, battery chargers, and electric vehicles. However, IPT cannot be used to transfer power across metal barriers, and power losses are of concern when metal objects are present close to the magnetic field. Capacitive Coupled Power Transfer (CCPT) offers an alternative to achieve contactless power transfer. Employing the electric field as the energy transfer medium, CCPT offers advantages such as confined electric field between the coupling plates, power transfer capability through metal barriers, low eddy current losses associated with metal surroundings, low standing power losses under no-load conditions, small size and low cost. Currently, CCPT is mainly considered for low power applications such as contactless battery charging for biomedical implants, robotics, mobile phones, etc. This thesis develops a CCPT system with utility interface for medium power application with 12 V DC, 3A output from a utility supply. A CCPT system consists of an inverter, a LC filter, and diode bridge rectifier output stage followed by the load. A half bridge based inversion circuit is used for CCPT architecture to reduce the overall cost of implementation. An output LC filter interfaces this stage to the output stage which is a diode bridge rectifier. The capacitor of this LC filter forms the non-contact power transfer surface. In order to interface this system with the utility, the CCPT conversion circuit is preceded with a conventional boost converter based power factor corrected rectifier. The CCPT half bridge is switched at resonant frequency to ensure maximum power transfer. The converter uses a frequency tracker based feedback network which forces the half bridge converter to be switched at the resonant frequency of the LC filter even with variation in the capacitive coupling. The mathematical models of each stage are developed to facilitate a design oriented analysis of the proposed circuit. The proposed circuit is verified using a lab scale prototype. The prototype is implemented using off-the-shelf components. With 50 nF coupling capacitor the proposed circuit transfers 3 A of output current at 12 V output at 75 % efficiency.

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Title : *Intelligent Real-Time Fault Diagnosis of Air Compressors Using Android Smartphone*
Author(s) : *Sarkar Sumit*
Roll No : *Y7027453*
Supervisor(s) : *Verma Nishchal Kumar*

Abstract

An intelligent fault diagnosis system involves following stages: data acquisition, preprocessing, feature extraction, feature selection and classification. The acoustic signatures emanating from air compressor are captured and measured using sensors in data acquisition process. The next step is preprocessing of the acquired data, this is done to transform data into a format which can be processed easily and effectively. The processed acoustic signatures are analyzed in time, frequency and wavelet (time-frequency) domains to extract different features from the signal. The extracted features are then sent into the classification model, but as all features may not be useful from classification point of view and will result in poor computational efficiency, hence the extracted features are first passed through a stage called feature selection which selects the features that are sufficient to give accurate results. The classifiers for classification are implemented based on Support Vector Machines. To perform all the above steps, different hardwares (Data Acquisition Kit, Computers) are used for data acquisition and processing stage, due to these dependencies the time consumed in performing fault diagnosis is higher. This necessitated development of an interface to perform all the above tasks on a single platform (device). An interface using Android has been developed to provide a simple and easily accessible platform for operators to perform fault diagnosis of air compressors, as all the components (hardware and software) needed in performing fault diagnosis like sensor (Smartphone's microphone) and processor are present in a single body it helps in reducing the time required to perform fault diagnosis as the acquisition and processing can be done instantly.

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Title : *Analysis and design of a modified two-switch buck-boost converter*
Author(s) : *J Sanyasi Naidu*
Roll No : *10104082*
Supervisor(s) : *Mishra Santanu Kumar*

Abstract

A regulated DC power supply plays an important role in realizing many electronic products like personal computers, microwave ovens, laser printers, medical instruments, stereos, televisions, electronic lighting, electronic pedals, etc. The recent advances in the field of power electronic devices and ICs have led to the realization of more cost efficient converters which has revolutionized the industry as a whole. The new devices have a favorable switching characteristic which leads to efficient and high power density converter design. Therefore, the modern converters have low loss and better regulation which helps in meeting the requirements of a well regulated DC power supply. A good regulated power supply should be able to produce a constant output voltage against variations in the load and input without losing stability. A closed loop control is used to generate a well regulated output which doesn't vary with input voltage and load variation. The thesis discusses the analysis of a modified two-switch buck-boost converter for regulated DC power supply applications. The effect of the coupled inductor leakage is also taken into account in the steady state analysis of the converter. This thesis also discusses the small signal analysis of the converter and design of a closed loop control system to regulate the converter output voltage against the variations in input voltage and the load. The power converter architecture is analyzed, designed, and validated using simulation in this thesis. An experimental prototype is also developed to validate the theoretical analysis. The experimental results show a good correlation between the theory and experiments.

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Title : *A Smart Gate-Driver For Light-Load Efficiency Improvement Of A POL Converter*
Author(s) : *Mishra Ankur*
Roll No : *10104015*
Supervisor(s) : *Mishra Santanu Kumar*

Abstract

The continually advancing fields of VLSI, Signal Processing, and Data Communication pose new challenges for the power-supply requirements of these systems. The new semiconductor integrated circuits (ICs) are continually demanding a lower supply voltage to power themselves, since it leads to a natural increase in the clock speed and integration density of the IC as well as dramatic reduction in the power consumption per clock cycle. Point-of-load (POL) converters are used to power these ICs. POL converters are designed based on the sophisticated requirements of very strictly regulated output voltage with ultra small voltage ripple, tight regulation, and faster load dynamic response. These converter need to have superior efficiency over the complete spectrum of load current. Most of the current research efforts have focused on improving the full load efficiency. This thesis proposes the design of a smart gate driver to improve the light load efficiency of the POL converter. The thesis work starts with design of a digital control based POL converter prototype to measure its efficiency. The converter loss are subsequently characterized to understand various factors that influence the light load efficiency. The factors that influence the light load efficiency the most are lower FET gate charge, switching frequency, and lower FET gate drive voltage. A Smart-gate-driver architecture is proposed that takes the load current as a input and based on this information, doctors the above converter parameters automatically. As a result the converter light load efficiency improves. The gate-drive architecture is IC implementable. The proposed controller is verified using a 10 V/10 A scaled down lab prototype. The proposed gate driver, changes the switching frequency from 200 kHz to 100 kHz from full to light load. It modifies the gate drive voltage from 10 V to 6 V from full to light load. It is observed that using the controller the light load efficiency can be improved by 3 % without affecting the full-load efficiency

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Title : *Design and Control Of High-Gain Isolated Resonant Boost Converter For PV Microinverter Application*
Author(s) : *Chakraborty Shiladri*
Roll No : *10104088*
Supervisor(s) : *Sensarma Partha Sarathi*

Abstract

Climate change concerns coupled with increasing fuel prices have led to the steady proliferation of renewable energy sources (RES) for electrical power generation in recent years. Solar energy is one such vastly popular RES which is converted to useable electrical energy by means of photovoltaic (PV) modules. An important consideration while dealing with PV modules is that of Maximum Power Point Tracking (MPPT). The extractable power from a PV module is a function of solar insolation, ambient temperature and the terminal load characteristics. Thus at a given solar insolation and ambient temperature, the terminal load characteristics can be varied optimally to extract the maximum available power. Again, as the output of a PV module is dc, an intermediate inverter stage (converting dc to ac) is necessary to feed ac loads. This can be done using either series - parallel combination of modules along with centralised/string inverters or using separate inverters (called microinverters) for each module. Compared to microinverters, centralized/string inverters have drawbacks of high-voltage dc cables between the modules and the inverter, losses in the string diodes and lower harvested energy as simultaneous MPP tracking of all modules cannot be achieved. Microinverters, however, demand high step up gains for grid integration as typical MPP voltages of individual modules are low. Another generic requirement of PV inverters is of galvanic isolation in the powertrain to limit circulating ground currents resulting from system or equipment grounding (statutory installation recommendations). The present work proposes a high-gain resonant-load dc/dc converter with inherent galvanic isolation as the input dc-dc stage of a PV microinverter. Possible three-element resonant tank topologies are deduced in a systematic way and one of them is found to be particularly advantageous. Operation close to the resonant frequency ensures high-gain and also ZVS operation, thereby mitigating the switching losses. Detailed design equations are derived in order to select suitable values of the resonating elements so that the required gain can be obtained at a desired switching frequency. MPP control is achieved by phase modulation of the VSI. A hysteresis controller ensures tight regulation of the dc bus voltage emulating the input side of the inverter stage. An additional loop is incorporated for excitation frequency control to ensure peak-gain operation under variation in tank parameters. As the state-space averaging technique is not valid for modelling of resonant converters, the extended describing function method has been used to develop the plant model. Simulation of the proposed system is done in MATLAB/Simulink. A laboratory prototype is built and tested. Experimental results obtained are in conformity with the simulation results and hence the effectiveness of the scheme is validated.

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Title : *Grid-Integration of a Three Phase PWM Current Source Inverter Based Solar Photovoltaic System*
Author(s) : *Kavimandan Anup*
Roll No : *10104016*
Supervisor(s) : *Das Shyama Prasad*

Abstract

Renewable or sustainable energy (SE) sources have attracted the attention of many countries because the power generated is environment friendly. Solar Photovoltaic (PV) technology has emerged as one of the most promising sources of power extensively used in standalone systems in remote villages as well as in grid-connected systems. The present thesis explores the design and development of a grid-connected 3-phase single-stage Pulsewidth Modulated Current Source Inverter (PWM-CSI) based solar Photovoltaic (PV) system. Grid-Integration requires inverters to meet tight technical standards. The chosen topology, a Current-Source Inverter (CSI), features a single-stage power conversion system used as an interface between photovoltaic array and the utility line. The principle of operation and control of this topology is described. These controls involve method for utilizing the maximum power from solar panels using MPPT technique like Perturb and Observe, method for synchronizing with the grid using an improved 3-phase Phase Locked Loop (PLL) which provides accurate phase, amplitude and frequency information of the utility voltages and method for inherent current control. The complete system was modeled and simulated using the software Matlab-Simulink. For experimental realization of the grid connected system, hardware components such as current and voltage sensor cards and protection card are designed and fabricated. DC-Link Inductor of 30mH rated for 24 A(rms) is designed to realize a current source at the CSI input. A switching frequency of 9 kHz is used so that output waveforms have low distortion. A second order Low Pass Filter (LPF) of 'CL type' is used at the output of the CSI for filtering the ac currents fed to the grid. Passive damping is used to safeguard against resonance at the inverter output. Experimental tests were carried out to evaluate the performance of the 3-phase grid-connected CSI. The control platform and the real time code for the hardware are built around the dSPACE system which is a real time digital signal processor running on configurable DS1104 Controller Board. The control signals are obtained through the I/O ports of the dSPACE board. These signals are processed by the modulation circuit and overlapping circuit which generates the gating signals as per the CSI gating pattern. Finally three phase sinusoidal currents are injected into the grid at unity power factor (UPF).

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Title : *DSP Based Parallel Operation of Inverters with Voltage and Instantaneous Current Sharing Controls Using Capacitor and Line Current Estimation*
Author(s) : *Bagchi Anindya Chitta*
Roll No : *10104011*
Supervisor(s) : *Sensarma Partha Sarathi*

Abstract

Increased power demand of present age and environmental concerns over conventional power production processes have stimulated extensive research in the area of Renewable Energy Sources(RES) for power generation. The main problems associated with RES are that, they are intermittent in nature and power produced from them is not suitable for directly feeding to utility grid. Hence storage of electrical energy from RES and further processing to obtain grid-frequency AC voltage are necessary. Voltage Controlled Voltage Source Inverters(VCVSIs) provide a perfect solution to this problem, using which it is possible to produce grid frequency AC voltage. To improve redundancy and reliability of the system, multiple inverters are used in parallel for high power levels. But, this requires accurate control schemes to nullify circulating current which is conspicuous of such topology. The solution is to control current shared by the parallel inverters, and the best option in this regard is instantaneous current sharing control. This method needs information of current through all inverters, and hence fast communication between the control center and inverters is required. As system size increases, total number of sensed variables and hence communication dependence of system operation increases. So cost of operation with the existing methods of instantaneous current sharing is quite high. The present work focuses on remedies of these problems. The filter capacitor currents and inverter line currents of each inverter are estimated instead of directly measuring them. This reduces sensor requirement, and hence reduces system volume and corresponding communication requirement. For cost-effective control implementation, Digital Signal Processor(DSP) is used. DSP is a low-cost, high-speed processor. With smart programming, very critical control algorithms can be implemented in DSP, and can be used as a standalone controller with the help of its flash memory. So, in the present work, the developed algorithms are implemented in DSP. The estimation algorithms are conceptually developed, and the voltage and current sharing controllers are designed as per the system requirements. A three-inverter system is simulated with these algorithms to test their effectiveness. Having obtained successful simulation results, experiments are performed with a two-inverter system up to 110V peak phase voltage, keeping DC bus charged at 300V. Current sharing has been achieved for up to 5A per inverter per phase with diode rectifier load. All the estimation and control algorithms are implemented in TMS320F2812 fixed point DSP, which is a very low-cost digital processor. The experimental results are found to be in conformity with the simulation results and hence the developed methods are validated

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Title : *DSP Controlled Single Phase Back To Back Converter For Online UPS Application*
Author(s) : *Gohil Khyatibahen Harilal*
Roll No : *10104040*
Supervisor(s) : *Sensarma Partha Sarathi*

Abstract

Power outage has become a critical issue due to day by day increase in electricity demand. But constant power supply is required for many industrial as well as household appliances. A solution to this problem is Online Uninterruptible Power Supply(UPS) which supplies power to the load irrespective of the availability of the utility supply. An Online UPS maintains a continuous supply of electric power to connected load by supplying power from a separate source (battery) without any time delay for switching between mains on mode and battery powered mode of operation when power failure occurs. A purely sinusoidal output voltage is obtained at the output even in the presence of distortions in the utility power supply by using Online UPS. Hence Online UPS is a very important device for reliable operation of various equipments. An Online UPS consists of a rectifier/charger, a battery set, an inverter, and a static bypass switch. In this work, single phase back to back converter with front end active rectifier and back end inverter is developed which is required for the normal mode of operation of Online UPS. Controllers for the active rectifier are designed to obtain unity power factor operation at the input side and a desired DC voltage in the DC link. Output voltage controller is designed for the inverter to obtain a sinusoidal output voltage of peak value equal to the peak value of utility supply voltage. Digital signal processor(DSP) is used to implement all control algorithms because of its advantages in cost, size, speed and reliability over analog controllers and other digital platforms. The converters and controllers are first simulated inMATLAB/Simulink. After getting satisfactory results in simulation, those are experimentally verified. Experimental results are found to be perfectly matching with simulation results, which proves the effectiveness of the design of the converters and the control algorithms

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Title : *Optimal Resource Allocation in 4G Wireless Systems for Multimedia Transmission*
Author(s) : *Parakh Shreyans*
Roll No : *Y9104072*
Supervisor(s) : *Jagannatham Aditya K*

Abstract

The development of 3G and 4G technologies has led to the tremendous increase in the demand for high quality multimedia applications. The technologies such as LTE, WiMAX, HSDPA, etc. provide high bandwidth and data rate to its subscribers. The perceptual quality of the multimedia transmission can be maximized by optimally allocating the bitrate to the subscribers. We employ convex optimization techniques to maximize the sum quality of image transmission by formulating the quality as objective function of its file size. Scalable Video Coding (SVC) provides additional versatility in transmission of bit streams by allowing the users to adapt the bitrate depending on the available bandwidth. We present a novel scheme for optimal OFDMA subcarrier allocation towards video quality maximization employing the paradigm of H.264 based scalable video coding. We deduce the rate and quality model parameters for video characterization of the SVC extension of the H.264/AVC and propose an optimization framework for sum quality maximization of the transmitted video streams in unicast and multicast 4G scenarios, taking into account the different modulation and coding rates of the multicast groups in the 4G wireless system. We also propose an application of the Vickrey-Clarke-Groves (VCG) auction based time-frequency resource allocation for H.264 SVC. The bit-rate and quality variation of a scalable video stream as a function of the quantization parameter depends on video characteristic parameters, which are unique to every video sequence. A centralized bitrate allocation is, however susceptible to subversion resulting from misrepresentation of the characteristic video parameters by malicious users. This, in addition to resulting in a degradation of the net video quality, might also benefit the users reporting incorrect parameter values through disproportionate resource allocation. To maximize the video quality, while punishing such malicious users, we propose a VCG procedure for 4G OFDMA resource allocation which computes the price of the allocated time-frequency resources, thereby aiding the operational support systems (OSS) in the core network. We also propose a utility function which prices the users depending on the bitrate allocation and demonstrate the existence of Nash equilibrium. We employ the quasiconcave nature of defined net utility and Nash equilibrium for bitrate allocation to the videos. Existence of Nash equilibrium ensures that the player has no incentive to deviate from a given strategy

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Title : *Performance Analysis of Linear Combinations of NYQUIST Pulses in the Presence of Timing Errors*
Author(s) : *Mohan Chander*
Roll No : *Y5827153*
Supervisor(s) : *Chaturvedi Ajit Kumar*

Abstract

We study the performance of various ISI free pulses and their linear combinations in the presence of timing errors. Using a linear combination of two Nyquist pulses so as to minimize the expected error probability, an optimum combination is obtained for a given distribution of timing error. We determine the optimum pulse for various combinations of Nyquist pulses like Raised-Cosine pulse and other recently proposed pulses (Better than Raised Cosine, Flipped Hyperbolic Secant, Flipped Inverse Hyperbolic Secant) in both Inter Symbol Interference (ISI) as well as Co-Channel Interference (CCI) scenarios. We compare the performance of the combinations of various possible pairs in the presence of fixed as well as randomly distributed timing errors and obtain the best combination pulse.

