Proposal I

Raju Kumar Gupta (Chemical Engineering, IITK)
and
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Nano-structuring of materials for energy and environment by molecular assembly

Nano-structured materials have been increasingly gaining interest and attention because of their attractive properties. However, their eventual use for real-life applications will depend on tuning their properties to the desired degrees and in developing low-cost methods of fabricating them with high reproducibility and reliability. We will investigate the feasibility of developing methods for fabricating composite and hybrid structures involving metal, oxide and semiconductors in combination with carbon-based constituents for applications in energy, environment and sensing. The objective is to understand the structure-property relationships among the constituents and to tailor the materials and fabrication so that desired properties are exhibited.

Cost-effective processing methodologies are of specific interest.

Proposal II

Automated Program Repair
(Proposal for NUS-IITK Joint PhD Programme)

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Software systems are growing exponentially, bigger and complex systems being created at a scale that was almost unimaginable a decade back. Program debugging and bug-fixing, always an demanding task on the intellect and patience of a programmer, has become increasingly difficult, and has rightly been demanding tool support from the research community.

The last few years have encouraged a plethora of debugging tools, drawing techniques from the areas of statistical inference to formal methods. Since program debugging is time-consuming, researchers have studied the possibility of automated program repair, which can be enunciated as follows. Given a program specification (in the form of test-cases or invariants) and a buggy program, can the bug be fixed automatically by a repair tool? Though multiple solutions have emerged, progress has been slow owing to the difficulty of the problem.

In this thesis, we propose to investigate in automated program repair along the following directions:

_ Design of new repair algorithms that are capable of fixing multi-statement defects and missing-statement errors: The state-of-the-art repair algorithms based on formal methods such as SEMFIX, hinged upon symbolic execution and program synthesis, only allow repairing of one statement at a time. In other words, if a program has a bug that is fixable by changing at least two statements, then repair fails. Moreover, the current repair techniques fail to deal with missing statement errors (i.e. bugs that require a new statement to be introduced). We propose to design newer algorithms that deal with these shortcomings.

_ Automatic synthesis of on-the-fly workarounds at runtime: A recent interest has emerged in the area of automatic workarounds: if a software system encounters a buggy execution (due to a thrown exception or

a assertion violation), an embedded runtime automatically restores the program to a previous checkpoint and executes an alternate sequence of statements that is semantically equivalent but does not exhibit the bug. These techniques inherently use the inherent redundancy in software to search for an alternate route of execution. However, as it is dependent on such redundancy being available, the scope of such techniques is somewhat limited. We propose to investigate if we can use program synthesis techniques to synthesize workarounds that avoid the bug. This completely subverts the debugging activity and generates repairs/patches which pass the necessary test cases.

_ Program repair and workarounds for security: Security has emerged as one of the top concerns in the software world. We propose to work on the design of on-the-fly workarounds such that security constraints are never violated, such as avoiding access control errors.

_ Combining evolutionary and formal repair algorithms: The research community is currently approaching program repair from two directions. On one hand, algorithms based on genetic programming attempt to use crossover and mutation operations to construct a repair. Though slow, these techniques are capable of supporting a large class of repairs. On the other hand, techniques based on formal methods (using symbolic execution and constraint solving) are often more efficient but support a smaller class of fixes. One immediate question that emerges is if these two orthogonal techniques be fused into an effective algorithm that draws the benefits of both these techniques.

Proposal III

Femtosecond Superresolution Microscopy developments with Chemical Bioimaging
Debabrata Goswami (IITK) & Young-Tae Chang (NUS)

A novel approach of using pulse pair and pulse train approach in conjunction with the Diversity Oriented Fluorescence Library Approach (DOFLA) would be developed for achieving super-resolution microscopy. Present developments and demonstrations on a few select fluorophores would benefit immensely from the fluorescence library technique and as such it would be a collaboration of the strengths of the developments of both the labs. The fluorophore synthesis and development would be performed at NUS while its applications to super-resolution microscopy with pulse laser technique would be pursued at the IIT Kanpur lab.