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Title : ***Product Development Of A Customizable Vision Based Keyboard Touchpad Entry System***

Author(s) : ***Deshpande Shirin***

Roll No : ***Y7027418***

Supervisor(s) : ***Venkatesh K S***

Abstract

The role of computerized machines in society is soaring high. Hence, the need for faster and more convenient Human Computer Interaction (HCI) systems has become essential. This is a multidisciplinary thesis which aims to use vision technology taking care of the requirements of the customer and incorporates the results for development of an affordable and easy-to-use product. The method we intend to develop here would be useful as a ‘customizable entry system.’ This dissertation delivers an algorithm for developing a product using techniques of stereo vision, statistical foreground detection and optical velocity flow. Here, this is followed by studying the customer requirements and linking them to the technical requirements. We need to perform 3D coordinate estimation and foreground and skin extraction for the scene as the goal of this method. In order to estimate three dimensional coordinates, we use the stereo camera system, as there are possibilities to develop a robust and affordable system using this method. For finding the tip of the intrusion for touch detection, we perform background and skin detection. For extracting foreground, we have utilized the statistical techniques of pixel classification into various categories. Touch detection is carried out using two methods, in order to furnish flexibility to the user. The results are found for various light conditions and background training processes. Suitable surveys and interviews have been carried out in the sample spaces of customers. The desirable and undesirable features of the product were linked to the technical constraints using the Quality Function Deployment

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Title : *Peer-to-Peer Software Design with a Distributed Redundant File System For Brihaspati-4: A Learning Management System*
Author(s) : *Agrawal Shruti*
Roll No : *Y7027424*
Supervisor(s) : *Singh Yatindra Nath*

Abstract

In communication networks, peer-to-peer systems have proved to be more robust and faster than centralized server-based systems. This is attributed to the distribution of tasks among several machines and their ability to assimilate information from multiple locations in a distributed system. Also, in a network of users within a community, peer to peer communication systems provide flexibility in terms of sharing information amongst the users. Learning Management System (LMS) is one such network which can be set up in an academic institution for distributing electronic content through the internet. It also includes the administrative tasks like authentication of members and the information shared by them. In this project, a peer-to-peer learning management system called Brihaspati-4 has been designed and developed. Based on JXTA, the system is compatible with all platforms and programming languages. The users would be able to run secure online courses and form groups of peers to run services amongst themselves. The issue of security involving the authentication of users and declaration of rights and permissions has been resolved using certificates in Brihaspati-4. An important function of an LMS is to share and locate the resources distributed among the peers. In Brihaspati-4, the mechanism of advertisements in JXTA for sharing and searching the resources has been exploited to visualize the entire file pool as a binary tree, as in the Unix file system. Thus, the software architecture is inspired from a society of human beings dependent on each other to procure pieces of information and feedback to form a more complete information. The software has been designed to segregate the modules of applications from the underlying protocols facilitating further extension of the software

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Title : *DSAT-MAC : Dynamic Slot Allocation TDMA MAC protocol for Cognitive Radio Networks*
Author(s) : *Agarwal Satyam*
Roll No : *10104083*
Supervisor(s) : *Singh Yatindra Nath; Roy Amitabha*

Abstract

Cognitive Radio Networks have enabled us to efficiently reuse the underutilized radio spectrum. The MAC protocol defines the use of spectrum at a given time by a particular user. In this thesis we propose a novel TDMA based MAC protocol with dynamically allocated slots. Most of the MAC protocols proposed in the literature employ Common Control Channel (CCC) to manage the resources among Cognitive Radio (CR) users. The CCC has many drawbacks such as channel saturation in case of large number of CR users and the problems in availability of a dedicated channel. The DSAT-MAC protocol is based on the TDMA mechanism, without using any CCC for control information exchange. The channels are divided into time slots and the CR users send their control or data packets over their designated slot. The protocol includes the provision for Quality of Service, where real-time data is transmitted with higher priority and least delay. The protocol also ensures a fair sharing of available spectrum among the CR users, with the mechanism to regulate the transmission of malicious nodes and energy efficient techniques for longer life of battery operated CR nodes. Theoretical analysis and simulation over ns-2 of the protocol reveals that the protocol can perform better in various CR adhoc network applications

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Title : *Ranging Accuracy Comparison Of FMCW Based Ranging Technique With Toa And RSS Based Ranging Techniques In Indoor Wireless Channels*
Author(s) : *Bhat Rajshekhar V*
Roll No : *10104075*
Supervisor(s) : *Singh Yatindra Nath*

Abstract

Location awareness(Localization) of sensor nodes in wireless sensor networks boosts up their spectrum of applications. Ranging is an integral and primary part of localisation in wireless sensor networks. A fair comparison of widespread ranging techniques based on, received signal strength(RSS) and time of arrival(TOA), with emerging technique based on frequency modulated continuous wave(FMCW), can be a guide to deploy suitable ranging technique in a given area. In this thesis, we compare the accuracy of RSS, TOA and FMCW based ranging techniques, using mathematical derivations and MATLAB simulations, for indoor wireless channels. The comparison for carried out in both single path and multi path channels. Cramer Rao Lower Bounds(CRLB) and Ziv Zakai Lower bounds(ZZLB) are used for comparison. We derive expression for CRLB for FMCW technique in multi path channel model. We also derive, effect of increase of number of nodes on ranging accuracy (scaling law) for RSS, TOA and FMCW based techniques for ranging in indoor channels. We found that FMCW based ranging technique provides better ranging accuracy than RSS and TOA based ranging techniques in single path channel model. FMCW based ranging technique is found to offer better ranging accuracy with lesser bandwidth than TOA based technique in single path channel. From the comparison based on ZZLB, we conclude that ranging accuracy of FMCW technique increases with higher rate compared to TOA technique when SNR increases. In multi path channels, TOA technique offers better ranging accuracy than FMCW technique. Based on our investigation of scaling law, we conclude that more the number of nodes participating in ranging, better is the range accuracy

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Title : *Energy Efficient Routing Algorithm for Wireless Sensor Network*
Author(s) : *Rastogi Vikram*
Roll No : *Y7027501*
Supervisor(s) : *Singh Yatindra Nath*

Abstract

With the recent growth in MEMS (Micro-Electro-Mechanical System) technology and increase in computing power of the devices, the wireless sensor networks have become more usable affordable and hence popular. The sensor nodes are mostly battery operated, and hence to maximize network lifetime energy saving of sensor nodes is a major issue we need to take into consideration while designing protocols. In the thesis, clustering based routing protocols have been discussed. Clustering Based Routing algorithms are more scalable and energy efficient than regular communication algorithms used in MANETs and wired networks. In this thesis we discuss a new algorithm called Flat-LEACH for routing data from sensor nodes to the sink in energy constrained wireless sensor network. The algorithm provides for some centralized control over a distributed network by merging the localization and hierarchical approaches. This results in formation of uniform clusters which improves the energy efficiency of the network. There is a bounded delay in transmission of packets from source to sink nodes as the packets move from outer coronas to the inner coronas.

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Title : *A grounded cognitive model for anaphors and metaphors*
Author(s) : *Nayak Sushobhan*
Roll No : *Y7027460*
Supervisor(s) : *Venkatesh K S; Mukerjee Amitabha*

Abstract

A computational approach is presented that traces the developmental process, from containment image schemas and action structures to metaphors, in four phases: a) perceptual discovery of image schemas, b) associating perceptual arguments and the relation with linguistic units, c) discovering a linguistic structure encoding the schema, and based on that, interpreting polysemous object occurrence, leading to anaphora detection and finally d) enriching the semantics of the schema via extended language usage (via a corpus). In the first three phases, no prior knowledge is used about either the perceptual or language domains; in the corpus analysis, the WordNet ontology is used. The input is an animation based on the Heider-Simmel video, together with a small corpus of transcribed commentaries. From the image sequence, the visual angles subtended by a landmark are calculated, and it's found that one cluster reflects containment. Action schemas are found through clustering of velocity and position features. These are then correlated with the sentences from the adult commentaries uttered contemporaneously with containment and action situations, yielding strong object-nouns and relation-preposition associations. For discovering linguistic constructs, no knowledge of grammatical category or syntax is used, but recurring patterns are found using the approach of [Solan et al.2002]. Knowing the units involved, several phrasal patterns (e.g. "X moved into", "in the Y", "A is chasing B" etc.) can be identified. These structures are further used to discover synonymous linguistic elements that refer to the same perceptual objects. Polysemous words are learned as anaphoras. Then a corpus is searched with the "in the Y" schema to identify container words and discover containment metaphors.

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Title : *Joint Error Optimization Algorithms for Multimodal Information Fusion*
Author(s) : *Chaudhary Kuldeep*
Roll No : *Y7027202*
Supervisor(s) : *Hegde Rajesh Mahanand*

Abstract

Fusion of information available in multiple modalities is challenging in the context of contemporary research on multi modal signal processing. The broad categories of feature level and model level information fusion have led to the development of user friendly and socially relevant applications like agriculture, health care and intelligent transportation. In this thesis the complementary information present in the audio and visual modalities is fused using a novel approach that jointly optimizes the error due to each modality. Algorithms that fuse information in the audio-visual modalities at the feature level are RST proposed using this joint error optimization approach. The proposed algorithms optimize a joint error function using the Bhattacharyya and Euclidean distances. The error function is itself formulated and based on a linear transformation of the means of the audio and visual modalities. A similar approach is used to propose algorithms for model level fusion based on a linear regression method. The algorithms are then evaluated by conducting experiments on audiovisual speech recognition on the GRID multi modal corpus. Experimental results on the GRID corpus indicate a reasonable improvement in word error rates (WER) over conventional fusion methods from literature. The significance of the proposed algorithms in intelligent transportation is also illustrated in this thesis. An In-Car multi modal database specially designed with commands used in driving is developed. Experiments on recognizing these multi modal commands indicate a reasonable accuracy t enough for deployment in intelligent transportation applications

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Title : *Application Layer Considerations for Multipath Transmission Control Protocol*
Author(s) : *Lahngir Lavkesh*
Roll No : *Y7027209*
Supervisor(s) : *Singh Yatindra Nath; Roy Amitabha*

Abstract

Transmission control protocol(TCP) is the most used protocol in the transport layer for modern internet traffic. The TCP connection is represented as a 4 tuple (local-addr, localprocess, foreign-addr, foreign-process). According to these 5 tuples, one tcp connection uses one local network interface card(NIC) and one foreign NIC for communication. If the host has multiple NICs like Ethernet and wireless (for example multihomed systems) which could be somehow utilized by the transport layer, then it could make data transmission faster than using just one path. IETF (Internet Engineering Task force) is developing a new transport layer solution, which allows an end point to efficiently use several paths for communication between one pair of host while the application sees it as only one connection. From the application point of view, it has only one socket to write and read the data, but with this modified transport layer there could be multiple paths, distributing the data in between themselves. Above design modifies the transport layer, so any application which uses TCP must be able to work correctly with MPTCP. The application which are not aware of MPTCP, they are called legacy applications or non MPTCP aware applications and MPTCP must be backward compatible with these legacy applications. Traditional socket API gives the control to application over the transport layer. However if an application is aware of MPTCP and its impact on performance, making MPTCPAPI for the MPTCP-aware applications can help tuning the performance of the application. And this API must be backward compatible with the legacy application. This thesis first discusses the importance of MPTCP and its impact on the applications. Further It discusses the need for an API and basic design. It also discusses the possibility of the advanced API. Finally It discusses the implementation of the basic API into linux kernel.

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Title : *Instrument Sound Separation in Monaural Music Signals*
Author(s) : *Mehta Bhuwan*
Roll No : *Y5827144*
Supervisor(s) : *Sircar Pradip; Verma Nishchal Kumar*

Abstract

Estimation of original instrument sounds from complex music signals is a challenging task and has received a lot of attention lately. Due to the nature of music signals and playing styles, there is a significant amount of overlap in both time and frequency, thus making source separation in music signals a difficult task to achieve. This thesis deals with the problem of separation of individual instrument sounds from monaural or single channel music signals. Our proposed approach to solve the problem is a two stage procedure; where the music signal is first factorized into elementary time-frequency components, which are then grouped into instruments. We use Nonnegative Matrix Factorization (NMF) to decompose the music signal spectrogram into components with fixed basis spectral structures and time varying gains. However, the problem with the NMF based factorization of music signals is grouping the separated components into instrument sounds. In this thesis, we have proposed component grouping methods based on source filter model of instrument sounds. Mel Frequency Cepstral Coefficients (MFCCs) can capture significant information about the spectral envelope of instrument notes, and so are used as features in our component grouping phase. In our thesis, we propose to group the components in unsupervised domain by simple k-means clustering of component features in feature space and in supervised domain by using pre-trained Support Vector Machine (SVM) based classifiers to classify the components. We conducted simulation experiments on large number of generated test signals to evaluate and compare the performance of our approaches. Besides this, in the thesis, we have also conducted an experimental study on performance of a parametric cost function α -divergence and compared it with two popular cost measures used for NMF. We also built automatic instrument recognition framework using MFCC as features and results were presented for the same.

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Title : *Auction Based Optimal Subcarrier And Power Allocation For H.264 Scalable Video Transmission In 4g OFDMA Systems*
Author(s) : *Sekhar Garlapati Chandra*
Roll No : *10104037*
Supervisor(s) : *Jagannatham Aditya K*

Abstract

Now a days, wireless communication plays a vital role as the increase of usage of mobile and internet access. Most popular Fourth Generation (4G) wireless communication techniques such as LTE and WiMAX employ OFDMA as PHY layer scheme enables the transmission of high data-rate for rich multimedia applications such as video conferencing, multimedia streaming, mobile TV and real-time surveillance. As the applications involving video transmission requires secure transmission of video streams, the H.264 Scalable Video Coding (SVC) standard enables layered compression, flexible extraction, transmission and decoding of partial bit streams to provide video services with varied temporal, spatial or fidelity resolutions to heterogeneous wireless end users. Auction based resource optimization has the better utilization of resources by the subscribers and produces more revenues to the providers. Convex optimization is a powerful optimization technique used to solve complex optimization problems with reduced computation risk. We present a revenue maximization scheme for optimal OFDMA subcarrier allocation for wireless video unicast/multicast scenarios. We formulate a pricing based video utility function for H.264 based wireless scalable video streaming, thereby achieving a trade-off between price and QoS fairness. These parametric models for scalable video rate and quality characterization are derived from the standard JSVM reference codec for the SVC extension of the H.264/AVC, and hence are directly applicable in practical wireless scenarios. With the aid of these models, we propose a novel auction based framework for revenue maximization of the transmitted video streams in the unicast and multicast 4G scenario. A closed form expression is derived for the optimal scalable video quantization step-size subject to the constraints of the unicast/multicast users in the 4G wireless systems. This yields the optimal OFDMA subcarrier allocation for multi-user scalable video multiplexing. The proposed scheme is cognizant of the user modulation and code rate, and is hence amenable to adaptive modulation and coding(AMC) feature of 4G wireless networks. Further, from the same parametric models for scalable video rate and quality we also present a quality maximization for optimal power allocation and the optimization problem is extended to the auction based scenario. We simulate a standard WiMAX based 4G video transmission scenario to validate the performance of the proposed optimal 4G scalable video resource allocation schemes.

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Title : *Optimal H.264 Scalable Video Scheduling Policies for 3G/4G Wireless Cellular Networks*
Author(s) : *Reddyvari Raja Vamseedhar Reddy*
Roll No : *10104101*
Supervisor(s) : *Jagannatham Aditya K*

Abstract

In this thesis we consider the problem of optimal H.264 scalable video scheduling, with an objective of maximizing the end user video quality while ensuring fairness in 3G/4G broadband wireless networks. We propose a framework to characterize the video quality based utility of the H.264 temporal and quality scalable video layers. Subsequently we formulate the scalable video scheduling framework as a Markov decision process (MDP) for long term average video utility maximization and derive the optimal index based scalable video scheduling policies ISVP and ISVPF towards video quality maximization. Further, we extend this framework to multi-user and multi-sub-channel scenario of 4G wireless networks. In this context we propose two novel schemes for long term streaming video quality performance optimization based on maximum weight bipartite and greedy matching paradigms. Simulation results demonstrate that the proposed algorithms achieve superior end user video experience compared to competing scheduling policies such as Proportional Fairness (PF) and Linear Index Policy (LIP).

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Title : *Robust Image Reconstruction Methods For Wireless Sensor Networks*
Author(s) : *Kudupudi Ram Manohar*
Roll No : *10104051*
Supervisor(s) : *Jagannatham Aditya K*

Abstract

This thesis is organized as two parts. One is Robust blurred Image Restoration and Second part is Robust Total Variation and Sphere Decoding based Image Reconstruction for Wireless Sensor Networks. Here we proposed novel approaches for robust blur removal and image reconstruction considering uncertainty in the blur kernel. The stochastic minimization approach models the kernel uncertainty as a stochastic spatial random process, while the worst case reconstruction is a robust minimax scheme which minimizes the maximum image distortion over a set of uncertainty blur kernels. The worst case minimization is demonstrated to be capable of image recovery employing knowledge of the nominal blur kernel matrix and uncertainty strength. Further, we also propose a semi-definite programming (SDP) based scheme for image recovery employing a linear matrix uncertainty model. Another key strength of the proposed schemes is that they can readily incorporate an L1 norm based total variational cost, thereby resulting in significantly superior performance of image reconstruction. Simulation results show that our approach is able to recover the images with superior visual clarity and lower mean squared-error compared to conventional nominal kernel based non-robust image recovery approaches. In second part of thesis we propose a novel scheme for low-complexity robust recovery in the context of image transmission over Rayleigh fading wireless sensor links. The proposed scheme employs an optimal maximum-likelihood (ML) scheme for transmit vector detection in conjunction with a total variation regularization factor towards sparsity of the image gradient vector. It is demonstrated that while the optimal decoder for image recovery has an exponential complexity, a relaxed sphere-decoder based vector symbol detection for robust image recovery yields near optimal results. Simulation results show that our method has a superior performance compared to the conventional maximum-likelihood based symbol detection scheme for image recovery in terms of mean squarederror and visual quality of the reconstructed image at the cluster head

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Title : *Optimal Power Allocation Schemes For Scalable Video Transmission in OFDM-Based Cognitive Radio System*
Author(s) : *Kumar Akash*
Roll No : *10104006*
Supervisor(s) : *Jagannatham Aditya K*

Abstract

Recent times have witnessed an unprecedented growth in the number of personnel wireless devices, which has led to an increasing demand and the resulting scarcity of the wireless radio spectrum. On a paradoxical note, measurements have demonstrated that a significant portion of the total wireless spectrum is vacant at any given instant of time as has been reported by the spectrum policy task force appointed by the Federal Communications Commissions (FCC). Thus, the spectrum scarcity in current radio communication scenarios is arising out of inefficient static frequency management policies. This has led researchers to propose and develop novel technology of Cognitive radio (CR) for dynamic allocation and management of the available radio spectrum. In our research we propose algorithms for power allocation towards Scalable Video transmission over an Orthogonal Frequency Division Multiplexing (OFDM) based Cognitive Radio (CR) system. In this context, we develop optimal power allocation algorithm to minimize the overall video distortion while restricting the secondary user interference. We demonstrate that the optimal power allocation policy can be achieved as a solution of an constrained convex optimization problem. We derive a closed expression for optimal power allocation using the Lagrange formulation. We also propose several low complexity schemes for near optimal video transmission and compare their performances with the proposed optimal scheme. We employ the two level Daubechies wavelet D2 to encode the video as a layered scalable stream comprising of one Base layer and several enhancements layers. Next, we consider Embedded Zero Tree Wavelet (EZW) video coding to obtain an embedded bit stream leading to a much finer scalable video stream. We segregate the obtained embedded bit stream into several groups forming different video layers. We further develop a complete robust video transmission system employing maximum Distance Separable (MDS) convolutional codes and corresponding Viterbi decoders. We carry out the transmission of several test video sequences over our wireless system and the performance of the proposed optimal schemes are compared with the other suboptimal schemes in terms of the Peak Signal to Noise Ratio (PSNR) of the received video stream. Presented numerical results demonstrate that the proposed optimal scheme results in a significantly enhanced PSNR of video transmission compared to the competing scalable and non-scalable schemes. These performance enhancements are also visually illustrated through the frame quality comparison of the received video streams under different schemes

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Title : *IP Mobility Using Proxy Servers*
Author(s) : *Kumar Abhay*
Roll No : *Y7027007*
Supervisor(s) : *Sanghi Dheeraj; Singh Yatindra Nath*

Abstract

The recent years have witnessed an unprecedented increase in the number of mobile Internet users and in the quality of network accessibility. The omnipresence of multiple access points to the Internet has enhanced today's smartphones to achieve "always connectivity". Mobile networking allows network connectivity and computing activities to not get disrupted when the mobile device changes its point of attachment to the internet. The standard protocols like Mobile IP and its extensions achieve the desired goal at the expense of making changes in the network architecture. They require a home agent and a foreign agent in the network to carry out the handover. Such a solution presents challenges in scalability and deployment becomes difficult. Also, for heterogeneous handovers, in which more than one kind of access networks are involved, the problem aggravates further. We have devised a new kind of handover technique which doesn't require any major establishment changes in the network architecture. Our approach targets mobile devices like smartphones which have multiple network interfaces. The proposed method uses Web Proxy servers for carrying out the connection handover at the application level. We have devised a new protocol as an extension to the HTTP protocol which allows proxy servers to talk to each other. All these ideas have been implemented on a notebook computer and have been tested for handover in a multi-access environment.

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Title : *Rapid Prototyping of Advanced Signal Processing Applications*
Author(s) : *Agrawal Pranjal*
Roll No : *Y7027299*
Supervisor(s) : *Hegde Rajesh Mahanand*

Abstract

Emerging signal processing applications require a sustained effort on the part of the developer to realize and deploy an application. A rapid prototyping platform for advanced signal processing applications will reduce the effort, cost and time required to develop and deploy an application. In this thesis, a rapid prototyping platform is developed for realizing multi-modal signal processing applications that involve real time interfacing of multi-modal signals both at the input and the output. The platform enables a user to input a variety of signals like audio, video, proximity, and Infra-red, process them in real time on a real time operating system (RToS), and deliver the necessary multi-modal outputs as required by the application. The hardware platform developed in this thesis consists of a cRIO (Compact-Reconfigurable Input-Output) controller and a chassis. As per the needs of the application, various IO modules can be connected to the chassis. The cRIO makes use of FPGA (Field Programmable Gate Arrays) programming which employs parallel signal processing and greatly enhances the speed of the execution of the algorithms. The use of FPGA helps in minimizing the jitter and improving the accuracy of the entire system. The platform also allows the user to simulate various applications and produce the required product only after entire testing has been done. The rapid prototyping platform hence allows one to concentrate on the design of the application rather than the platform compatibility issues. Various potential applications of the platform, including applications of signal processing for wireless sensor networks are also discussed. A portable intelligent meeting capture system that can be rapidly deployed in smart meeting rooms is implemented on the platform and its advantages are elucidated. The setup consists of a microphone array which computes the two-dimensional direction of arrival (DOA). The azimuth and the elevation angles are computed using advanced signal processing algorithms like GCC-PHAT which are implemented on the RToS. The DOAs are communicated to a wireless networked camera which steers in real time towards the active speaker. Performance evaluation of the rapidly prototyped system is tested in real time meetings in terms of average error deviations in the DOA. The accuracy of the results indicates further miniaturization of the system and a possible deployment in future.

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Title : *Study and Implementation of SIP(Session Initiation Protocol)
Inter working with Brihaspati-Sync*
Author(s) : *Singh Manish*
Roll No : *10104056*
Supervisor(s) : *Singh Yatindra Nath*

Abstract

The open source Session Initiation Protocol (SIP) is a Voice Over Internet Protocol which is used for establishing sessions over internet and recently has become the choice in technology for voice communication over networks. Any application which use sessions (signalling) can use SIP. The focus of this work is to establish a session using SIP for transfer of different data like voice, video, whiteboard data, desktop sharing between an open source SIP client and Brihaspati-Sync. Brihaspati-Sync is a lecture delivery online system, built using JAVA, which is presently using proprietary signalling based on Hypertext Transfer Protocol (HTTP). It uses peer-to-peer networking for creating multicast lecture sessions. The lectures announced by a user or instructor can only be fetched from a Reflector which is a special module used at one or more servers to bootstrap the virtual overlaid topology. It periodically updates the Brihaspati-Sync indexing server about the load conditions, number of end clients connected, list of various lecture session it is serving. Reflector is a main entity, to whom instructor and student clients are connected. Reflector provides audio-video feed from instructor client to student clients. Specific aim of this work is a) to study SIP (Session Initiation Protocol) Inter working with Brihaspati-Sync and b) to develop the software based Signalling Gateway Interface and SIP Client for Implementation of SIP Inter working with Brihaspati-Sync. Signalling Gateway Interface on one side accepts the requests based on Session Initiation Protocol (SIP) from SIP client including the authentication credentials of Brihaspati-Sync and establishes a session based on SIP transactions with the SIP client. On the other side Signalling Gateway Interface sends a request based on Hypertext Transfer Protocol (HTTP) to Brihaspati-Sync Indexing server with those authentication credentials which it has received in SIP client request. Hereafter proper authentication is carried out with Indexing server, which establishes a session on behalf of the SIP client who has made a request for live lecture stream data. Signalling Gateway Interface fetches the list of active sessions (from Brihaspati-Sync Indexing server) authorised to the client whose credentials have been sent to Brihaspati-Sync Indexing server. The list of active sessions include the Reflector IP, session ID and user name. As mentioned above, the Reflector gets the live data feed from the client who has announced the session. The Signalling Gateway sends the list of active session to the SIP client. SIP client chooses the session from which it wants to get the data feed. It sends back the chosen session to signalling gateway, which in turns now connects to the Reflector(Reflector IP is mentioned in the chosen session) to get the desired data feed. Hence in this way the SIP client joins the active lecture stream. Presently the above interface is built only to receive the Whiteboard data feed.

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Title : *Aircraft approach parameters from airstrip visual data*
Author(s) : *Soni Palash*
Roll No : *Y7027272*
Supervisor(s) : *Gupta Sumana; Venkatesh K S*

Abstract

Accurate attitude detection for aircraft's has been a classical problem in airplane navigation. Attitude information, which refers to the planes altitude and orientation in space, assumes critical importance especially in case of automatic landing. The contemporary devices like barometer are highly inaccurate. In this dissertation, we propose a novel approach to automatic landing using the homography of the airstrip in images captured through an onboard camera. This approach involves signal processing of images to extract certain features of the runway and subsequent application of classical projective geometry to determine navigational parameters of airplane. It is assumed that the dimensions and other relevant details of the particular airstrip are known beforehand

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Title : *Single and multi channel speech enhancement using LP residual cepstrum*
Author(s) : *Padaki Harish*
Roll No : *10104043*
Supervisor(s) : *Hegde Rajesh Mahanand*

Abstract

Clean speech acquisition from distant microphones in speech communication system is often affected by the phenomenon of reverberation. Reverberation affects the quality of the perceived speech and reduces its intelligibility. This can degrade the performance of speech based applications. In this thesis single and multi channel speech enhancement methods which use the excitation source information in the speech signal are proposed. The Linear Prediction (LP) residual of the reverberated speech signal is deconvolved to obtain the LP residual cepstrum and used herein for speech enhancement. A relation between the LP coefficients and LP residual of clean and reverberated speech is first derived. It is observed that the LP coefficients are not affected by the reverberation. However the reverberation considerably effects the LP residual. By using the inherent properties of the LP, the reverberated LP residual is found to be convolution of clean LP residual and Acoustic Impulse Response (AIR). This motivates the use of cepstral subtraction in the proposed single channel technique to enhance the clean residual from the convolved mixture of clean residual and AIR. Subsequently the reverberation effects are manifested in the form of spurious peaks between the peaks of the LP residual. The spurious peaks can be suppressed using multi channel techniques using spatial and temporal averaging. The perceptual evaluation of the proposed methods is performed on the MONC database, by using both objective and subjective measures. The performance evaluation is also presented as word error rates by conducting experiments on distant speech recognition at various Direct to Reverberant Ratio(DRR) on the MONC database. The proposed methods perform reasonably better than other methods available in literature

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Title : *Probabilistic Detection Methods for Acoustic Surveillance Using Audio Histograms*
Author(s) : *Marri Shivashankar Reddy*
Roll No : *10104089*
Supervisor(s) : *Hegde Rajesh Mahanand*

Abstract

Detection of distressed speech is critical for acoustic surveillance in an assisted living environment. Production of distressed speech signals can be considered as audio events in such an environment. These audio events generally occur in situations that need human intervention in the assisted living environment and need to be detected automatically. Widely used audio event detection methods in the literature are Universal Gaussian Mixture Model (UGMM), Gaussian Clustering, and One-Class Support Vector Machine (OCSVM). These methods perform well when one uses concatenated feature vectors of high dimension. In this thesis probabilistic detection methods are proposed for audio event detection. The proposed methods use audio histograms to detect events in a well defined acoustic space. The proposed methods are type of novelty detection method, since audio data corresponding to the event is not used in the training process. These methods hence alleviate the problem of collecting large amount of audio data for training statistical models as is usually done in practice. These methods are also computationally efficient since a standard feature set like the MFCC in tandem with audio histograms are used to perform audio event detection. Experiments on audio event detection are conducted on the SUSAS database available from LDC. Two performance measures, False Detection Rate (FDR) and True Detection Rate (TDR) are computed and the Receiver Operating Characteristics (ROC) curves are obtained for the proposed probabilistic detection methods. The proposed methods perform significantly better than the audio event detection methods available in literature. A cell phone based alert system for an assisted living environment which is based on audio histogram method is also developed and tested. The system indicates a reasonable performance.

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Title : *A Novel Upstream Bandwidth Allocation In Ethernet Passive Optical Networks Using Bidding Process*
Author(s) : *Anil Kumar Ankireddy*
Roll No : *10104013*
Supervisor(s) : *Singh Yatindra Nath*

Abstract

Passive Optical Network (PON) is one of the most promising solution in access networks, that can support the increasing demand for high bandwidth. There are many different standards in the literature like ATM PON (APON), Gigabit PON (GPON), Ethernet PON (EPON) . Among the PON standards EPON is the most attractive solution because of its low cost, high speed, low overhead and familiarity. EPON uses dynamic bandwidth allocation scheme for efficient utilization of upstream bandwidth. But many of the centralized dynamic bandwidth schemes proposed in literature have higher average packet delays and are distance dependent. To overcome this drawback we have proposed a new distributed dynamic bandwidth allocation scheme. Our scheme decreases the average packet delay and average queue length while maintaining higher throughput. It also enables the quick registration process using the control wavelength. The proposed algorithm uses the separate control wavelength for bidding process. The winner will use upstream channel and informs others users about the duration for which he is using the upstream channel . The results of the proposed algorithm are compared with the existing standard IPACT algorithm. The comparisons indicate that our algorithm performs fairly better than the standard algorithm

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Title : *Innovations cost function based tuned and constant gain Kalman filter approaches to target tracking with wireless sensor networks*
Author(s) : *Yadav Maj Ashwin*
Roll No : *10104020*
Supervisor(s) : *Singh Yatindra Nath; Naik Naren*

Abstract

Wireless Sensor Networks is a fast emerging field with very diverse applications in the civilian and military domains such as environmental monitoring, industrial sensing and diagnostics, infrastructure protection, battlefield awareness etc to name a few. One of the most fundamental and widely used approaches to target tracking is the Kalman filter. It is well known that in presence of unknown noise statistics there are difficulties in the Kalman filter for yielding good results. Hence the issue of tuning of the noise covariances becomes important. It is observed that in several practical situations of the KF operation after an initial transient the gain settles down to a steady state value. Hence working directly with constant Kalman gains it is possible to obtain good tracking results dispensing with the use of the usual covariances. The thesis is aimed at studying the performance of tuned and constant gain Kalman filters in wireless sensor network target tracking scenarios. A peculiarity of the wireless sensor network scenario is the need to incorporate the twin issues of multisensor data fusion and computational complexity. The three types of filters studied are the reference, tuned and constant gain Kalman filters for both the linear and non linear state variable models in typical wireless sensor network settings. Our numerical studies show that the constant gain Kalman filter gives good comparative performance in both the stand-alone and data-fusion modes for the target tracking problem. This is especially significant since the constant gain Kalman filter circumvents or in other words trades the gains with the filter statistics which are more difficult to obtain. Also to the best of our knowledge, these are unique numerical studies in the context of wireless sensor networks.

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Title : *Peer-to-Peer Replication Management in JXTA for Brihaspati-4 : Learning Management System*
Author(s) : *Manda Avinash*
Roll No : *10104054*
Supervisor(s) : *Singh Yatindra Nath; Roy Amitabha*

Abstract

Over the last decade Peer-to-Peer (P2P) systems have become very popular in information and communication industry. The centralized client-server systems are being replaced by P2P systems in areas of file sharing because they are highly scalable and cost effective compared to the centralized systems. In this thesis, a distributed peer-to-peer Learning Management System (LMS) Brihaspati-4 has been designed to replace the existing centralized LMS system. LMS is used in educational institutions to conduct e-learning programs and to share the course content online. In Brihaspati-4 users can run course peer groups and share lecture notes online. The files are shared securely over the network using course key encryption, digital signatures and digital certificates. Files with write permission can be modified and new versions of same file can be created. Version control is proposed to manage different modified versions of same file and to replace older versions with newer versions. In P2P systems, peers which are responsible for data storage and processing can join and leave the network at any time. To maintain high data availability in the network in spite of dynamic behavior of the peers a replication management technique has been proposed. In this technique, data in the network is replicated and stored at different peers. The number of data replicas to be maintained is decided based on the data priority level. Number of replicas available in the network are monitored periodically and replication management is done accordingly. A P2P application development platform JXTA has been used to develop Brihaspati-4. JXTA consists of generalized P2P protocols which are compatible with all platforms and programming languages. Replication management technique has been proposed and implemented in JXTA to make Brihaspati-4 more robust

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Title : *Performance Evaluation of Node Disjoint Multipath Routing Protocol for Mobile Adhoc Networks*
Author(s) : *Gupta Rajendra Kumar*
Roll No : *10104072*
Supervisor(s) : *Singh Yatindra Nath*

Abstract

A mobile ad hoc network (MANET) represents a system of wireless mobile nodes that can communicate with each other without the need of communication infrastructure. This kind of wireless communication is made by sending packets from one to another node where nodes act as a router as well as host. Routing is very complex in such networks due to mobility of nodes and wireless channel characteristics of the medium. Since there is no fixed topology for MANETs, so routing protocols that can adopt according to network topology are needed for such networks. On-demand(reactive) routing protocols are generally used since they consume less routing load (in terms of signaling traffic) than proactive protocols. Conventional protocols for MANET are based on single path route discovery. Using a single path, it is difficult to respond to a large burst of traffic even though additional network resources may be available. In ad hoc networks, multiple paths are desirable since they provide fault- tolerance and can be used simultaneously for data transfer. Node-disjoint multipath routing protocol provides independent paths for data transfer thus assures less end-to-end packet delay and more packet delivery ratio than single path routing protocols. AODV (Ad Hoc On-demand Distance Vector) which is widely used for MANETs creates single-path between a pair of source and destination nodes. In this thesis, I have simulated a Node disjoint multi-path routing protocol based on AODV and evaluated the performance against AODV. This Protocol establishes the main route by the mechanism based on AODV, then second(backup) route search process takes place while data is being transmitted using first route thus it reduces the end to end delay between source and destination. This process finds the route that is node-disjoint from the main route by not selecting nodes participated in the main route. When either of the main route or the second(backup) route is broken, data is transmitted continuously through the other route. Simulation results shows that Node Disjoint Multipath Routing Protocol performs better than AODV in low network congestion and higher nodes mobility

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Title : *Design and Analysis of a novel protection scheme in Wavelength Division Multiplexing Passive Optical Networks*
Author(s) : *Reddy V.Sai Samartha*
Roll No : *10104098*
Supervisor(s) : *Singh Yatindra Nath; Roy Amitabha*

Abstract

In this thesis we propose a novel protection scheme for wavelength division multiplexing Passive optical network. The objective is to provide protection at a lower cost. We use cascaded array waveguide grating in remote node which can support large number of end users. This scheme provides protection to feeder fibre failure, distribution fibre failure and also array waveguide failure in remote node. Furthermore, in order to provide protection even to source failure at Optical line terminal we modify the structure of optical network unit and optical terminal unit. We perform cost analysis, reliability analysis and also calculate the restoration time and losses. Meanwhile, cost analysis and reliability analysis shows that our schemes can provide higher reliability with lower cost per optical network unit. We analyse BER for both the schemes with respect to transmitted power

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Title : *A New Color Video Compression Scheme Using Color Mapping Into Textured Gray Images*
Author(s) : *Kumar Sambuddha*
Roll No : *10104080*
Supervisor(s) : *Gupta Sumana*

Abstract

Color video compression has become a necessity in the advent of newer applications of color video and its increasing size for higher definitions. New approaches are used to achieve more compression over the traditional and standard compression techniques. Considerable progress has been made of color transfer based compression techniques that do not modify standard encoders but add some pre-processing and post-processing steps. We present a novel, simple yet robust, color transfer based compression technique that can be integrated with the standard encoders like MPEG-2, H.264/AVC etc. We achieve the compression by discarding the color components from all frames in a video sequence except those of the Intra (I) frames. The colored intra frames are converted to gray textured images. The method is developed based on embedding the colors of the intra frames to low visibility high frequency textures of its gray luminance image. This is achieved by decomposing the luminance of the intra frame using the non-decimated DWT or discrete wavelet frame transform (DWFT) and replacing the bandpass subbands by the chrominance signals. The lowpass band is same as that of the luminance signal. At the output of the decoder, the colored intra frames are recovered using the wavelet transform. Instead of calculating motion vectors, we identify and reuse the motion vectors present in the decoder. The remaining luminance frames of the video are colored with the help of identified motion vectors and the color information of the preceding frames. The proposed codec considerably improves the compression ratio achievable by the standard codec, at the cost of slight increase in computation time at the decoder end

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Title : *Uncalibrated Projector-Camera System for any Continuous Planar and Nonplanar Surface*
Author(s) : *Deotale Gunjan Prakash*
Roll No : *10104031*
Supervisor(s) : *Venkatesh K S; Gupta Sumana*

Abstract

Projector camera based system has now become the emerging field for using the applicability of projector for different uses beyond perpendicular projection. In this thesis, we have made an effort to contribute to this field by developing two different methods. First we started with Projection on Non- planar surface and recovering undistorted image. The basic idea of this method is to divide the surface into number of small planar surface applying homography correction and reconstruct the pre-warped image to obtain undistorted projection. The issue with this method is that, it was using all small parts of image for reconstruction of prewarped image, however, by clubbing smaller parts of image which have same homography this method considerably reduces the time required for computation. Next we started with multiple projector system instead of single projector primarily for getting high lumen output by superposing the projector output on the screen and later for increasing area of projection by placing projector side by side correcting it geometrically and photometrically to obtain undistorted wide area of projection.

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Title : *Image/Video Restoration Using Sparse Representation*
Author(s) : *Yenduri Naveen*
Roll No : *10104107*
Supervisor(s) : *Gupta Sumana*

Abstract

Sparse Representations have drawn considerable interest in the recent years. Among them overcompleteness and sparsity can be considered as a powerful tool in the analysis and representation of signals. According to this approach each natural signal can be considered as a linear combination of atom signals from an overcomplete dictionary, encouraging the sparsity of the linear coefficients. Applications that use sparse representation are many and include regularization in inverse problems such as denoising, inpainting, demosaicing, compression and more. Most of the activity in this field has been focused on mainly two problems: (i) performance of sparse decomposition algorithms and their accuracy analysis, and (ii) dictionary composition methods. The 'sparse decomposition' problem can be considered as - given a signal and an overcomplete dictionary, the aim is to extract the least possible set of atoms from the dictionary to represent it. As this problem is known to be NP-hard, exact solution cannot be found so several approximation algorithms have been suggested over the last few years. Among them the basis pursuit, the matching pursuit, and their variants were widely used in literature. The second major problem addressed in recent years in this field is to learn approximate dictionaries that lead to the existence of sparse representations of a family of signals. In this thesis we concentrate on this dictionary learning process using K-SVD technique from the corrupted image. We extended the color image denoising using K-SVD technique to Color video denoising by propagating the trained dictionary from current frame to next frame and reducing the number of iterations required normally for the next frame. In this thesis we also propose a new method to remove salt and pepper noise in gray scale images and color images. This is done in two stages. In the first stage impulse noise detection scheme is employed to detect the noisy pixel. This filter uses the morphological noise detector to classify the pixels as either corrupted or uncorrupted. In the second stage we treat the noisy pixel as a missing pixel in the image and apply inpainting based on the sparse representations to the pixels that are identified as corrupted pixels in the first stage. It can be easily extended to random value noise in gray scale images using SDRM filter for noise detection and in second stage noisy pixels are inpainted using the same inpainting algorithm. We extended this to removal of salt and pepper noise in gray scale videos by using 3D patches which implicitly handle the motion. We consider the classical applications of this image inpainting algorithm for scratch removal and Text inpainting.