Proposal IV

Nanophotonics with optically confined nanoparticles
Debabrata Goswami (IITK) & Qing-Hua Xu (NUS)

Using femtosecond laser optical tweezers, nanoparticles can be further tuned to show several novel linear and nonlinear properties. Using the library of the novel nanocomposites with enhanced optical properties from the Xu lab, the femtosecond tweezer lab of Goswami could completely redefine a new paradigm in nanophotonics.
The level of confinement as well as its tuning could result in tailored optical responses that could also have important applications in light-harvesting.

Proposal V

Development of efficient and highly stable nanocatalysts for solar hydrogen generation
Faculties from IIT Kanpur – Drs Sri Sivakumar and Raj Ganesh S. Pala, Dept of Chemical Engineering
Faculty from NUS – Dr. Suresh Valiyaveettil, Department of Chemistry

Contemporary need of world energy is supplemented by fossil fuels with the emission of environment unfriendly carbon sources which affect the nature adversely and lead to Global warming. Solar energy is an eco-friendly and an eternal source of energy which is only alternative at present to avoid such adverse effects of non-renewable energy sources. Recent research focuses on the conversion of solar energy to chemical energy in form of hydrogen wherein the photomaterials aid to split water molecules into useful chemical fuels (water splitting reaction) in presence of

sunlight. Though photoactive materials such as Si, Fe_2O_3, ZnO, Si, GaAs, CdSe, CdTe, InP, CIGS, TiO_2, etc have been employed as stable semiconductors from long time for solar energy conversion schemes, however, these materials offers limited efficiencies due to the large band gap, charge carriers recombination, corrosion and stability in solutions. Several methods have been attempted to alleviate these issues such as doping, sensitizing, composite semiconductor photocatalysts, however, such methods improved efficiency in small increments. In order to circumvent these issues, recently, much attention has been paid on wide applicability of the plasmonic-metal /semiconductor nanocomposites in many applications such as solar cells, dye degradation, and sensing. The surface plasmon resonance (SPR) of noble metals (i.e. Au, Ag, Cu) can be tuned by changing geometric parameters and compositions and thus fabricate a versatile nanostructure and devices designed to absorb a large fraction of solar spectrum. Furthermore, such noble metals nanoparticles (NPs) can reduce recombination of charge carriers by trapping the electrons, for further improving the efficiency of photocatalyst. Additionally, we will focus on the development of polyelectrolyte membrane to separate hydrogen from oxygen.

Work plan: The selected student will spend time in both institutions to design new materials, fabricate devices and test the performance. The proposed supervisors have strong track records in research. The expertise of each group is crucial for the success of this project. The research groups of Sivakumar, and Valiyaveettil have significant expertise in design, synthesis and characterization of materials suitable for energy conversion. Also, laboratories of Pala and Valiyaveettil have sufficient facilities for device fabrication and testing. So this team is complementary and offers the student with expertise and access to various facilities in both institutions to develop efficient devices and test the performances. The student will spend 2 years in IIT and 2 years in NUS to complete his program. We will follow all the rules and regulations of both institutions and provide sufficient training to the student to learn and perform in IIT and NUS.

Quarters	**Year 1 (IIT)**				**Year 2 (IIT)**				**Year 3 (NUS)**				**Year 4 (NUS)**			
Project Implementation Schedule	**Q 1**	**Q 2**	**Q 3**	**Q 4**	**Q 1**	**Q 2**	**Q 3**	**Q 4**	**Q 1**	**Q 2**	**Q 3**	**Q 4**	**Q 1**	**Q 2**	**Q 3**	**Q 4**
Synthesis and characterization of nanomaterials																
Optimization of structure and properties of materials with different techniques																
Fabrication of Devices																
Optimization of the correlation between design and performance of devices																
Testing and optimization of performances of materials/devices																
Paper publication and IP documentation																
Write thesis																

Proposal VI

YN Mohapatra IIT Kanpur

Correlation between processing conditions and electronic defects in printed organic devices on flexible substrates

Brief Description:
The project aims at developing electrical and optical techniques of studying polaron and exciton dynamics in printed organic devices such as solar cells and organic thin film transistors. The nature of traps or defects will be characterized to identify the physics controlling the characteristics of these devices. Specially the focus will be on identifying correlation between processing conditions and the dynamics controlling the material properties such as mobility, diffusivity and charge trapping centres relevant for device applications. Use of inorganic nanostructures in improving and controlling the properties will also be studied keeping the focus on the physics of exciton, charge trapping and carrier dynamics.