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Title : *Symbol timing and carrier phase synchronization for burst mode satellite communications*
Author(s) : *Singh Ankit Kumar*
Roll No : *10104014*
Supervisor(s) : *Vasudevan Kasturi*

Abstract

Burst transmission of digital data and voice is widely adopted in satellite time division multiple access (TDMA) networks. In these applications the propagation medium can be reasonably modeled as an additive white Gaussian noise (AWGN) channel and knowledge of carrier frequency, symbol timing, and carrier phase is necessary for coherent demodulation of the received waveform. This thesis work presents an estimation of the timing and carrier phase in burst-mode satellite communication over an AWGN channel. The synchronization process is assisted by a preamble sequence appended in front of each burst and composed of alternating binary symbols. The use of this preamble results in an estimation algorithm of less complexity. The modulation for preamble is assumed to be quadrature phase shift keying (QPSK) while for the data to be transmitted, 8-QAM modulation technique is assumed. Carrier phase and symbol timing synchronization is of two types, data-aided and non-data aided synchronization. In this work we focus only on data-aided synchronization technique. Timing and phase estimates are subsequently computed and the performance of the proposed scheme is compared with Cramer-Rao bound. The system is simulated for preamble lengths of 64 and 128 with random-phase random-timing (RP-RT) and with random-phase fixed-timing (RP-FT). The preamble length is restricted to one-tenth of the data length. Finally, the symbol error rate for the overall system is compared with the theoretical results

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Title : *Optimum Detection of 16-QAM in Coloured Noise*
Author(s) : *Verma Amit*
Roll No : *10104009*
Supervisor(s) : *Vasudevan Kasturi*

Abstract

Conventional Viterbi Algorithm is optimum in presence of white noise but in practical situation noise is coloured or correlated. This correlation is usually due to the non-ideal nature of the receiver filters. Conventional detection scheme proves to be a sub-optimal technique in presence of such correlated noise. The optimum detection techniques for both uncoded and coded (trellis coded) signals in additive colored Gaussian noise (ACGN) have been derived earlier in the literature. For detection of coded signals in colored noise, the linear equalizer-predictive Viterbi algorithm (LE-PVA) is the optimum scheme. The whitening property of the prediction filter is the basis for the optimal performance of the LE-PVA. In this thesis we extend LE-PVA approach to systems employing larger constellations eg. 16-QAM. The computational complexity of PVA increases for higher order prediction filters and for bigger constellations. The set partitioning technique is used to maximize the minimum squared Euclidean distance between coded 16-QAM symbol sequences. Simulations are carried out for coded 16-QAM signal corrupted by coloured noise obtained by passing white noise through a filter. The improvement in performance using the proposed method for the coded 16-QAM constellation is demonstrated through SNR vs BER plots. The coded 16-QAM signal is obtained by passing the uncoded bit stream through a rate 3/4 convolutional encoder followed by mapping by set-partitioning

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Title : *Turbo Equalization Of Serially Concatenated Codes Using A PDFE-STMAP Receiver For Different Interleaver Patterns*
Author(s) : *Khare Vaibhav*
Roll No : *10104099*
Supervisor(s) : *Vasudevan Kasturi*

Abstract

With the introduction of turbo equalization it has become possible to achieve low error rates over ISI channels. The turbo equalizer has two main components namely, the maximum a posterior (MAP) decoder for the inner code and the MAP decoder for the outer code. The inner MAP decoder operates on super trellis (ST), which incorporates the trellis for the inner code and also takes into account the additional memory due to a prediction filter, employed in a predictive decision feedback equalizer (PDFE). This turbo equalizer structure is referred to PDFE-STMAP. This thesis deals with the performance study of PDFE-STMAP receiver for different interleaver patterns. It has been found from simulations that the S-random interleaver performs slightly better than a random interleaver

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Title : *Malicious User Detection Using Multiple Outlier Tests For Cooperative Spectrum Sensing In Cognitive Radio Networks*
Author(s) : *Singh Praveen Kumar*
Roll No : *10104069*
Supervisor(s) : *Banerjee Adrish*

Abstract

Revolution in wireless technology has introduced many useful applications. But with increasing application, the demand for spectrum has also soared. Spectrum is a limited radio resource and methods are being searched to optimize the use of available spectrum. These efforts are bearing fruit in form of cognitive radio which is being looked as the future of wireless technology. Cognitive radio is an intelligent paradigm which uses its capabilities to access the channel state information and then accordingly adjusts its parameters to increase efficiency in spectrum utilization. The cognitive radio performs a series of steps like spectrum sensing, spectrum sharing, spectrum management etc. to achieve this goal. However, as with other technologies, cognitive radio also has its own security issues like jamming attack, primary user emulation attack, malicious user attack etc..Active research is being done to increase the reliability of cognitive radio operations. It has been shown that presence of few malicious users can severely affect the performance of a cognitive radio system. The malicious users compromise the spectrum sensing operation of cognitive radio by sending false sensing values. This attack, therefore, is also called SSDF (spectrum sensing data falsification) attack. Outlier detection is one of the major data mining method that has been used to detect anomalous observation and to reject it, where appropriate. Outliers are discordant values not agreeing with the rest of the observation. Various outliers tests have been proposed in literature to detect these discordant values. Since in SSDF attack the reported values are not in agreement with the rest of true values, these outliers tests can be used to detect them. In this thesis we propose a method based on block outlier test procedures to suppress the malicious users in cognitive radio. We compare two well known tests, one proposed by Shapiro and Wilk and the other by Tietjen and Moore . Since these tests require an estimate of the number of outliers, we have proposed K-means clustering as a possible solution to this problem. However the goodness of clusters in K-means algorithm depends heavily on choice of initial centroids. Hence we compare various initialization methods to arrive at the most efficient seed selection method. The malicious user attack in a cognitive radio system can occur in various ways. Several attack models have been proposed in literature to effectively understand and overcome the effect of a malicious user. Apart from these, the malicious user action can also be modeled in terms of probabilistic attack. We consider several such models and explore the possibility of applying outlier detection method in each case. We also propose a new cooperative malicious user attack model and a method based on outlier detection technique to counter this attack

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Title : *Effect Of Cyclic Frequency Estimation Error and Timing Mismatch On Cyclostationary Detection Of Frequency Hopping Signal*

Author(s) : *Pandit Onkar Arun*

Roll No : *10104065*

Supervisor(s) : *Banerjee Adrish*

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Title : ***Compressed Sensing Based Cooperative Spectrum Sensing For Wideband Cognitive Radio***
Author(s) : ***G Vivek***
Roll No : ***10104035***
Supervisor(s) : ***Banerjee Adrish***

Abstract

In our research, we considered centralised cooperation based cognitive radio model for sensing the wideband channel. Based on the joint sparsity (means that the occupancy status of all the channels is same for all the secondary users at a time) model and compressed sensing, we develop an algorithm for detection of holes. The performance is enhanced by jointly detecting the occupancy status of the channel and achieving a trade off between the sparsity of the signal and variance of noise.

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Title : *Scalable Hierarchical Distributive Auto Configuration Protocol for Stand Alone Mobile Ad hoc Networks*
Author(s) : *Phaneendra A Krishna*
Roll No : *10104001*
Supervisor(s) : *SinghYatindra Nath; Roy Amitabha*

Abstract

Mobile Ad hoc Networks(MANET) are autonomous wireless networks in which each mobile node can act as a router. Nodes in a mobile ad-hoc network are free to move and organize themselves in an arbitrary fashion. MANETs are suited for use in situations where an infrastructure is unavailable or to deploy one is not cost effective. Most MANET literature assumes that nodes of the network are configured immediately after joining the network. However there is no centralized server in the network which can configure the incoming mobile nodes as soon as they enter network. Therefore there is a need for a distributive auto configuration protocol to configure the mobile nodes entering a Mobile Ad hoc Network. This auto configuration protocol must also deal with network partitioning and network merging. Several auto configuration protocols have been proposed in the literature. However we have shown that these solutions degrade the performance metrics as the number of nodes increases. We have proposed a hierarchical auto configuration protocol in which only certain nodes in the network termed cluster head nodes can configure the mobile nodes in the network. The main idea of our protocol is to logically divide the address space into three fields termed partition number, cluster number and node id in the cluster. We have used IPV6 local unicast address format for our theoretical and simulation purposes. However we slightly modified our protocol to deal with private IPV4 addresses. We have shown that our protocol performs better than those proposed in the literature

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Title : *Image Denoising Using Non-Local Kernel Regression And Locally Optimal Wiener Filter*
Author(s) : *Posa Vikranth*
Roll No : *10104105*
Supervisor(s) : *Gupta Sumana*

Abstract

In recent years, images and videos have become part of our daily life and used in variety of applications such as astronomy, scientific, geographical information extraction, military and so on. So the demand for an accurate and good quality image has considerably increased. Images/Videos acquired from the imaging systems suffer from degradation like blurring, down-sampling and noise. In restoring the images, the first step to be performed is denoising of images. Software based denoising approach has universal appeal as they are device independent. In this thesis we consider the problem of image denoising and propose two algorithms useful for image denoising. The first method is based on Non-Local Kernel Regression with Photometric and Geometric similar patches. Patches are said to be Geometrically similar if the structure of patches are similar, eventhough there is a change in the intensity values. Patches are said to be Photometrically similar if their intensity values in each pixel position differ by a chosen threshold. In this method, the idea of applying Non-Local Kernel Regression over Photometric and Geometric similar patches led to better denoising performance, compared to using only Local and Non-local Kernel Regressions. The second method we propose is used for denoising color images. Patch-based Locally Optimal Wiener Filter (PLOW) is a local filter, which exploits the patch redundancy in the images. The parameters for denoising are calculated from redundant patches and denoising is performed by local Wiener filter. The existing PLOW method for color images considers the color image as three gray scale images, and denoises each channel independently. In the proposed modified PLOW approach, we exploit the cross color correlation among the RGB channels and obtain better denoising performance. The proposed methods are validated by denoising several noisy images with noise standard deviation varying over a large range. We demonstrate through the simulation results that proposed algorithms gives significant improvement in PSNR and computation time compared to existing denoising algorithms

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Title : *SLAM with Straight Space Edges*
Author(s) : *Ailani Vaishali*
Roll No : *10104100*
Supervisor(s) : *Venkatesh K S*

Abstract

For a mobile robot, finding its new position and at the same time, incrementally building the map of an unknown environment is called Simultaneous Localization And Mapping (SLAM). SLAM consists of three parts: Extracting features from the scene captured by a mobile robot, tracking those features in time and finding new position of camera and plotting them to get the trajectory of mobile robot. In this thesis, straight lines in 3-D space are used as features since they are ro- bust compared to point features. To get the 3-D information, Kinect (A camera developed by Microsoft corporation) is used which provides RGB color image as well as the depth map through the IR sensor on it. We create an edge descriptor which contains 6 parameters (three inclinations and three interceptions with the 3-axis) of a straight edge in 3-D and also an edge template based on the texture of an edge and its surroundings. We establish correspondences between edges in two consecutive frames by using a template matching algorithm. Once matching is done, we find the rotation and translation of edges from one frame to the matched corresponding edge in the next frame using simple geometry. If we consider the background to be stationary, the three camera rotations from one frame to another, is of the same magnitude as of the rotations of edges but in the opposite direction. Similarly, camera translations will also be of same magnitude but in the opposite direction to that of the edges. The new camera position is estimated by applying the transformation on previous position of the camera and the map is updated. Finally we compare our estimate using the proposed algorithm with that of actual trajectory of camera which we get using Personal Space Tracker(PST). At the end we present system modelling of the algorithm output in relation to the ground truth generated by the PST

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Title : *Robust Background Estimation In Heavily Intruded Videos*
Author(s) : *Sabarwal Bhumi*
Roll No : *10104023*
Supervisor(s) : *Venkatesh K S*

Abstract

Background estimation is often required in video surveillance applications. This thesis presents a new set of techniques for background estimation in very high traffic conditions, where the background is visible for very small periods of time. The algorithm exploits the simple fact that regions containing the background in the video sequence would always show a stable content (for a stationary background), as opposed to the moving foreground which is highly unstable and variable. An algorithm for requantizing data and plotting pixel wise requantized histograms is proposed. This algorithm is highly robust to sensing noise and requires much lesser computations than existing approaches that give comparable performance. Also, it can not only eliminate frames with moving vehicles but even those with transient vehicle stops from being considered in background estimation. Moreover, with the considerable computational reduction provided by requantization it becomes possible to look for block wise background estimation, which provides a much more accurate estimate of the background. We also exploit the temporal consistency of the data and apply the temporal consistency algorithm to requantized data. This approach is particularly useful in fast moving traffic videos and also takes care of homogeneously colored traffic. At last, we use the requantized histogram approach for color videos, which further improves the result. Results show that the background estimate differs very less from the samples of actual background.

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Title : *Spectrum Sensing of Unknown Frequency Hopping Signals using Nonuniform Sampling: Effect of Quantization and Sensing Periodicity*
Author(s) : *Srivastava Abhishek*
Roll No : *10104003*
Supervisor(s) : *Banerjee Adrish*

Abstract

With the explosive growth in the user's demand, the need to access the spectrum, (which is already crowded at some bands and less crowded at other) has created the requirement of development of opportunistic communication system. The military bands are also in the category of heavily used spectrum bands. Hence, opportunistic communication system is also a requirement of military systems. In this thesis, we investigate the possibility of application of nonuniform or random sampling scheme for the detection of spectrum holes, when primary users are using wideband frequency hopping spread spectrum (military VHF band of 30-88 MHz). Since it is required to give the vacant channel information, so we have to sense the channel in frequency domain. The nonuniform sampling allows us to simultaneous sense the whole wideband band spectrum which contains non-overlapping spectra bands with less number of samples in comparison of traditional uniform sampling. We will see the effect of average sampling rate over the detection of maximum hopping rate of frequency hopping signals. We also show reduction in computation by using nonuniform spectrum estimator in comparison of using uniformly sampled spectrum estimator and the effect of misalignment between transmitter and signal detector. In this thesis we will show the effect of quantization, which is an essential part of any practical communication system. We will develop and analyze the quantization noise model for nonuniform spectrum estimator. In frequency hopping scenario the frequency of signal is time varying and is governed by Hop rate of the transmitter, hence we have to sense the channel periodically. We will develop a model of sensing periodicity for frequency hopping scenario and will analyze the maximum transmission time for the secondary user without any harmful interference with the primary users.

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Title : *A Study of Technologies for Upgradation of Legacy Optical Network Elements*
Author(s) : *Bhardwaj Yogesh*
Roll No : *10104106*
Supervisor(s) : *Singh Yatindra Nath*

Abstract

This thesis analyzes the existing circuit switched oriented Communication Transport Network of an Enterprise and its Network Elements in an abstract way. The legacy transport network is predominantly PDH/SDH from the last-mile, access to the Core. The deficiencies of the current mode of operation of the network to accommodate new IP/Ethernet services and future operational/technical requirements of the Enterprise are enlisted. There is no operational benefit of replacing the installed TDM equipment as long as it can support the required needs in terms of services and capacity. It is found out that using existing SDH infrastructure to offer new data services is the most cost-effective approach, resulting in the least risk. We have evaluated alternative based on Multi Service Provisioning/Transport Platform (MSPP/MSTP) and Packet Optical Transport Platform (POTP) that can support current needs, but also be future-proof and scale up to future demands. A brief summary of various new technologies used in MSPP/MSTP/POTP i.e. GFP/VCAT/LCAS, DWDM, ROADM, OTN and Carrier Ethernet is given. The modular design architecture of MSPP/MSTP/POTP gives network operators the option to build the best solution for their needs today by implementing either a complete, optimized, multi-layer transport solution, or only selected sections of the product on a standalone basis as needed, while ensuring they keep the options open for the right solution in the future. The migration/deployment strategy for up gradation of communication infrastructure based on MSPP/MSTP and POTP is given. A survey was done to determine the product portfolios of several telecommunication equipment vendors based on MSPP/MSTP and POTP. The salient features of products are also given in Appendices.

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Title : *Group Delay based methods for Detection and Recognition of Whispered Speech*
Author(s) : *Vedavyasan Kishore*
Roll No : *10104050*
Supervisor(s) : *Hegde Rajesh Mahanand*

Abstract

Recognition of whispered speech is gaining importance in many speech based applications in the areas of forensics and covert operations. The problem of robust detection and recognition of whispered speech within phonated speech is very important in this context. The group delay function in many of its modified forms has been used effectively for recognition of phonated speech in noise due its inherent robustness to ambient noise. On the other hand it has not been investigated for its effectiveness in recognizing whispered speech, which is generally characterized by a shift of formants to higher frequency regions. In this thesis, the effectiveness of the group delay function for detection and recognition of whispered speech is investigated. The group delay function in its spectral form is able to differentiate phonated from whispered speech using the mean height-bandwidth product of the formants in the lower and mid frequency regions of the short term spectrum of speech. The mean height-bandwidth vector is obtained herein across all frames and is further smoothed using a moving average filter. The smoothed temporal version on this vector is able to detect the phonated to whisper change points. Four forms of the group delay function which use cepstral, LP based and MVDR based smoothing on the denominator of group delay are proposed in this thesis for change point detection. Another method which uses only the numerator of the group delay function is also analyzed. Algorithms for whispered speech detection using the aforementioned methods are also presented. Experiments on whispered speech detection are performed on the CHAINS database and a cell phone whispered speech corpus collected on digital telephony lines. Subsequent recognition of whispered speech using MLLR adaptation of phonated hidden markov models is also performed. Experimental results are compared to various methods for whispered speech detection available in literature. The proposed group delay based methods perform reasonably better than the conventional methods as indicated by the experimental results on detection and recognition of whispered speech

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Title : *Text and Symbol Information Extraction from Images and Videos*
Author(s) : *Singhal Deepak*
Roll No : *10104029*
Supervisor(s) : *Gupta Sumana; Venkatesh K S*

Abstract

The detection and recognition of text from video is an important issue in automated content-based indexing of visual information in video archives. In this thesis, we present a comprehensive system for extracting and recognizing artificial and scene-text from unconstrained, general-purpose videos. Scene text is an important feature to be extracted, especially in vision-based mobile robot navigation as many potential landmarks such as nameplates and information signs contain text. This thesis proposes a new edge-based text region extraction algorithm, which is robust with respect to font sizes, styles, color/intensity, orientation, effects of illumination, perspective distortion, and the complexity of image background. Exploiting the temporal feature of videos, the proposed text segmentation method is applied only on selected frames (which are significantly different) for extracting text from a video scene. Subsequently, the frequency of these significantly different frames would help us recognize whether texts are moving or static. The direction of moving texts can also be determined by taking the correlations of the reference frame with the next frame, with different spatial shifts applied to it.

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Title : ***Reliable Multipath Routing For Optical WDM Mesh Networks***
Author(s) : ***Singh Major Ajay Bir***
Roll No : ***10104005***
Supervisor(s) : ***Singh Yatindra Nath***

Abstract

With the explosive growth of the Internet, we are seeing an enormous growth in network traffic. Internet traffic has been doubling every few months and this trend appears to continue for a while. To satisfy the increasing demands from various types of customers, it is very important for the network operator to continuously upgrade its network resources. The benefits of routing traffic with multiple paths include efficient link capacity utilization, more evenly distributed traffic load, and implicit partial link failure protection if paths are link-disjoint. The virtual concatenation (VCAT) technique in the next-generation optical network can split requested connection bandwidth into a set of traffic sub-streams, which can be independently routed across the network via multiple paths. We have proposed a new multipath routing algorithm which improves network throughput and network resource utilization and provides reliability. We aim to achieve this by exploiting VCAT/LCAS technology to minimize the maximum link utilization, thereby, properly distribute the load throughout the network and simultaneously address several reliability issues by supporting minimum bandwidth service (vs. no service at all in case of a network element failure).

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Title : *Compression Schemes for Triangulated Meshes using Projection and Strips*
Author(s) : *Sheker C*
Roll No : *10104025*
Supervisor(s) : *Gupta Sumana*

Abstract

In 3-D animations and graphics, triangular meshes play an important role to build 3-D surfaces of simple and complex objects. Meshes generally require a huge amount of data for storage and transmission. Hence the compression of 3-D meshes is an active area of research. In this thesis, we propose two compression schemes for 3-D manifold triangular meshes. The first scheme compresses geometry and connectivity data separately. Connectivity data is compressed independently, while the geometry compression uses connectivity data. For geometry data, we propose a compression technique using projection and connectivity guided prediction. The 3D mesh is transformed into two 2D images and standard image processing techniques are applied to get the compression. We used JPEG coding for compression of images. This method is lossy in nature. For connectivity data, we present a new compression algorithm based on the idea of making strips. The algorithm first encodes the connectivity information of a mesh into an output text file using the recursion and stack operations. In the second method, we modify the connectivity compression algorithm developed in the first method, such that it encodes both geometry as well as connectivity data at the same time. Reconstruction techniques are developed for both the methods. The satisfactory results are obtained for a variety of 3-D models with different image resolutions. The Quality of the reconstruction is validated in terms of both, the Hausdorff distance and Euclidian distance between the original and reconstructed meshes respectively

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Title : *Estimation of aircraft state from optical flow*
Author(s) : *Dwivedi, Venkatesh Kumar*
Roll No : *10104102*
Supervisor(s) : *Venkatesh K S*

Abstract

Vision based systems is an upcoming field of research and is of prime interest in Unmanned Aerial Vehicle and Micro-UAV systems. We have presented an approach to estimate the states of an aircraft using Optical flow derived from an onboard camera. An additional range sensor has been used to find the depth information. Equations relating the states of aircraft to observed Optical flow have been derived. Geometrical structure existing on Optical Flow field has been utilised to simplify the problem. A linear least square method is then used to solve the problem. Results obtained are verified against a synthetic video. Synthetic video is created by assuming a perspective projection model for camera

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Title : *Prediction of satellite image sequence using ANFIS: adaptive network based fuzzy inference system with feature selection*
Author(s) : *Chakradhar Cherukupally*
Roll No : *10104026*
Supervisor(s) : *Sircar Pradip; Verma Nishchal Kumar*

Abstract

A new method is presented for the prediction of future images of an image sequence. Feature selection techniques like Mutual Information (MI), Principal Component Analysis (PCA) are studied for future image generation of an image sequence using simple ANFIS: Adaptive Network Based Fuzzy Inference System model and it is presented. Image sequence is represented in a unified hyperdimensional color and spatiotemporal feature space, so that all pixels are uniquely determined. This is used as an input to train the network. Individual ANFIS models are organized for Red (R), Green (G) and Blue (B) color components of each pixel respectively and the output is then tuned for the R, G and B color component for each of the corresponding pixel of the future image to be predicted. Feature selection techniques like Mutual Information is used to improve the performance of the model. Results has been compared with results of Principal Component Analysis (PCA) from [1]. Image quality metrics like Mean Structural Similarity Index (MSSIM) and Canny based Image comparison Metric (CIM) is used to judge the quality of the predicted future images. Two image sequences, first is an atlantic cyclone, second of igor cyclone are used to verify the model and next ten images of the image sequences were successfully generated.