Possible Collaborator from NUS: Prof. Peter Ho (Deptt. of Physics, NUS)

Proposal VII

Amitabha Bandhopadhyay BSBE IITK

Low Boon Chuan and/or Sanjay Swarup and/or Christoph Winkler
NUS

Excerpts from an e-mail from Prof. Amitabha Bandopadhyay

I am a developmental biologist who is interested in cartilage and bone development. I looked through NUS website and I could find three colleagues with whom I may mentor PhD students jointly.

1. Low Boon Chuan - dbslowbc@nus.edu.sg - http://www.dbs.nus.edu.sg/staff/lbc.htm

Dr. Chuan is interested in exploring signaling pathways from a mechanistic perspective. I am interested in understanding the role(s) of BMP and Wnt signaling pathways in cartilage and bone differentiation. It is possible that we may find some common ground to mentor a student.

2. Dr. Sanjay Swarup - dbsss@nus.edu.sg - http://www.dbs.nus.edu.sg/staff/sanjay.htm
Dr. Swarup is interested in metabolic pathways more from a network/bioinformatics point of view while I am interested in understanding the role of metabolic enzymes and metabolic networks in different developmental contexts. Dr. Swarup may want to look at this publication from my lab (http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0063670;jsessionid=84B18D7B8C28367B0483A4235140B2B7). To complement gene discovery work I collaborate with my colleagues in CSE (Prof. Harish Karnick and Dr. Arnab Bhattacharya) to develop next generation bioinformatic tools for biologists. Together with Dr. Swarup we may push this agenda in newer directions.

3. Christoph Winkler - dbswcw@nus.edu.sg - http://www.dbs.nus.edu.sg/staff/christoph.htm
Here my primary interest is if Dr. Winkler would be willing to use fish as a model system for cartilage and bone development. Through various genomic and bioinformatic studies we have implicated many new genes in cartilage and bone development. To test their function in mouse is beyond our scope in India. I am thus attempting to do the same in cell culture system as well as chicken embryos. In parallel if we can also use zebrafish and/or Medaka the quality of the studies will be very high.

My objective with a joint PhD program would be to expose my student(s) with two different academic cultures and to possibly broaden the repertoire of research tools that a student may utilize to understand the molecular basis of cartilage and bone development.

Proposal VIII

Dr. Bishakh Bhattacharya (IITK)
Dr. Lee (NUS)

Title: MEMS/NEMS based Energy Harvesting Device for Broad Band Frequency of Vibration

Vibration based energy harvesting devices are ubiquitous today. However, most of these devices are either efficient at a single frequency of excitation or at best suitable for a narrow band of excitation. In this project, we intend to study and develop a range of energy harvesting MEMS/NEMS devices which can extract vibration energy from ambience in a broad frequency spectrum. In order to develop such a system, we propose to design systems with actively controlled structural parameters including stiffness, inertia and boundary condition of the mechanical system such that efficient energy transformation can take place for a wide frequency band.

Proposal IX

Dr. Laxmidhar Behera
Possible collaborator from NUS: Prof. Ye Wang

Multi-channel Multimodal bio-signals control assisted Music Therapy based Medical applications

This Project aims at using multi-modal bio-signal based feedback approach to study the efficacy of Music Therapy on psychological problems like MDD (Major Depressive disorder), Hypertension, Uncontrollable Anxiety, Stress, Sleep disorders. This work would start with the establishment of a Polysomnography lab in a few weeks within Intelligent Systems Lab, Department of Electrical Engineering at IIT Kanpur. We need to conduct some experiments with patients listening to music with simultaneous monitoring of multiple bio-signals like Electro-Encephalogram (EEG), ElectroMyoGram (EMG), ElectroCardioGram (ECG), Electrooculogram (EOG). Although there are state of art works in literature focusing on EEG and Western Music, we will look at a novel multimodal approach to studying rhythmic, vibrational effects of Indian Classical Music on the mental states and psychological pain of the patient suffering from depression, Anxiety, Hypertension, Sleep Disorders. As a starting point we will begin with using some available objective quantifiers of Psychological pain like Heart-rate Variability, Frontal- EEG Asymmetry and develop some more such measures for multiple non-invasive signals like EMG (muscle-tone) and so on. Automation of this approach would lead to development of some personalised music recommendation systems based on such bio-feedback.