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Title : ***Path Diversity Schemes in OFDM Receiver By Increasing The Sampling Rate By Integers and Fractional Numbers***
Author(s) : ***K Raghavendra***
Roll No : ***10104070***
Supervisor(s) : ***Sharma Govind***

Abstract

Orthogonal Frequency Division Multiplexing (OFDM) is one of the Frequency Division Multiplexing technique with the constraint that all the subcarriers are orthogonal to each other. Because of its efficient use of frequency spectrum and robustness to the multipath channel, OFDM is used in the wireless communications such as WLAN, Wimax, 3GPP long term evolution LTE etc. Multiple antennas at a transmitter and a receiver achieves antenna diversity when signal is faded by the multipath environment. However it is difficult to implement multiple antenna elements in small terminals. The Fractional Sampling Scheme in OFDM receiver is considered to achieve path diversity with single antenna. In the FS scheme, the received signal is sampled at the rate higher than the baud rate. The Sampling points are selected according to the frequency response of the channel. In our thesis, the sampling rate is increased by integers as well as rational numbers. The Channel Estimation is done by Minimum Mean Squares method (MMSE). The selection of Sampling points by our proposed model achieves lower BER than in the FS OFDM systems. Our proposed FS OFDM systems has improved the Signal to Noise ratio (SNR) by about 3 – 4db than the FS OFDM systems.

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Title : *Performance Evaluation And Throughput Optimization of Vehicle to Infrastructure Network MAC Layer*
Author(s) : *Kode Naga Prasan*
Roll No : *10104062*
Supervisor(s) : *Singh Yatindra Nath*

Abstract

In 802.11p, by using the default Contention Window (CW) values, the throughput varies with the number of nodes in the coverage area. In dynamically varying systems, the default CW values lead to undesired throughput. The 802.11p supports multiple data rates, so a problem of performance anomaly exists. The performance of 802.11p Media Access Control(MAC) in “vehicle to infrastructure network” is studied by considering zero back off stages. The performance anomaly problem is solved by selecting CW values, such that the ratio of transmission opportunity of different rate nodes is equal to the ratio of their rates. The throughput of the system is optimized by providing proportional fairness, in order to obtain optimal CW values in terms of number of nodes. The mathematical results show that, throughput of the system can be optimized, provided, the information about number of active nodes in the coverage area is available.

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Title : *Energy-Efficient Directional Routing Protocol Using Depth Based-Controlled Flooding For Dynamic Multihop Underwater Wireless Sensor Networks*

Author(s) : *Pranam K P*

Roll No : *10104068*

Supervisor(s) : *Singh Yatindra Nath; Roy Amitabha*

Abstract

The idea of applying sensor networks into underwater environments resulting in Underwater Wireless - Acoustic Sensor Networks has attracted significant attention in the recent years. Even though underwater sensor networks (UWSNs) share some common properties with terrestrial sensor networks, such as the large number of nodes and limited energy, UWSNs are significantly challenging and different in many aspects from the traditional ground sensor network technology. Providing scalable and efficient routing services in UWSNs is very challenging due to the unique characteristics of UWSNs such as low bandwidth, high error probability, low transmission rate, high propagation delay, highly dynamic topology due to high mobility of nodes with water currents, 3-D topology etc. Most of the existing protocols for UWSNs are based on the assumption that location information of the sensor nodes are available (HH-VBF, H2DAB, MCCP, Adaptive etc.) or are based on flooding the network (SBR-DLP, HH-VBF etc.). But the localization in underwater environment is an extremely challenging task and always doesn't yield accurate result. And in the case of flooding, the network load is extremely high and increases energy consumption so drastically that the network lifetime of the battery operated UWSN is significantly reduced. So in this thesis, as a solution to the above problems, we proposed an Energy-Efficient Directional Routing Protocol Using Depth Based-Controlled Flooding for Dynamic Multihop Underwater Wireless Sensor Networks which performs routing by controlled flooding using directional antennas and uses redundant packet suppression techniques using multiple buffers & varying retention times based on depth obtained from an inexpensive depth sensor mounted on the node. The proposed protocol doesn't require the full dimensional location information to handle network dynamics efficiently and as opposed to other flooding based-protocols result in less energy consumption & reduced network load, since directional controlled flooding is used instead of full scale flooding. The proposed protocol takes advantage of multi-sink architecture and also increases the reliability by using ACK packets. We have shown that the proposed protocol performs better than those proposed in the literature

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Title : *Automatic Deblurring of Motion Blurred Images using Flutter Shutter*
Author(s) : *Rai Anindya*
Roll No : *10104012*
Supervisor(s) : *Venkatesh K S*

Abstract

Motion blur is the result of relative motion between an object and camera during the integration time of an image. Since the motion can be in any arbitrary direction with any velocity, deblurring of motion blurred images becomes a hard problem. This thesis presents an automatic, novel and fast approach to deblur a motion blurred image. When we take an image, because of the finite exposure time, moving objects get smeared in the direction of motion. This temporal filtering destroys important high-frequency spatial details. Thus image deblurring becomes an ill-posed problem. Instead of leaving the shutter open for the entire exposure duration, we “flutter” the shutter open and shut according to a binary pseudo-random sequence. Fluttering changes the filter response to that of a broad-band filter without zeros which preserves the high frequency spatial details and thus the corresponding deconvolution becomes a well posed problem. We have discussed the dependence of different modulating codes on the deblurring process. We have applied the flutter shutter as a software flutter shutter where the coded exposure images are simulated by the software. Certain code sequences whose frequency response are broadband in nature give better deblurring results compared to any random binary code sequence. The dependence of length of code on the extent of blur is shown. The deblurring process is made automatic by estimating the direction and length of blur first and then using this information as input to deblur the coded exposure image

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Title : *Digital Restoration Of Partially Degraded Archived Films And Color Videos*
Author(s) : *Ghosh Soumik*
Roll No : *10104093*
Supervisor(s) : *Gupta Sumana*

Abstract

Archived videos are susceptible to many damages. The occurrence of partial color artefacts (PCA) has been one of the major issues for digital videos. In this thesis we propose a semi-automatic process to detect PCA arising from emulsion melting and also extend the process for detection of blotches. The primary objective of this work is to restore partial color artefact regions that are the damaged areas in a video in which only partial information is present. We use the hue plane of the HSV color space to detect the artefact patch area. On specifying the patch area, a "source area" is assigned to the patch, from where the true pixel values are drawn to restore the artefact region. This is a pixel-based approach. We choose for each pixel of the artefact region, a pixel in source area which is in an optimal position from the affected pixel in terms of physical distance and color distance, and replace the value of the current affected pixel by the source area pixel. Many existing artefact removal techniques have no proper basis for finding the mask around an artefact and are also unable to recover the partial loss in original colors when the artefact size is large. These are very critical issues in detection and restoration of artefacts. In our algorithm we have thoroughly reasoned out the selection of the corrupted region and its robustness to handle large size of artefacts. Several severely damaged frames are recovered using this algorithm. The problem of non uniform color cast in videos is also considered and is resolved by a variable color cast removal algorithm. The algorithm uses the mid tone thresholds obtained from artefact free frames, to remove color cast in corrupted frames. The quality of the results obtained is judged completely based on one's visual impression. Results achieved through this proposed method has been quite satisfactory.

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Title : *On Performance Improvement of Cognitive Radio Communications Using Cooperative Relay Networks*
Author(s) : *Goud G Chandra Shekar*
Roll No : *10104034*
Supervisor(s) : *Banerjee Adrish*

Abstract

Cognitive radio communications depends on the licensed spectrum of primary users. There are different ways of accessing this licensed spectrum. We consider the Interweave spectrum access scenario, where the communication takes place using the unused portions of licensed spectrum. The availability of the unused licensed spectrum is very dynamic both temporally and spatially and so the efficient use of the available unused spectrum is very important in Cognitive radio. Cooperative communication techniques are employed in the cognitive radio networks for effective use of the radio spectrum and to improve the BER performance by exploiting virtual diversity that helps in combating multipath fading in wireless communication networks. In cooperative communications, the cognitive radio users cooperatively participate in the communication depending on the spectrum availability. In our thesis, we consider a simple three node cognitive radio network system and show different cooperative relaying networks for this system based on the spectrum availability at each radio node. Two cooperative relay protocols: Amplify-and-Forward (AF); and Decode-and- Forward (DF), are used respectively for presenting the BER analysis and Throughput analysis of the system. For improving the system performance, we formulate the convex optimization problems for minimizing the BER and also for maximizing the system throughput subjected to transmission power constraints. From the simulation results we show a significant improvement in the system performance with optimal power allocation compared to that of equal power allocation for Cognitive radio communications using cooperative relay networks.

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Title : *A Secure Peer Group Management Using Digital Certificates For Brihaspati-4 Learning Management System*
Author(s) : *Shanmugam Balamurugan*
Roll No : *10104022*
Supervisor(s) : *Singh Yatindra Nath*

Abstract

Peer-to-peer network is a distributive network where the peers collaborate to share the network resources like storage memory, computing power and bandwidth. Each peer acts as server and client to other computers. Peer-to-peer network is advantageous than the client server network in many ways. Therefore the client server is no longer used in a large distributive network. A peer-to-peer network is often a reasonable choice in a network where significant growth in numbers of users is expected. Brihaspati-4 is an e-learning system where there is a requirement of high scalability, large resources, zero fault tolerance and decentralization. The P2P environment has become popular in recent times because of its high potential to scale and lack of central point failure. The JXTA community has presented an open-source peer-to-peer overlay framework called JXTA. It allows specifying a set of collaboration and communication protocols which enable the creation and deployment of peer-to-peer (P2P) applications. Hence we use JXTA to build Brihaspati-4 a P2P learning management system. Along with the popularity of the P2P system, the security issues are also increased. As there is no central server to monitor the peers, the security operations are difficult to be performed in a peer to peer network. Therefore, there is a need for a lot of research in the security area. In this thesis, we propose a method for a secure peer group management. This method has been proposed after exploring the security issues that are expected in Brihaspati and a study of the security layer of the Jxta. In this project we create a peer group and join the peers to this peer group with use of digital certificates ensuring the authenticity. We also extend it to provide a file transfer mechanism where the mutual authentication is performed within the group. The algorithms for ensuring confidentiality and data integration are also proposed. The secure peer group management method is implemented and tested in order to deploy in Brihaspati-4.

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Title : *Multimodal speaker diarization with pattern based adaptive spectral clustering*
Author(s) : *Desai Mangesh Dilip*
Roll No : *10104032*
Supervisor(s) : *Hegde Rajesh Mahanand*

Abstract

Automatic Speaker Diarization is widely used in audio indexing and for improving the performance of speech based applications in noisy conditions. Generally solutions to the speaker diarization problem use content based audio features in tandem with hierarchical clustering techniques. Multi modal methods which utilize the information present in both the audio and visual modalities are an active area of research in speaker diarization. This thesis proposes a novel multi modal speaker diarization method using waveform based features in tandem with partitional clustering techniques. The audio and visual information is captured by multiple audio-visual sensors. The multi modal features are then computed using spatial cues and correlation techniques. They are structured to follow a particular pattern by identifying the pivot camera and pivot microphone. An adaptive partitional clustering algorithm that exploits the pattern based features is also proposed which use shrinkage based eigen decomposition in the multi modal feature space to robustly cluster the multi modal features. Speaker diarization experiments are then performed using the proposed pattern based adaptive clustering approach on the CUAVE multi modal database. Additional experiments are also performed on the multi modal data collected on the Lab testbed. The performance of the proposed multi modal method gives a reasonably better performance in terms of Receiver operating space and diarization error rate when compared to conventional methods available in literature. Robustness analysis of the multi modal features are also used to cross validate the experimental results on speaker diarization.

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Title : ***Time, Storage And Display Optimized Processing Of Light Field Data For 3d Virtual Views***
Author(s) : ***M Deepika***
Roll No : ***10104030***
Supervisor(s) : ***Venkatesh K S***

Abstract

Light fields contain the information of the light rays permeating a scene in every direction at every point in space, which is essentially a 2D array of 2D images. This work aims at synthesizing a novel view of a scene when required, which can be interpreted as extraction of the appropriate 2D slice of the 4D light field. Towards this end, the work aims at improving the computational techniques of processing the light field data - efficiency in terms of computation time and storage space. Reducing the reconstruction time with minimum loss in the visual perception of the generated image is done by efficiently storing the already generated novel views and using them for reconstruction of the further views. Also, the ray-tracing algorithm is improvised so that partially computed images are displayed initially and as the computation progresses, the resolution of the displayed image increases. Further, the large amount of information in the light field data is efficiently sampled and the generation of the novel view is done using the compressed data. Additionally, the thesis proposes efficient techniques to allow virtual camera displacements that are normal to the camera plane, to generate 'true zoom' effects. Optimal camera selection with minimization of the data and computation required for this application are also considered.

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Title : *Two-Dimensional Direction Of Arrival And Time Delay Estimation*
Author(s) : *Kumar Kailash*
Roll No : *10104047*
Supervisor(s) : *Sircar Pradip*

Abstract

In this thesis, we present a simple method for two-dimensional direction of arrival (DOA) and absolute time delay (TD) estimation. We use an L- shaped array. The method relies on simple geometry of the array of antennas. It turns out the DOA estimation problem reduces to two one-dimensional problems. We use a variant of Prony's method in each dimension to estimate the DOAs. For time delay estimation, we assume that the clocks at transmitter and receiver are synchronized. Base station provides a time slot by sending a signal "Ready To Receive" to the source. After receiving the signal from the base station, the user sends his xed sequence code to the base station. We calculate time delay by processing the received signal at the base station.

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Title : *Improved Data Extraction from Digital Images Captured using UH-ICCD imaging System*
Author(s) : *Sinha Alok Kumar*
Roll No : *10104007*
Supervisor(s) : *Venkatesh K S*

Abstract

Digital image processing is used as a powerful technique in many elds. Experimental mechanics is one of them which uses it extensively. In one part of our work, an image processing method has been presented to study the mechanical behaviour of certain non-crystalline transparent materials. Our approach is capable of detecting centerlines of the fringes captured by CCD camera, when placed in a light field polariscope. It provides a good automatic method for stress analysis. In our method, we are doing binarization after smoothening the fringe images then applying a thinning algorithm. Thinning approach is used generally in optical character recognition, we presented this with some improvement for good detection of fringe lines. In our second part of thesis we focus on distortion free data extraction using Ultra high speed image acquisition system. Noise during image intensification, distortions due to photo multiplier and optical elements introduce limitations in the accuracy of the measurements. These aberrations can not be removed by average filtering, domain filtering and homomorphic filtering. We use Flat field correction for distortion removal. Several experiments are performed to observe the accuracy of the correction method. Data like displacement and strain data are measured using digital image correlation methods. We find that it reduces pixel to pixel intensity variability, resulting in consistency of the data to the original one and reduced deviation in the measurement of both displacement and strain fields

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Title : *Robust Dual Cumulative Sum Algorithm for Cooperative Spectrum Sensing*
Author(s) : *Kadam, Sachin*
Roll No : *10104079*
Supervisor(s) : *Bansal Rakesh K; Sharma Govind*

Abstract

Cognitive radios are the devices which use the channel licensed to other users. For this, they make observations about the status of the channel, analyze it and then use it when licensed users are not using it. While making observations, cognitive radios might observe the data which may be contaminated by outliers due to environmental disturbances, channel impairment etc. We consider the problem of suppressing these outliers in cooperative spectrum sensing techniques. In this work we use Huber's least favorable pair based on mixture model with appropriate nominal distributions in the DualCUSUM algorithm, a sequential change point detection algorithm used for spectrum sensing. We show that proposed robust DualCUSUM algorithm performs better than existing DualCUSUM algorithm in the presence of outliers. We also show by simulations that better performance can be achieved when the design parameter used in obtaining the least favorable pair equals the actual contamination level in the data

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Title : *Theory, Representation And Techniques For Silhouette Metrology*
Author(s) : *Das Monideepa*
Roll No : *10104059*
Supervisor(s) : *Venkatesh K S*

Abstract

Shape from Silhouette method has been widely used in the field of Computer Vision for 3D reconstruction. However, when the 3D reconstruction is done under perspective projection, the reconstructed 3D model of the real world object has error in its dimensions. The error is introduced because of the depth issue. In this thesis, a novel method has been proposed to improve the accuracy of the error correction algorithm and hence achieve a more accurate model of the real world 3D object. Representation of complex shape is a central problem in the field of Computer Vision. An algorithm has been proposed to reconstruct the complex shape. It has been done using the concept of beak functions. The shape generated is almost convex and concavities are not detected because Shape from Silhouette method can generate only convex object. When a 3D model of a concave object like a straight through hole in a block is generated using silhouette method, the concavity of the object may not be detected. It happens because the 3D model of the object is generated using 2D silhouette images of the object, but when the object is rotated along a particular axis, it might happen that the concavity is never captured in the 2D images of the object, and hence not visible in the reconstructed 3D model of the object. Here, a theorem has been proposed which gives the appropriate choices of, and the minimum number of axes of rotation needed in order to generate the actual 3D model of the concave object. It also formally defines the class of 3D objects for which silhouette reconstruction is possible.

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Title : *Sequential Change Detection using Universal Estimators of Entropy and Divergence*
Author(s) : *Juvvadi Deekshith Rao*
Roll No : *Y7027128*
Supervisor(s) : *Bansal Rakesh K*

Abstract

This thesis focuses on sequential change detection problem with minimal knowledge of source statistics through universal estimators of entropy and divergence. The first part of the thesis deals with simulation studies of a test by Jacob-Bansal(2008) designed for detecting a change when the change takes place from a known stationary ergodic process to an unknown stationary ergodic process. Based on the simulations, we make observations regarding the variation of its performance with problem parameters and test parameters. We also provide a technique to improve the time complexity of the test. In the second part, we propose a test to detect a change from a stationary Markov ψ -mixing process to a stationary ergodic process. Statistics of both the sources are unknown except for a training sequence generated by the distribution before the change. The test uses a statistic which approximates the statistic used in the popular CUSUM (Page) test by using a divergence estimator. We propose a universal divergence estimator which estimates divergence between a stationary ergodic process and a stationary Markov ψ -mixing process based on a Fixed-Database-Lempel-Ziv(FDLZ)-based cross-parsing technique implemented on two sequences, one generated by each of the processes. We prove the almost-sure convergence of the estimator. We also prove the almost-sure convergence of match-lengths and use this result in the proof of convergence of the estimator of divergence rate.

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Title : *Speech recognition using Acoustic Universal Structure in limited training data conditions*
Author(s) : *Kadapa Manoj Kumar Reddy*
Roll No : *10104058*
Supervisor(s) : *Hegde Rajesh Mahanand*

Abstract

Recognition of continuous digits spoken by humans is important in the applications like voice dialing, call routing, data entry, roll number verification, and credit card verification. However, one of the major challenges in speech recognition is the non-availability of large training data. As the vocabulary, size increases the performance of automatic speech recognition system decreases. This can be alleviated by the use of a large training data set at the expense of increased computational complexity. On the other hand, the performance of speech recognition systems is also affected by the huge variability in speech due to the changing ambiance, variety of sensors used and difference in the gender and age of the speakers. In this thesis both, the above-mentioned issues are addressed by building speech recognition systems that use limited training data and are robust to the variability in the speech signal. The proposed method uses Acoustic Universal Structure (AUS), which is a novel acoustic representation of speech. The AUS considers only the information present in the speech signal while ignoring all speaker specific information. The AUS captures only the phonetic description of the sound since it computes the distance between the phonetic distributions of the sound. The computational complexity of the AUS method of speech recognition increases as the vocabulary increases although it facilitates for the use of limited training data. This issue is also addressed in this thesis by proposing two novel algorithms that use the string AUS and selective digit synthesis to improve the performance of the recognition system while using limited training data. The proposed algorithms are used in the experiments for the continuous digit recognition on the TIDIGITS and the MONC databases. Additional experiments are conducted on the HINDI digit database. The experimental results illustrated as word error rates indicate a reasonable improvement over conventional HMM based recognition methods at various SNR levels and training data size. The computational complexity is motivating enough to use it for cell phone based transactions.

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Title : *A comparative study of ray and wave theory for phase contrast tomography*
Author(s) : *Meena Jyoti*
Roll No : *Y7027184*
Supervisor(s) : *Naik Naren; Munshi Prabhat*

Abstract

In x-ray imaging, hard x-rays(high energy) characterized by straight path travel, deep penetration and absorption provide a basic tool to estimate the internal structure of the body. However because of high absorption and deep penetration, problems of ionization also come into the picture. Increasing the x-ray dose to get a high resolution image has emerged as a concerning and crucial factor in medical imaging. On the other hand soft x-rays(low energy) are characterized by refraction, diffraction and they are less absorbed. Their amplitude is affected by the absorption coefficient while their phase is affected by the refractive index of the medium. In this thesis, towards an objective of soft-tissue imaging with x-ray phase contrast tomography, we make a novel comparative study of models and reconstructions in ray-theoretic and wave-theoretic(Rytov approximation based) phase-contrast optical tomography. Further, with the objective of enabling greater flexibility in modeling and reconstruction schemes, a local plane wave approximation based phase-retrieval from beam-deflection-data is proposed and evaluated. Reconstruction schemes in ray optical tomography are typically based on beam-deflection and optical path length difference data-types. Further the use of wave-theoretic approaches such as the Rytov linearized approximation enables us to conceptually better address the issues of multifrequency reconstructions, since information observed by wave approximation are frequency dependent while in ray approximation frequency comes in form of scaling factor, in addition the Rytov approximation converts the nonlinear reconstruction problem of OPD-based ray-inversion to a linear problem.

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Title : *Robust portfolio optimization of quadratic constrained quadratic optimization (QCQP) problems considering extreme value distributions*

Author(s) : *Kashiv Harshit*

Roll No : *Y7027168*

Supervisor(s) : *Singh Yatindra Nath&Sengupta Raghu Nandan*

Abstract

Optimization models are playing an increasingly important role in financial decision making. The famous asset allocation problem is one such problem which is usually handled by constructing a portfolio of assets and then optimizing based on some historical data. But the coefficients or variables used in modeling are often derived from the data at hand which may or may not be 100% accurate. The method of Robust Optimization is one which takes care of uncertainty in the historical data by creating a robust counterpart for the original model. This model is supposed to solve the original problem and give an optimal solution which is feasible for any realization of the uncertain coefficients/ parameters within pre-specified uncertainty sets of these coefficients/parameters. The focus of this thesis is to model quadratic chance constrained optimization problems using robust optimization approach with application in financial portfolio optimization. Chance Constrained optimization problems are a special class of optimization problems where one tries to minimize or maximize a convex objective function given a system of randomly perturbed convex constraints with certain probabilities. In our research work, we formulate and solve four interesting chance constrained portfolio optimization problems using RO method. In the first and third model, we consider a chance constraint portfolio optimization problem, where we consider a convex objective function subject to a system of randomly perturbed chance constraints where the probabilities are given. In financial optimization we try to minimize the risk and maximize the return. The robust counterpart of this quadratic constrained quadratic model takes the form of second order cone optimization problem (SOCP) after certain order reductions. In the second and fourth model, we use the concept of Hyperbolic Absolute Risk Aversion (HARA) utility function. The returns in HARA utility function is assumed to follow the Gumbel distribution; which is a special class of EVD. Using the assumption of return distribution, we derive the expected value and variance of HARA utility function. These two moments of HARA are used in the model in the objective function for our second model, where the expected value is maximized, while the variance is minimized subject to probabilistic constraints. Results obtained by considering different combinations of HARA utility function parameters for in-sample or sample I are compared with the out of sample or sample II data sets. For the data analysis part, time series data of assets of 25 different stocks for a range of 10 years is considered. The use of fat tailed distributions for financial modeling is very important, and in investment allocation problems, distributions of portfolio returns are in general heavy tailed and do not fall under the category of elliptical distribution. So Extreme Value Distribution (EVD) of financial returns is considered to take care of tail risks. Block

Bootstrap re-sampling technique is used to estimate the relevant parameters of the individual financial returns. Our research work tries to capture the effect of extreme uncertainty of parameters, and we propose solutions that are robust with respect to extreme realization of parameter values. Thus in all the models, EVD of financial asset returns are considered to measure the tail risks and we consider robust formulations of portfolio optimization models using these financial assets listed in Nifty-50 which are (1)ACC (2)ONGC (3)JINDAL STEEL (4) AXIS BANK (5)RANBAXY (6)BHEL (7)ITC (8)RELIANCE (9)DR.REDDY (10)BPCL (11) SAIL (12)SBI (13)CIPLA (14) SIEMENS (15)TATA MOTORS (16)M&M (17)TATA STEEL (18)WIPRO (19) HDFC (20) HDFC BANK (21)HERO HONDA (22)HINDALCO (23)HUL (24)ICICI BANK (25) INFOSYS TECH.

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Title : *Ant Colony Optimization algorithms on Quantum-dot Cellular Automata and Digital Circuits*
Author(s) : *Chakravarty Diptarka*
Roll No : *Y7027141*
Supervisor(s) : *Ghosh Bahniman*

Abstract

Ant Colony Optimization is a swarm intelligence metaheuristic proposed in the 1990's in order to solve combinatorial optimization problems. The design of the approach was based on foraging behaviour of ants. This thesis concentrates on the continuous domain version of ACO and develops an idea of level which can significantly impact the solutions of it. This thesis shows the idea of level develop into an algorithm which can improve performance of existing algorithms such as random sampling, ACO for continuous domain and Quantum Ant Colony Optimization (QACO) for 2-3 test functions. This thesis also solves the problem of logic optimization of Quantum Dot Cellular Automata Circuits using the continuous version of ACO, novel ACO with level and a novel designed 3-state QACO algorithm. The results of these are compared with solutions of Genetic Algorithms used before and other previous proposed approaches. Final part of the thesis involves solving the problem of finding optimum transistor sizes in order to get the optimum balance between delay and power for four digital circuits, of different complexity. The circuits are optimized using QACO, Learning Automata, level ACO for continuous version and compared with ACO results on them done previously. For this thesis, perl code of algorithms were written and HSPICE has been used for simulations of the digital circuits

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Title : *Novel Circuits in Quantum Dot Cellular Automata*
Author(s) : *Agrawal Diwakar*
Roll No : *Y7027144*
Supervisor(s) : *Ghosh Bahniman*

Abstract

Quantum Dot Cellular Automata (QCA) is a promising technology which has the capability to take the progress of digital electronics further after the CMOS devices hit the physical limit of device scaling. This work starts with the discussion of basics of QCA technology and various logic circuits developed. An area efficient T flip-flop circuit is presented which is better than the previous designs in terms of the number of QCA cells as well as the wasted area. This thesis then proposed novel solutions for three important problems which are frequency reduction techniques in QCA, FPGA Devices and Memories. First part of thesis presents techniques to operate a QCA circuit at a frequency which is a fraction of the universal clock frequency. For this purpose many intermediate circuits like periodic signal generator and master-slave flip-flop circuits are designed. Prospective applications are suggested and their implementation details are discussed. A novel architecture for implementation of FPGA in Quantum Dot Cellular Automata has been presented. A new connection scheme is used for the CLB (Configurable Logic Block) array. UGA (Universal gate applier) has been proposed in place of LUTs (Look up tables). Comparison of various FPGA architectures has been done with the help of a circuit of a full adder. Promising results have been observed in terms of improvement in area, latency and programming time of FPGA. The last part of thesis discusses various memory architectures for Quantum Dot Cellular automata. New hybrid memory architecture has been proposed and comparison has been done on the basis of area and latency. It is shown that the hybrid memory can be used as a tradeoff between area advantage of serial memory and latency advantage of parallel memories to get an optimized result. At last a protocol for using the serial memory has been outlined to make it compatible with circuits handling parallel data

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Title : *Spin Transport in Graphene Stacks*
Author(s) : *Misra Soumya*
Roll No : *Y7027441*
Supervisor(s) : *Ghosh Bahniman*

Abstract

Spintronics, the study of the spin property of electrons in a material and its application in electronics, has become a topic which has invited a plethora of academic as well as experimental research. One of the materials being considered as having immense potential for spintronic applications is graphene, the two dimensional sheet of carbon. Graphene and multi-layer graphene stacks have shown many unique and remarkable electronic properties as a result of which it is currently being studied and researched in great detail. In this work, spin transport has been studied in graphene stacks theoretically using semi-classical Monte Carlo simulations. Spin relaxation caused by Elliott Yafet and D'yakonov Perel' (DP) mechanisms have been incorporated for studying spin transport. The aim of this study has been to determine the spin relaxation lengths of the different graphene stacks to determine their suitability for spintronic applications. Spin relaxation has been examined in single layer graphene, bilayer graphene and multilayer graphene. The effects of temperature, gate voltage and the number of layers have been explored and presented as the main work of this thesis. Moreover, a comparison of spin transport has also been made for trilayer graphene in its two physical manifestations, Bernal and Rhombohedral. It is observed that bilayer graphene has a significantly higher spin relaxation length than single layer graphene. Moreover, on increasing the number of layers, it is observed that the spin relaxation length increases up to 16 layers and then becomes constant. Finally in trilayer graphene, it is observed that Rhombohedral stacking leads to a higher spin relaxation length.

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Title : *Implementation, Layout and Simulation of Multiplier Circuits in Quantum Cellular Automata Technology*
Author(s) : *Nagaraju Munigala*
Roll No : *10104061*
Supervisor(s) : *Ghosh Bahniman*

Abstract

According to Moore's law, the number of transistors that can be placed on an integrated circuit doubles for every 18 months approximately. Recent advancements in CMOS technology have led to the implementation of designs with extremely small size and with higher device density. Advances in the CMOS technology cannot move forward after a few years due to various problems. One of the most promising nanotechnologies which can replace the present transistor based CMOS technology is the Quantum-Dot Cellular Automata. The major advantages with this technology are lesser power dissipation, improved speed and dense structures. This work describes the newest design of 1bit Full adder, 1Bit Serial adder and serialparallel multiplier circuits. Carry delay Multiplier (CDM) and Carry Shift Multiplier (CSM) are designed by using the design structure of Bi-Serial adder and Full adder, promising the dense structures. It uses the 3input majority gate for the carry generation and 5 input majority gate for the sum generation. The circuits are simulated and analyzed using QCADesigner 2.0.3 software tool and the results are compared with earlier designs.

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Title : *Design of High-Order Fully-Differential Gm-C Low-Pass Filter in 0.18 μm CMOS Technology*
Author(s) : *Agrawal Geetika*
Roll No : *10104038*
Supervisor(s) : *Ghosh Bahniman*

Abstract

A number of design issues and technology advancement motivate extensive research in transceiver design at the nano-scale. One of the critical blocks of an RF transceiver is the low-pass filter (LPF) as it is responsible for isolating the baseband signal which carries the information from out-of-band interference. Several competing circuit technologies are available for monolithic implementation of filter. Among all, Gm-C implementation is selected for its simplicity, high speed, low power consumption and tunability advantage. The thesis aims to design a fifth order fully-differential Gm-C low-pass filter with a cut-off frequency of 205 MHz using a 180 μm CMOS process. The filter attains a high DC gain which is critical when integrating the LPF with the other receiver blocks. A higher LPF gain ensures that the amplitude of its output baseband signal is above the sensitivity level of the next stage. Also in the same receiver block, amplification and filtering can be performed by the same circuit. Due to its robustness to process parameter tolerances, LC-ladder filter topology is selected. The LC-ladder prototype is emulated using the signal flow graph methodology. The filter consumes a power of 34.56 mW under a supply voltage of 1.8V. As the basic building block of the Gm-C filter, a transconductor based on a differential pair is designed and characterized. In order to stabilize the input and output common-mode voltages, the transconductor is employed with a common-mode feedback (CMFB) loop. The simulation shows that the fully-differential transconductor has a gain of 21 dB and 3.47 mW power dissipation. The Gm-C biquad is designed and analysed using element replacement design methodology. Cut-off frequency and passband gain of the biquad are 202.6 MHz and 6.8 dB respectively.

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Title : *Design of 2.4 GHz LC Voltage Controlled Oscillators with Band-switching Capacitor Array in 0.18 μm CMOS Technology*
Author(s) : *Sharma Ruchi*
Roll No : *10104078*
Supervisor(s) : *Ghosh Bahniman*

Abstract

Voltage controlled oscillator (VCO) is an important component in many RF transceivers. Thus, the design of high performance voltage controlled oscillators is very important and still is an active research area. The advancement in communication system has set current trend to utilize multi-bands and multi-standards applications. It becomes difficult for VCO to achieve wideband tuning range, low phase noise and low power consumption simultaneously. In order to break this trade off among tuning range, phase noise and power consumption, voltage controlled oscillator with band-switching capacitor array can be used. This work presents the design of 2.4GHz LC voltage controlled oscillators with band-switching capacitor array in 0.18 μm CMOS technology. The inductor available as L_SLCR20K_RF in cadence and PMOS inversion mode varactors were utilized to form the LC tank of the VCO. NMOS, PMOS and CMOS LC differential voltage controlled oscillators designed with and without band-switching capacitor array are compared. The CMOS LC cross-coupled voltage controlled oscillator with noise filter is also designed to improve the phase noise. Further, CMOS voltage controlled oscillator with PMOS tail current source is designed to compare it with the VCO using NMOS tail current source. Thus, this work aims at comparing the performances of various oscillator topologies, lowering of phase noise and getting reasonable tuning range.

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Title : *Design and Comparison of Low Power Low Noise Amplifiers for Wireless Applications*
Author(s) : *Odharia Miten*
Roll No : *10104064*
Supervisor(s) : *Ghosh Bahniman*

Abstract

Transceiver is the integral part of a communication system and the signal received by wireless receivers is generally very weak. LNA (Low Noise Amplifier), which is usually the first block of a receiver, is designed to handle such signals. The LNA is expected to have a high gain and a low noise figure. The work mainly focuses on design of LNAs using CMOS 0.18 μm technology for three applications: Bluetooth, GPS (Global Positioning System) and UWB (Ultra-Wide Band). A cost effective 2.4 GHz LNA for Bluetooth applications using inductive degeneration is proposed which gives a gain of 17 dB and a noise figure of 2.5 dB which consumes 8.1 mW power. It also gives excellent input and output matching. After that a 1.1 GHz LNA for GPS and wireless LNA applications with inductive degeneration is given which provides a gain of 22 dB and a noise figure of 1.43 dB with a power consumption of 9 mW and matching at input and output. Also, a wideband LNA, operating in the frequency band of 3.1 to 7 GHz and used for lower UWB applications, is presented. It extends the narrowband operation of inductively degenerated topology to wideband application using a high pass LC filter at input for wideband match. It exhibits a gain of around 10 dB and a noise figure of around 3 dB with a power consumption of 7.2 mW. Finally, a UWB LNA operating from 3 to 10 GHz is proposed using common gate topology and a Butterworth filter at input for a wideband match. It provides a gain of around 10 dB and noise figure from 2.4 to 3.7 dB with power consumption of only 5 mW

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Title : ***A Low Voltage, 3-Stage CMOS Power Amplifier for Wireless Communications***
Author(s) : ***Verma Vikas***
Roll No : ***10104104***
Supervisor(s) : ***Ghosh Bahniman***

Abstract

The wireless market has experienced a tremendous growth and development since the introduction of the first mobile phone systems, with a steady increase in the number of subscribers and new application areas. The power amplifier (PA) is a key building block in all RF transceivers. To lower the costs and allow full integration of a complete radio System-on-Chip (SoC), it is desirable to integrate the entire transceiver in a single CMOS chip with low supply voltage. It is becoming significantly harder to meet the stringent requirements on linearity, output power, and power efficiency of PAs at lower supply voltages. This thesis addresses the potential of integrating linear and efficient Power amplifier at low supply voltage. In total two class AB PAs have been designed, a 2-stage and a 3-stage. These PAs have been designed in a 0.18 μm CMOS technology, targeting the 802.16e WIMAX standard operating in the 3.7 GHz frequency having stringent requirements on linearity. First a 2-stage power amplifier using common source technique is designed, gives relatively low efficiency and power gain and then with the help of cascoded technique a 3-stage power amplifier is designed. This proposed 3-stage power amplifier having relatively high efficiency and gain, that is suitable for 3.7 GHz mobile WIMAX subscriber station application

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Title : ***A 5.9GHz Very Low Noise High Gain LNA***
Author(s) : ***Kumar Ashish***
Roll No : ***10104018***
Supervisor(s) : ***Ghosh Bahniman***

Abstract

Being the very first block of receive chain LNA has to be able to receive the maximum part of the signal and that too without adding much noise to it, the gain should be as high as possible along with these requirements some other requirements are there that has to be fulfilled like linearity, power dissipation. Source-degenerated LNA topology has been the main topology of interest because of its various advantages. In this work the same topology has been used and by modifying the basic circuit improved performance is being achieved. S_{11} of -37.69dB, S_{21} of 15.36dB, S_{12} of -32.5dB and an excellent noise figure of .79dB is achieved.

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Title : *Effect of Device Size on Its Efficiency and Module Design for Bulk Heterojunction P3HT: PCBM Organic Photovoltaic Cells*
Author(s) : *Pittu Ravi Babu*
Roll No : *10104066*
Supervisor(s) : *Iyer S Sundar Kumar*

Abstract

There has been a steady and rapid increase in the Power Conversion Efficiencies (PCE) achieved in Organic Photovoltaic cells (OPV). Now that individual cells perform well, building of large area modules containing individual cells connected in series and parallel has become critical as it is observed that the performance of individual cells decreases with increase in cell size. In this thesis, the main focus is on optimizing the OPV module design, taking into account the effect of increase in size of individual cells present in the module. In the first part of the thesis, a distributed resistance model is described. The model overcomes some of the limitations of lumped parameter model when applied to large area devices. Simulations were carried out in this model to study the dominant parameters that limit the maximum Indium Tin Oxide (ITO) electrode length of an OPV cell. Second part of the thesis presents three different OPV cell designs. In first design ITO length of the OPV cells is increased in step wise keeping the other OPV cell dimension (Aluminium (Al) electrode dimension) fixed. In the second design, ITO length of an OPV cell is fixed and Al electrode length is increased. In the third design, all the cells are square in shape and area is increased step wise. In the first design, we observed decrease in PCE with increase in ITO length. For the chosen dimensions, the observed rate of PCE decrease in this design is more than what simulations show. Fabrication process variations and shunt paths in the device area are more likely to cause this deviation. In second design, we did not observe any decrease in PCE at all. In the third design because both dimensions are increased, increase in ITO dimension resulted in slight decrease in PCE. Based on the simulation and fabrication results obtained, a design methodology that maximizes OPV module PCE is described in the third part of the thesis. The module PCE is observed to attain maximum value when the ITO length of OPV cells in it is fixed at 14 mm. This optimum cell length is almost independent of module area and it depends on space used to connect two adjacent cells in series in the module and the sheet resistance of ITO electrode.

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Title : *Study of Spin Polarized Transport in III-V Semiconductor*
Author(s) : *Nimje Swetali*
Roll No : *Y7027465*
Supervisor(s) : *Ghosh Bahniman*

Abstract

Spintronics which exploits both the property of electric charge and spin is the emerging field in last few decades. It involves using the spin degree of freedom and this can provide added advantages over conventional electronics by providing new capabilities and new functionalities. Spintronics based devices require control of the spin polarization in the device channel. Spintronics devices combine storage, detection, logic and communication capabilities to produce a multifunctional device on a single chip which could replace several components. We investigated spin relaxation in semiconductors for determining the suitability of a material for spintronics. Semiclassical Monte Carlo is used with spin density matrix calculations to study the spin transport in a semiconductor. Spin relaxation is explored in various III-V compounds for different dimensionality systems and Ge/Si core shell nanowire. The effect of temperature and driving electric field on spin relaxation length is investigated. The spin relaxation length increases with confinement of motion and decreases with temperature. Also spin relaxation length is weakly dependent on driving electric field.