Proposal X
Dr. Laxmidhar Behera
Collaborator from NUS: Prof. Shuzhi Sam Ge Department of Electrical & Computer Engineering, NUS

Design & Control of Visually Guided Autonomous Quadrotors

A quadrotor, also called a quadrotor helicopter or quad copter, is a multi-copter that is lifted and propelled by four rotors. These autonomous UAVs are especially useful for surveillance and disaster management. Visual control based automation is specially favored for unstructured environment, hence perfectly applicable for quadcoptors which are meant to operate in such unknown environment. This project aims to develop innovative visual control algorithms [1-2] tailor-made for quadcoptors which will make quadcoptor navigation autonomous and stable. On previous research on flying vehicles, vision is usually used as a secondary sensor. In this proposed approach, the goal is to use visual feedback as the main sensor feedback, which is not only responsible for detecting where the ground objects are but also for helicopter localization. Visual control strategies employing schemes such as feedback linearizing controllers, back stepping controllers & other suitable controllers will be developed for the 2D and 3D rotorcraft models. The project will include experimental validation of visual control of quadrotor in surveillance application in an indoor environment.

1. Indrazno Sirazuddin, Laxmidhar Behera, TM McGinnity, and Sonya Coleman, ‘Image Based Visual Servoing of a 7 DOF Robot Manipulator Using an Adaptive Distributed Fuzzy PD Controller’,

IEEE/ASME Trans on Mechatronics, 2013, online:
http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=06471828
2. P Prem Kumar, Laxmidhar Behera and G Prasad, A Single Network Adaptive Critic based Redundancy Resolution Scheme for Robot Manipulators. IEEE Transactions on Industrial Electronics, 2012, DOI: 10.1109/TIE.2011.2143372, Vol 59, Issue 8, 3241 – 3253, Aug 2012

Proposal XI
Dr. Nishchal Kumar Verma
Department of Electrical Engineering, IIT Kanpur
Possible collaborator
Dr. Nitish V. Thakor
Department of Biomedical Engineering, NUS, Singapore
Department of Electrical and Computer Science Engineering, NUS, Singapore

Brain Machine Interface using EEG

During past several years, researchers have focused their efforts in quest of solution in which the neural signals, produced inside the human brain, can be connected with computer and it can also be used to restore mobility and communication abilities for patients suffering from damaged central nervous system. Huge scientific efforts have been made to restore sensory-motor disabilities and some extraordinary breakthrough have been made in last two decades like moving robotic arm for self-feeding, controlling wheelchair using brain signals. Some BMI applications for day to day usage, noninvasive methods with improved spatial resolution and reduced cost of the system will likely to play and important role in improving quality of life.

Proposal XII
Prof Anil Seth
Collaborator from NUS: Limsoon Wong (NUS)

Project title: Expressive power of realistic query languages

Most existing studies on the expressive power of query languages have focused on what queries can be expressed and what queries cannot be expressed in a query language and on more theoretical query languages like the relational algebra . They do not tell us much about whether a query can be implemented efficiently in a query language (and, particularly, in a realistic query language such as SQL). In contrast, the general goal of the proposed project is the development of powerful general methodology for studying the intensional expressive power of realistic query languages, especially those that support nested relations, aggregate functions, powerset or recursion operations. In particular, we hope to generalize previous results such as [Wong, PODS 2013, pp 285-295; Hella et al., JACM 2001, pp 880-907]. The research is expected to span the areas of database theory, finite model theory, logic, and complexity theory.