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Title : *Analysis of Spin Transport in II-VI Semiconductors*
Author(s) : *Sharma Ashutosh*
Roll No : *Y7027097*
Supervisor(s) : *Ghosh Bahniman*

Abstract

The field of spintronics has emerged as a fusion of magnetism, nano-physics, micro-electronics and quantum mechanics. It is a growing area of research with new advances in technology coming up. It brings together two basic properties of an electron- charge and spin. This enables us to design devices with unprecedented capabilities, suggesting that it will dominate conventional electronics in future. Numerous semiconductor materials and structures are being investigated for use in spintronics. There has been significant progress in design of storage devices, memories through research for GMR, MRAM, spin-FET, spin-valves etc. Spin relaxation is a key factor in spintronics and for deciding suitability of a semi-conductor material for devices. We are studying spin transport using a semi-classical Monte Carlo method which involves spin density matrix calculations. There are various magnetic and opto-electric properties of a material which influence spin transport in a channel. There are various mechanisms which are responsible for spin relaxation, important ones being covered in this work. Since spintronics aims at utilizing both magnetism and conduction, there is a growing interest in Diluted Magnetic Semiconductors (DMS). Spin relaxation in II-VI semiconductor materials: CdS, CdSe, CdTe, ZnO, ZnS, ZnSe, ZnTe have been analyzed for nanowires and 2-D channel structure. Effect of magnon scattering is also studied in their corresponding II-Mn-VI DMS materials. Effect of varying driving electric field, temperature and concentration of Mn doping is being considered. Comparison has been presented between nanowire's and 2D channel's behavior

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Title : *Effect of Built-In Potential on Planar Heterojunction Solar Cell*

Author(s) : *K Nitesh*

Roll No : *Y7027186*

Supervisor(s) : *Baquer Mazhari*

Abstract

Understanding Bilayer heterojunction organic solar cell requires the study of several processes like exciton creation and diffusion; polaron pair generation, dissociation and recombination; free electron and hole generation; carrier transport through the Donor and Acceptor layers and carrier extraction at the electrodes. Since, a commercially available simulator doesn't exist; a custom simulator has been designed to simulate the bilayer solar cell. The simulator has been validated using a number of examples including a single layer-single carrier device and a bilayer solar cell, results for which were available in literature. The dependence of open circuit voltage on the work functions of cathode and anode has been studied with this simulator. The open circuit voltage (VOC) was found to be constant and independent of the built-in potential for the cases of efficient injection at electrodes, but once injection from either one of the contacts becomes inefficient, VOC reduced linearly with the reduction in built-in potential. The open-circuit condition occurs due to nullification of the generation of free carriers through polaron-pair dissociation by bimolecular recombination of the free carriers at the interface. This process has been shown to be independent of built-in potential for the case of efficient contacts thus resulting in independence of open circuit voltage. However, for the case of inefficient contacts, rate of recombination has been shown to depend on the barrier heights at the electrodes which in turn leads to a dependence of open-circuit voltage on the built-in potential. The dependence of open circuit voltage on the various other factors like mobility, polaron pair generation rate, etc. has been analysed. The variation with the polaron pair generation rate has been shown to have a slope of 0.05 corresponding to an ideality factor of 2 for high built-in potentials. However, for low built-in potentials, saturation was observed in the dependence of open circuit voltage on the polaron pair generation rate. An equivalent model was used to fit the current-voltage characteristics and model parameters were extracted under both light and dark conditions for different built-in potentials. Parameters like reverse saturation current density and ideality factor extracted from the dark characteristics of the solar cell match well with the same parameters extracted under light for high built-in potentials. However, for the case of low built-in potential solar cells, large discrepancies have been shown in these parameters. The ideality factor in the case of dark was 1.05, but when extracted under light, the ideality factor came out to be about 1.77. Similarly, the reverse saturation current extracted from light characteristics has been observed to be several orders of magnitude larger than the parameter extracted from the dark characteristics. The discrepancy in the values of these parameters in the case of lower built-in potentials was attributed to the large change in the rate of recombination at the interface between the light and dark cases

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Title : *Monte Carlo Simulation Studies Of Spin Transport In Graphene*
Author(s) : *Hiranandani, Dharmendra*
Roll No : *Y7027137*
Supervisor(s) : *Ghosh Bahniman*

Abstract

The research area of spintronics has been gaining momentum for quite some time now. With the extraction of single layer of honeycomb structure of graphite, termed graphene, and with its spectacular structural and spin transport properties, the research of spin devices has seen paradigm shift. In any spin based device, there are three fundamental processes – spin injection, spin transport and spin detection. It is the spin transport that this thesis investigates. Certain crucial areas that can affect spin relaxation length (or spin dephasing length) have previously been ignored during the course of theoretical study of graphene and its bilayer. Three crucial areas have been studied in this thesis. Firstly, we aim to take into account electron-electron scattering which shows its adverse effects when devices are operated at low temperatures. The second would be the effects of ripples and microscopic corrugations on graphene and its significant impacts at room temperatures. And third, the effect that magnetic substrate causes on the spin of graphene’s electrons through the spin wave particle called magnon. Semiclassical Monte Carlo simulation methods have been employed to study these scattering mechanisms. The spin relaxation lengths are studied at various temperatures and an attempt has been made to determine the dominance areas of different scattering mechanisms. Electron-phonon interactions are taken to be reference for comparisons with these new mechanisms.

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Title : *Four Phase Single Transistor Type Dynamic Logic for Improved Noise Margin and Speed*
Author(s) : *Paliwal Nishant*
Roll No : *Y7027262*
Supervisor(s) : *Mazhari Baquer*

Abstract

This thesis presents a Single Transistor Type Dynamic Logic (STTDL) design approach which uses only either N-type or P-type devices to implement digital circuits. Gated diode based voltage boosting technique is used to compensate the degradation of voltage due to threshold (V_T) drop across the MOSFET. Four-Phase Logic is used to address the problem of cascading of logic blocks. Performance comparison with static CMOS and Domino logic shows advantages in terms of both area and speed. Layout shows that area usage for basic 2-input, 3-input, and 4-input Nand gates implemented using N-type STTDL design is reduced by 40%-50% in comparison to area used by Domino logic and is slightly lesser in comparison to CMOS design. Moreover, simulation results show that gate delay can be reduced by 25%-40% in comparison to static CMOS or Domino gate. Reduction in gate delay decreases as voltage boosting level increases. It is also shown that the proposed logic promises even better performance for technologies where p-type and n-type devices have significant difference in their performance. The savings in area and improvement in gate delay are 40%-65% and 30%-50% respectively in comparison to static CMOS or Domino logic design where n-type and p-type transistor mobility differ by a factor of 10. Results are presented for basic logic circuits like NAND, NOR, Half Adder, Full Adder, 4-bit Shift Register and 4-bit carry lookahead adder to illustrate the proposed design and an approach for sizing the transistors and gated diode is presented to increase the speed of the circuit. Full Adder implemented using N-type STTDL design is compared with Full Adder implemented using CMOS and Dual-Rail Domino design. N-type STTDL Full Adder circuit proves to work as fast as Dual-Rail Domino Full Adder with speed reduction of 42% in comparison to static CMOS Full Adder and saves 38% area in comparison to Dual-Rail Domino design.

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Title : *A Four-Terminal Gate-Controlled Thin Film Organic Thyristor*
Author(s) : *Ashok Arjit*
Roll No : *10104017*
Supervisor(s) : *Mazhari Baquer*

Abstract

Devices that exhibit bistable or negative differential resistance (NDR) are interesting for memory and switching applications. Semiconductor devices exhibiting S-type NDR, commonly called thyristors, have been used in controlling the AC current in applications such as inverters, motor control etc. Although, there has been significant development in the field of flexible and printed electronics, the integration of a complete system using these techniques requires the development of a thyristor like device for power conditioning circuits. This thesis describes a novel device that exhibits such characteristics and is based on the principle similar to the conductivity modulation used in a unijunction transistor. This device consists of an accumulation mode Organic Thin-Film Transistor, in which the organic semiconductor is replaced with an organic heterostructure consisting of an Electron Transport Layer (ETL) and a Hole Transport Layer (HTL). In addition, an emitter electrode is added on top of the HTL between source and drain. Upon application of suitable voltages to gate and drain, NDR characteristic in the emitter current-voltage characteristics are observed due to conductance modulation caused by creation of another channel of current flow. Simulations of a Pentacene-C60 device with a channel length of 300 μm showed a Peak to Valley emitter voltage ratio of 2.54. It also showed low Peak current (0.1 nA/ μm) and two orders of magnitude higher Valley current (13.4 nA/ μm). The proposed device also has the advantage that peak and valley voltages can be tuned by gate and drain biases. Preliminary attempts at fabrication of this device failed, as the C60 is not air-stable. Another challenge faced was the alignment of the shadow mask, for emitter electrode, between the source and drain electrodes.

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Title : *Analysis of DC Current-Voltage Characteristics for Measurement of Built-in Voltage and Mobility*
Author(s) : *Mantri Prachi*
Roll No : *Y7027289*
Supervisor(s) : *Mazhari Baquer*

Abstract

Since an organic semiconductor has very few free charge carriers of its own, for a better device performance, their injection from the electrodes becomes of prime importance. For this purpose, metal-organic interface behavior needs to be understood. One approach to study it can be through built-in voltage (V_{bi}) in a single layer organic device. Methods to accurately measure V_{bi} exist, but some of them are complicated enough that they cannot be routinely done and others are quite sensitive to the presence of traps in the device. In this thesis, a simple technique to extract V_{bi} from the DC dark I-V characteristics of organic single layer devices is presented. The method is based on observing a peak in the derivative curve of the log-log plot of I-V characteristics which occurs due to presence of V_{bi} across the device. It is shown to be fairly accurate even when traps are present. Single layer devices were fabricated with different cathodes using P3HT or MEH-PPV as active material. Peaks observed using the proposed method were fairly consistent. Devices with P3HT:PCBM blend with Al or Ca/Al as cathode were also fabricated and interesting observations were made. Another important parameter which affects device performance in terms of switching speeds and charge transport is mobility. One of the common techniques for estimating mobility is through space charge limited current (SCLC). It is shown that mobility extracted in this way can lead to a high percentage of error. An improved SCLC model for mobility extraction is proposed using which, the percentage of error reduces by more than 50%. Lastly, another useful technique to analyze the dark I-V characteristics in detail is described which gives regions of different slopes suggesting a particular behavior of the device in a specific region. It helps to locate an exponential region initially showing the presence of V_{bi} . It also assists in clearly identifying the presence of traps and associating a trap filling voltage with them, which is claimed to be a measure of trap concentration. Also, the method was used for V_{bi} estimation and the extracted values were found to be in good agreement

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Title : *Process Developments for Making a Monochrome Passive Matrix OLED Display with Novel Integrated Shadow Mask*
Author(s) : *K Naveen Kumar*
Roll No : *Y7027248*
Supervisor(s) : *Anand Raghubir Singh; Iyer S Sundar Kumar*

Abstract

In present scenario, displays have a significant role in day to day life. Electronic displays in different forms are present in numerous products ranging from calculator to large flat panel screens. The LCD displays have a major share in market among present display technologies. However, LCD and other display technologies have limitation of higher power consumption, viewing angle, back-lighting, larger weight and are fragile. Displays based on organic light emitting diodes (OLED) have made significant progress in past two decades as they do not suffer the limitations mentioned above. 'Active matrix (AM)' and 'passive matrix (PM)' are two ways in which an OLED dot matrix display can be made. Present work is concerned with developing few processes used in fabricating PM display. ITO surface treatment, optimization of different organic layers for thickness, carriers' mobility, efficiency, and novel approach of making integrated mask has been experimented. High quality Transparent Conductive oxide (ITO) is required for making OLED display. As deposited ITO has large rms roughness, high peaks unevenly distributed across the surface, low conductivity and un-optimized work function, no display will work properly without proper surface treatment. To improve the ITO surface parameters, sulfuric acid, 7% NaOH, 15% NaOH treatments have been done. Though the expected improvement in conductivity and roughness is not achieved with the treatments, I-V-L characteristics of devices are improved. We have observed sulfuric acid and NaOH treatments are compatible to organic materials CuPC and m-MTDATA respectively. To make PMOLED display using integrated mask, small molecules m-MTDATA and CuPC are experimented in place of PEDOT as Hole Injection Layers (HIL). For the first few runs of device fabrication with m-MTDATA as HIL, no device and hence no Electroluminescence was observed. As the problem of high temperature during sealing was diagnosed and arrangements were made to cut off heat during sealing, we started getting OLEDs with good EL. Further, optimizations of different organic layers for thickness, doping of HTL with F4-TCNQ and ETL with LiF for better conductivity and higher efficiency are carried out. The best result is obtained with CuPC as HIL in PIN device structure. A novel integrated shadow mask with strips of Silicon Dioxide having tapered overhang on both sidewalls has been proposed and implemented. This mask being made of SiO₂ has the potential of being robust and hard, and can be subjected to proper cleaning treatments such as RCA1. Further work and issues are discussed to improve various processes to get a working PM dot matrix display.

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Title : *Digital Design Using Quantum Cellular Automata*
Author(s) : *M Giridhar*
Roll No : *10104039*
Supervisor(s) : *Ghosh Bahniman*

Abstract

Quantum dot Cellular Automata (QCA) is a transistor less computational model which is expected to provide high density nanotechnology implementations of various CMOS circuits. QCA has been constrained by the number of basic gates available. This thesis aims at familiarizing the new nanotechnology. Following which implementation of various logic circuits using the architecture embedded in the technology. Further more introducing better circuits which are more compact and less complex. Also this thesis aims at using five input majority gate to implement two adder circuits achieving implementation in lesser number of cells and higher density.

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Title : *Implementation of VLSI circuits in Single Spin Logic Paradigm*
Author(s) : *Shukla Soumitra*
Roll No : *10104094*
Supervisor(s) : *Ghosh Bahniman*

Abstract

The VLSI industry from long time was driven by the Moore's Law who in 1965 predicted that VLSI industries will double its effectiveness roughly in every 18 months. In the recent times this law has started losing its significance because any further miniaturization of silicon devices is coming to a standstill because of the problem of power dissipation. Amidst this the newly emerging field of Spintronics has shown some new interesting methods of building circuits. One of these methods uses, a single electron, a quantum dot and magnetic field. This style of building circuits is called Single Spin Logic Paradigm. In this thesis we show the implementation of some common circuit with different number of elements and complexity in this paradigm. In the second part of the thesis we will solve the famous Landau-Lifshitz-Gilbert equation of magnetism for thin films numerically. For this we will use classical Runge-Kutta algorithm and write the code in MATLAB. We will use a simple macro spin 3D model for the entire physical phenomenon's those contribute in the magnetization dynamics of thin films. Later we will run the written codes for some of the test cases and analyze the behavior of the output that we get. In the end we will discuss the drawbacks and limitations present in the code

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Title : *Fabrication, Annealing and Degradation study of P3HT:PCBM based Organic Solar Cells on PET*
Author(s) : *Priyankar Navesh*
Roll No : *Y7027249*
Supervisor(s) : *Iyer S Sundar Kumar*

Abstract

In this thesis, some processing and reliability issues of Organic solar cells (OSC) on flexible polyethylene terephthalate (PET) substrates have been studied. Firstly, the effect of surface treatment of hydrophobic ITO coated PET has been studied. Secondly, the effect of solvent vapour annealing on P3HT:PCBM blend is studied and the possibility of substituting it for thermal annealing has been explored. It appears performing comparable to thermal annealing in terms of film morphology as well as device efficiency with significantly lower processing time. Finally, some initial work on increasing the stability and lifetime of devices on PET has been carried out by using commercially available cyclic transparent optical polymer (CYTOP) to encapsulate OSC on PET. It has been seen that the use of CYTOP mitigates the initial degradation observed in unencapsulated devices. The processing for these devices was optimized for the Organic Processing Laboratory in IIT Kanpur to obtain a power conversion efficiency under AM 1.5 one sun illumination of 0.25%.

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Title : *Study Of RTDS And Effect Of Scattering Using NEGF*
Author(s) : *Shah Sourav*
Roll No : *Y7027443*
Supervisor(s) : *Ghosh Bahniman*

Abstract

With continuous scaling of CMOS devices, it became necessary to explore alternative devices which can provide high frequency performance with lower power densities. Resonance Tunneling Diode (RTD) has a lot of promise in this regard. In this thesis we perform a comprehensive analysis of modeling of RTD based on quantum-mechanical model. Non-equilibrium Green's function (NEGF) formalism has been used to obtain the I-V characteristics of the RTDs. Four different RTD structures based on AlAs/GaAs, HfO₂/Si, HfO₂/Ge and AlAs/InSb have been analyzed with barriers of RTDs made up of AlAs and HfO₂. Other performance characteristics of the device like negative differential resistance (NDR) and Peak-to-Valley Current Ratio (PVCR) has been discussed. Variation in I-V characteristics with variation of well-width and barrier- width has been plotted and their causes have been analyzed. The effect of acoustic phonon scattering on the performance of the devices has also been discussed in detail for all the cases. It has been observed that AlAs/GaAs RTDs have the best performance but the performance, of other RTDs can be matched with that of AlAs/GaAs RTDs by varying the well width and the barrier widths. Moreover, we observe that the acoustic phonon scattering have a significant effect on their performance

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Title : *Design and Realization of Dielectric Resonator Based Single and Dual Mode Bandpass Filter*
Author(s) : *Shukla Nishant*
Roll No : *Y9104048*
Supervisor(s) : *Biswas Animesh; Srivastava Kumar Vaibhav*

Abstract

The requirement of a wideband microwave filter is very common in modern communication system specially in advance communication satellites where it is required to comply with the least loss, better selectivity, desired flatness as well as least possible weight. Dielectric resonators are one of the best solutions for the miniaturization as well as for the higher-Q realization. In this thesis overall design process of single and dual mode bandpass filter has been illustrated. The TE₀₁ mode, which is a dominant mode of a cylindrical DR, having high dielectric constant has been utilized for the realization of single mode while higher order modes called hybrid modes, are utilized for dual mode bandpass filter. The main advantage of dual mode filters over single mode filters is the miniaturization of the filters physical structure while having the flexibility of realizing elliptic functions. The draw-back of the dual-mode dielectric resonator filters is their inferior spurious characteristics. Cascaded quadruplet (CQ) topology has been considered as the best suited method for the realization of the microwave filters. Cascaded triplet (CT) topology is also a popularly used topology which produces single transmission zero. Each CQ is responsible for the production of a specific TZ pair. For the CQ case, the two zero pairs can lie on the real axis or on the imaginary axis or one pair on the each axis. The cross coupling in the CQ is positive if the TZ pair that it is realizing is on the real axis, and negative if the pair is on the imaginary axis. In the case of Dielectric resonator based filters, positive coupling is realized by having an iris between resonators while negative coupling can be realized by using a metallic probe. Designed single and dual mode bandpass filters have been fabricated and measured

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Title : *Microwave Modeling and Characterization of Metamaterials*
Author(s) : *Anagha Sudha Madhuri*
Roll No : *10104010*
Supervisor(s) : *Akhtar M Jaleel; Biswas Animesh*

Abstract

A rectangular waveguide approach for measuring complex permittivity and permeability of metamaterials in the microwave frequency band is presented. The proposed approach makes use of the measured transmission and reflection coefficients of the test samples by placing them into a section of rectangular waveguide of appropriate dimension. The rectangular waveguide approach has widely been used to measure dielectric properties of simple dielectric and composite materials. However, they have not quite frequently been applied to characterize metamaterials due to many complexity involved with these kinds of artificial materials. Metamaterials are artificially fabricated structures, which are usually realized in terms of the periodic repetition of the fundamental element called unitcell. Four different types of unitcell structures are considered in this work, which are simulated using the full wave electromagnetic field simulators in order to estimate their equivalent reflection and transmission coefficients in the prescribed band. The simulation is carried out in free space as well as in the waveguide media. The effective dielectric and magnetic properties of these unitcell structures are determined using the proposed method, and these data are compared with the published results. The effect of real part of permittivity and permeability with the variation of each parameter of metallic inclusion is analyzed under parametric analysis. After validating the proposed method with the help of simulated data, a number of unit structures are fabricated in order to measure those using X-band rectangular waveguides. The unitcell structures are repeated along the cross-section such that they precisely fit into the inner dimensions of the X-band waveguide. The scattering coefficients of these metamaterial samples placed into the waveguide are measured using the vector network analyzer. Finally, the complex permittivity and permeability of these samples are reconstructed from the measured scattering coefficients data using the proposed method. A comparison is made between the simulated and the experimental results, and any difference between the actual and the determined values is properly analyzed.

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Title : *A study on Locally One-Dimensional FDTD Technique and its application in modeling of Left-Handed Metamaterials*
Author(s) : *Singamaneni Sateesh Kumar*
Roll No : *10104091*
Supervisor(s) : *Srivastava Kumar Vaibhav*

Abstract

Time domain methods in computational electromagnetics has seen greater light because of their potential to accurately model and simulate problems with broadband response. In particular, the demands for efficient analysis of the high-frequency broadband structures has led to the development of time domain techniques. As a result, the finite-difference time-domain (FDTD) method proposed by K. S. Yee in 1966, has been developed and widely accepted in solving electromagnetic problems. However it's capability of handling electrically large or high-Q structure problems is limited by the requirements of large computation memory and time. Such requirements are due to the numerical dispersion errors and the Courant- Friedrich-Lewy (CFL) stability condition. Therefore, we study the numerical technique with focus on reducing both the computational time and computer memory requirements. In this thesis we study a numerical technique which alleviates or overcomes the timestep size problem due to CFL stability condition. In order to overcome the CFL stability constraint unconditionally stable Locally One-Dimensional (LOD) FDTD technique is used. In this 3-step LOD-FDTD the time-step is split into three sub-steps such that each substep corresponds to variation only in one direction. Now, using this algorithm time step is no longer restricted by the CFL stability condition but by the modeling accuracy of the LOD-FDTD algorithm. Numerical results are presented to demonstrate the time saving and stability of the 3-step LOD-FDTD method and hence it is found that the LOD-FDTD method has advantages over the conventional FDTD scheme in modeling structures with fine geometry. LOD-FDTD allows the use of a much larger time step while numerical dispersion errors remain acceptable. Of late new class of materials called metamaterials has emerged. These artificial materials with their unusual constitutive parameters possess immense potential applications such as super lens imaging and focusing. In this thesis wave propagation inside the metamaterial is shown using LOD-FDTD technique. The metamaterials are modeled using a Drude constitutive parameter model to include their dispersive effect.

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Title : *CPW Fed Wideband Patch Antenna Using Slots And
Multiband Patch Antenna Using Metamaterial Loading*
Author(s) : *Vepuri Niranjan*
Roll No : *10104103*
Supervisor(s) : *Srivastava Kumar Vaibhav*

Abstract

Planar patch structures are very attractive for WLAN antenna design because they have low-profile; they can be etched on a single substrate and can provide the feature of broadband and multiband antennas. In most of the broadband and multiband antennas design, coplanar waveguide feeding technique (CPW) is used because of the advantages like less radiation from the feed structure, wider bandwidth and integration with the microwave monolithic integrated circuits (MMICs). Metamaterials (MTM) are the artificial structures engineered to exhibit unusual electromagnetic properties such as anti-parallel phase and group velocities and negative refractive-index. Due to these unusual properties, MTMs are widely used in antenna applications. In this work, three antennas which are fed by the CPW transmission line and are used in WLAN applications are proposed. First one is CPW fed slot patch antenna which includes the two rectangular slots inside the patch. Due to the inclusion of the slots, three resonances will be excited when combined gives a wide band response. The antenna has 30 % higher bandwidth compared to the conventional patch antenna. This antenna can be used in 5.2/5.8 GHz WLAN application. Second structure is CPW fed Tri-band antenna with metamaterial loading which uses metamaterial-inspired loading underneath the substrate in addition to the rectangular patch structure which is fed by a CPW transmission line on the top of the substrate. This antenna gives three resonances at 2.3 GHz, 3.6 GHz and 5.5 GHz respectively. Tri-band Antenna has been fabricated using photolithography technique and tested. This antenna finds the application in upper Wi-Fi band (5.15 – 5.80 GHz) and Wi-MAX band (3.3 – 3.8 GHz). Finally, the third one is CPW fed slot patch antenna with metamaterial loading which uses metamaterial-inspired loading underneath the substrate in addition to the slot patch structure. By using the MTM loading we can create another resonance at 3.55 GHz in addition to the resonance of 4.6 GHz due to the patch with slots structure. This antenna finds application in upper Wi-Fi band (5.15 – 5.80 GHz) and Wi-MAX band (3.3 – 3.8 GHz).

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Title : *A Novel Design Approach of Microstrip Based Radial Power Combiner/Divider*
Author(s) : *Das Sayan*
Roll No : *10104086*
Supervisor(s) : *Biswas Animesh; Srivastava Kumar Vaibhav; Jain Akhilesh*

Abstract

Power combiner/divider structures are widely used in microwave frequencies to combine the output powers from several amplifier units which overcome the limitation of high power handling capacity of microwave transistors. There are different varieties of power combiners available, but N-way power combiners are widely used for their capability of combining power from several units in a single step. Among different N-way combiners, radial combiners have proved to be efficient. Radial combiners can be designed in strip line, microstrip line or waveguide medium, but microstrip combiners are comparatively easier to fabricate. Depending on the nature of application, these combiners can be designed for operating as narrowband or wideband device. In this thesis, a design technique of 16-way dual band microstrip radial power combiner is given at two different frequency ranges. One of them gives good response at L and C band, and another gives good response at C and Ku band. The achieved input to output coupling is -12 dB, and isolation between peripheral ports is more than -15 dB, which are in good agreement with theoretical results. The results are almost same for dual frequencies

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Title : *Design of Multilayer Microwave Absorbing Materials and Constitutive Parameter Extraction of Metamaterial Absorbers*
Author(s) : *Baradiya Hitesh*
Roll No : *10104046*
Supervisor(s) : *Srivastava Kumar Vaibhav*

Abstract

The two most often employed radar cross section (RCS) reduction techniques are shaping and use of radar absorbing materials. The modification of an aircraft's shape is limited to certain aerodynamic principles. Recent design for RCS reduction approaches for a balance between shaping and other reduction techniques. The technique is based on an arrangement of dielectric or magnetic materials that present the appropriate impedance to the incident wave. The design goal, therefore, is to determine a coating consisting of N layers, such that coating exhibits a low reflection at a prescribed set of frequencies for parallel and perpendicular polarizations. Genetic algorithm (GA) tool of MATLAB has been used for optimization of multilayered coating. This algorithm offer several advantages over the existing optimal control and simulated annealing (SA) techniques. The concept of metamaterials, exhibiting negative permittivity and permeability, is attracting a lot of attention. Such materials are also termed left-handed materials (LHMs). In the frequency domain all materials can be described electrically by their complex permittivity (ϵ) and permeability (μ). These constitutive parameters determine the response of the material to electromagnetic (EM) radiation. This thesis also examines a method to determine the effective permittivity and permeability of both conventional materials and metamaterials. Ansoft HFSS is used to model the materials in free space environments to calculate the S-parameters (S11 and S21) from which the constitutive parameters are extracted.

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Title : *A Novel Design Approach of Triple Band Wilkinson Power Divider using Dielectric Resonator*
Author(s) : *Srivastava Mrigank*
Roll No : *10104060*
Supervisor(s) : *Biswas Animesh; Srivastava, Kumar Vaibhav; Jain Akhilesh*

Abstract

Wilkinson power divider is one of the most essential circuits in RF design field used mainly for power division or combination in different microwave circuits such as mixers, balanced amplifiers, and antenna array etc. Nowadays wireless telecommunication industries require multi-band operation devices. Here a novel design of triple band Wilkinson power divider using dielectric resonator is presented. This design is operating not only at one frequency f_0 but also at its first two odd harmonics i.e. $3f_0$ and $5f_0$. Dielectric resonator is used as a high permittivity load. All the features of a conventional Wilkinson power divider, such as an equal power split, impedance matching at all ports, and a good isolation between the two output ports, can be fulfilled at $3f_0$ and $5f_0$. Moreover, in this design size reduction techniques are also applied to make it more compact. Operating first bands centre frequency is 650 MHz and other two bands are in L and S band respectively. First band centre frequency is according to the requirement of RRCAT Indore

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Title : *A Novel Matching Circuit Design For A Low Noise Amplifier Using Composite Right/Left Handed Transmission Lines*
Author(s) : *Dube Satvik*
Roll No : *Y7027397*
Supervisor(s) : *Srivastava Kumar Vaibhav*

Abstract

It has become increasingly vital to opt for miniaturization in order to increase the integration density, minimize power loss and ultimately reduce the cost of the network for wireless and satellite technology which forms the motivation for this thesis. In this thesis, the design issues namely the gain, noise figure, stability of a low noise amplifier present at the receiving front end of a wireless network, are investigated. For the analysis of noise, the model proposed by Rothe and Dahlke is employed. A technique for the reduction of noise using a feedback inductance is discussed and a network consisting of components nullifying the defects induced mutually providing a reasonable balance between gain and noise figure, while providing stability to the amplifier, is developed at 2.5 GHz. In this thesis, the main objective is to miniaturize the area of the input and output matching networks using the concept of composite right-left handed transmission lines. The matching is first carried out at 2.5 GHz, by the conventional process of normal transmission lines. It is then replaced by the balanced lumped single unit cell model of the CRLH line whose parameters are optimized to yield the desired performance followed by the balanced lumped two unit cell model. The microstrip realization of these models are developed using microstrip transmission lines, short stubs and interdigital capacitors and the various design parameters involved are optimized for gain, noise figure and stability of the LNA, taking the homogeneity consideration into account. The resulting LNA from the one unit cell model is found to yield a gain of 15.231 dB with a noise figure of 1.528 dB and an unconditionally stable operation at 2.5 GHz while the LNA from the two unit cell model yields a gain of 15.245 dB, a noise figure of 1.635 dB while maintaining an unconditionally stable operation at 2.5 GHz. The areas for the input and output matching sections for the one unit cell model are found to be reduced by 72.03% and 46.70% respectively. Similarly, for the two unit cell model, areas for the input and output sections are reduced by 80.52% and 84.73% respectively, thus leading to the miniaturization of the matching networks to a large extent.

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Title : *A Novel Annular Shape Microstrip Feeding Technique For Ring Dielectric Resonator Antenna For Wideband Applications*
Author(s) : *Kumar Rajnish*
Roll No : *10104074*
Supervisor(s) : *Srivastava Kumar Vaibhav*

Abstract

Dielectric resonators have been widely used in shielded microwave circuits such as filters and oscillators. The dielectric resonator antenna employs the idea of using dielectric resonator in unshielded environment in order to radiate. The small size, low conduction and dielectric loss and different radiation characteristics due to different modes excited, makes them an attractive element to be used as an antenna. The choice of a wide range of dielectric constant and different shapes and sizes is also an advantage. The far-field radiation pattern of dielectric resonator antenna is a characteristic of the resonating modes. For a broadside pattern, hybrid mode is suitable. In this thesis, an annular shape microstrip feed has been designed. This microstrip feed is used to excite four different shapes of dielectric resonator antenna: Ring dielectric resonator antenna, Half-split ring dielectric resonator antenna, Cylindrical dielectric resonator antenna and Half-split cylindrical dielectric resonator antenna. The proposed feed is able to excite a hybrid mode in the dielectric resonators and because of the proposed feeding technique, the antenna offers a wide bandwidth with broadside radiation patterns. Among all the structures of dielectric resonator, the half-split ring dielectric resonator offers maximum bandwidth of 74.87% at a center frequency of 5.77 GHz.

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Title : *A Dual-Band Hexagonal Patch Antenna Based On Complementary Split Ring Resonators*
Author(s) : *Sidana Yash*
Roll No : *Y7027519*
Supervisor(s) : *Srivastava Kumar Vaibhav*

Abstract

The present work concerns with designing a dual band microstrip antenna based on (CSRR) with improved bandwidth than the conventional microstrip antenna. Hexagonal radiating patch has been used instead of a rectangular patch because of its wideband characteristics. CSRR has been etched on the ground plane instead of the patch which minimizes interference with the radiation of the patch and hence enhances gain. Two configurations have been designed and analysed in this thesis, using a single CSRR and two CSRRs respectively. With the single CSRR structure dual band response is obtained at 2.38 GHz and 5.23 GHz with -10dB bandwidth of 154 MHz and 180 MHz respectively. On the other hand, the two CSRR structure obtained -10dB bandwidth of 134 MHz and 210 MHz at the two resonant frequencies of 3.47 GHz and 5.65 GHz respectively. These structures obtained an increase in the bandwidth by more than 300% at first resonance and more than 50% at second resonance frequency.

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Title : *Design of coplanar sensor for complex permittivity measurement of dielectric samples*
Author(s) : *Shete Manisha*
Roll No : *10104057*
Supervisor(s) : *Akhtar M Jaleel*

Abstract

In the recent years interest in planar devices is increased due to their miniature size, low cost compared to waveguide and range of frequency operation. Hence sensors using microstrip and coplanar devices are being investigated in recent years. Coplanar has advantage over micro strip that it is less dispersive than microstrip its impedance remains constant from 0.5 to 40 GHz, hence coplanar is ideal for broad band permittivity extraction of dielectric samples. This work explores measurement of permittivity of thin samples using coplanar waveguide. In this work a conductor backed coplanar is designed for 50 ohms, the air gap between conductor and side grounds is kept small so that fields confine to the air gap and we have even mode field. Then sample whose permittivity is to be measured is placed freely on top of this sensor, this is referred as MCCPW (Multilayered Conductor backed Coplanar Waveguide). Scattering parameters are measured using V.N.A (Vector network analyzer), to reduce effect of higher order modes the sample is placed at the center of coplanar waveguide. There is no requirement on dielectric samples to be measured only its surface should be flat for good contact with coplanar waveguide. From measured scattering parameters at the coplanar ends T matrix approach is used to obtain S parameters at the sample interface then reflection and transmission coefficient is calculated, in the measured frequency band using transmission/reflection theory to calculate effective permittivity of the MCCPW structure. Fill factors are calculated from geometry of the structure and by using effective permittivity and fill factor of the structure permittivity of the sample is extracted. In this thesis, a special algorithm is developed in order to avoid the ambiguity of the achieved solution for complex permittivity, which usually occurs when the electrical length of the test sample is more than a wavelength. It may be mentioned here that for extracting the permittivity of low loss samples, longer specimens are preferred as the accuracy of the extracted permittivity is usually low for shorter samples. It is also to be noted that for samples having higher permittivity, the physical length of the test specimen would have to be chosen as very small if the proposed algorithm is not applied. From practical point of view, the advantage of the technique proposed in this thesis is that our experimental setup employs only two SMA to coplanar end launchers instead of the expensive microwave probe stations usually being used in the past for carrying out such kinds of measurements. The effects of the coplanar end launchers in this work are taken into account by a simple de-embedding technique using the transmission matrix approach

Title : *Design and Development of Microwave Filters based on Coplanar Waveguide(CPW) using an Inverse Scattering Approach*
Author(s) : *Prasad Harishankar*
Roll No : *10104044*
Supervisor(s) : *Akhtar M Jaleel*

Abstract

In recent times, as microwave and communication systems have grown up tremendously, the size reduction has become important in order to make more compact equipments. Microwave filters find extensively use and may be seen today in many communication equipments. In this thesis, a novel approach is proposed to design coplanar waveguide based microwave planar filters using the inverse scattering technique. The proposed method is basically based on the solution of an inverse scattering problem to get one dimensional impedance profile, which is then transformed into geometry of the appropriate filter to satisfy the specified pass-band characteristics (i.e., frequency response of filter). The above approach involves solving one dimensional Riccati differential equation using a newly proposed renormalization technique, which is then inverted for obtaining the impedance profile in terms of the Inverse Fourier transform of the spectral domain reflection data. The impedance profile is finally converted into the coplanar waveguide geometry using standard relationships, which is then fabricated for any desired application. In this dissertation; firstly we have fabricated microstrip filters to validate our proposed approach. Their responses of simulated result as well as measured results are within specified limits. Secondly we extend the above explained method to coplanar waveguide (CPW) geometry. The main emphasis in this thesis is the coplanar waveguide geometry as it reduces size of filter and can be easily integrated with microwave monolithic integrated circuits. Finally an algorithm for coupled line filters design, is also developed

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Title : *Microwave Imaging of Dielectric Objects from Band Limited Reflection Data*
Author(s) : *Kumar Ashutosh*
Roll No : *10104021*
Supervisor(s) : *Akhtar M Jaleel*

Abstract

Reconstruction of the permittivity profile of multilayered dielectric media is of considerable interest in various fields. The ability of microwaves to penetrate inside dielectric media makes microwaves techniques extremely suitable for analyzing structures made of multilayered dielectrics. The penetration of the microwaves through certain bodies makes them a convenient agent for the non-invasive imaging and testing of materials and objects. This thesis mainly deals with the technique of depth-dependent permittivity profile reconstruction for planar and stratified objects from the measurement of band limited reflection coefficient data in the microwave frequency range. The overall procedure is based on solving the corresponding inverse scattering approach using the proposed renormalization technique. The main advantage of the proposed technique is that it can be used to generate the dielectric image of the object under practical cases when the measurements can be taken only in certain frequency band. In our study we have developed an approach for investigating the interaction of microwaves with the dielectric object. The mathematical formulation and the appropriate theory for the analysis of planar dielectric objects and media have been developed. The methods for solving the corresponding inverse scattering problems have been proposed, and they have been successfully applied in cases of planar media and waveguide problems. The inhomogeneous permittivity profiles of a number of multilayered and stratified media have been reconstructed using the proposed scheme. The reconstructed dielectric images have been validated using both the simulated and the experimental data.

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Title : *Development of Waveguide Based Microwave Sensor for Characterization of Hazardous Liquid Chemicals*
Author(s) : *Batham Sushil Kumar*
Roll No : *10104090*
Supervisor(s) : *Akhtar M Jaleel*

Abstract

A simple, efficient and nondestructive, rectangular waveguide (RWG) based microwave sensor is developed for the electromagnetic characterization of hazardous liquid chemicals. The proposed approach makes use of the measured transmission and reflection coefficients of the liquid sample, which is facilitated by placing the custom built sample holder filled with the liquid specimen into a section of rectangular waveguide of appropriate dimension. The TRL calibration procedure is applied for the calibration of the waveguide system using the waveguide calibration kit. The proposed method is intended to be mechanically suited for holding liquid samples into the waveguide. A specialized WR-90 (X-band) waveguide section was designed and fabricated for the measurement of the scattering coefficients of liquid sample using the proposed approach. The liquid specimen was filled into a cuvette, which is basically a commercially available square shaped polystyrene holder especially customized for the present experimental setup, in order to fit it into the waveguide section. The complex relative permittivity of the test specimen is reconstructed from the measured scattering coefficient using an accurate analytical model in combination with a numerical optimization process. The numerical optimization approach makes use of the commercially available 3-D electromagnetic field simulator in order to simulate the actual experimental setup to generate the reflection and transmission coefficients. These simulated scattering coefficients are then compared with the measured reflection and transmission coefficient data obtained from the VNA, and the error between the simulated and the measured scattering coefficients are minimized using suitable optimization routines to find the complex permittivity of liquid material. The initial values for the optimization routines are obtained using the proposed analytical model. The proposed waveguide based sensor allows the electromagnetic characterization of liquids in a noninvasive and nondestructive way, thus making it very well suited for the rapid electromagnetic characterization of chemical warfare liquid agents. The complex permittivity of a number of liquid dielectrics, such as ethyl alcohol, glycol and distilled water and for a 2-chloroethyl ether, which is simulants of the sulfur mustard (Blister Agent), a chemical warfare agent, for 5% and 10 % concentration with distilled water are measured using the proposed approach. The measured data are compared with the published data as well as with the data obtained using the traditional open ended coaxial probe technique in order to validate the measured values

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Title : *Microwave Modeling of Mixed Dielectrics and Metal Dielectric Composites*
Author(s) : *Gupta Tannu*
Roll No : *10104096*
Supervisor(s) : *Akhtar M Jaleel; Biswas Animesh*

Abstract

In recent years there is a lot of interest to sinter and process ceramics and metal dielectric composites with Microwaves. This is because of certain advantages offered by microwave heating such as reduced cycle time, selective heating, low energy requirement, etc. However, the complex interaction of microwaves with metal-dielectric composites is not clearly understood. This thesis aims to design an appropriate homogeneous model of the metal-dielectric composites and then calculate its medium properties (effective permittivity and permeability) at frequencies 2.45GHz and 30GHz, commonly used for Industrial Microwave heating. In Microwave antenna modeling, the unit cell concept is used to design arrays of radiators. Similar concept is used here to model the metal-dielectric composites in terms of properly defined Unit cells. Suitable design parameters are used to satisfy both the microscopic and macroscopic specifications of the composites. The effect of packing fraction of the composites, size of the metal particle, gap between the particles and presence of metal-oxide on the medium properties are also studied here. To extract the permittivity and permeability values, the S-parameters of the Unit cell design are calculated and used in the developed retrieval algorithm. In order to design the Unit cell for the metal-dielectric composites, simpler case of mixed-dielectrics (dielectric-dielectric composites) are analyzed first. Their medium properties are verified by well established mixing laws (Maxwell-Garnett mixing rule and Logarithmic Law of mixing). After validation using the mixed dielectric, a number of metal dielectric composite structures are considered. Appropriate Unit cells are defined in each case in order to compute the scattering coefficients. The effective dielectric and magnetic properties are then estimated from the S-parameters of the proposed approach. The unit cell approach is also compared with the waveguide approach to confirm its validity. For waveguide case, the cross section of waveguide is filled by appropriate number of unit cell. Using this model, S-parameter values are obtained and then used to extract the permittivity and permeability values for waveguide case. The permittivity and permeability values of two approaches are found to be in good agreement.

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