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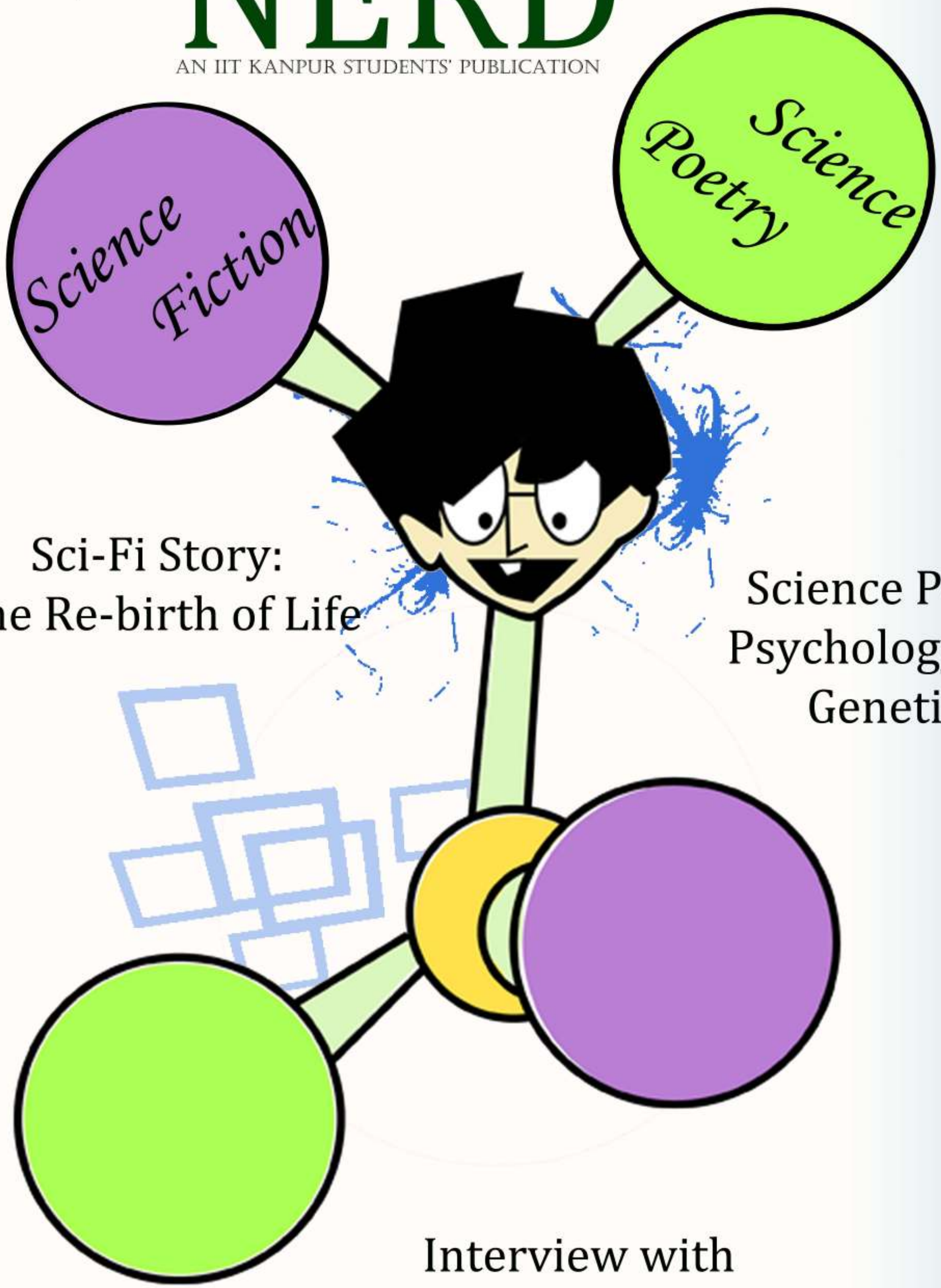

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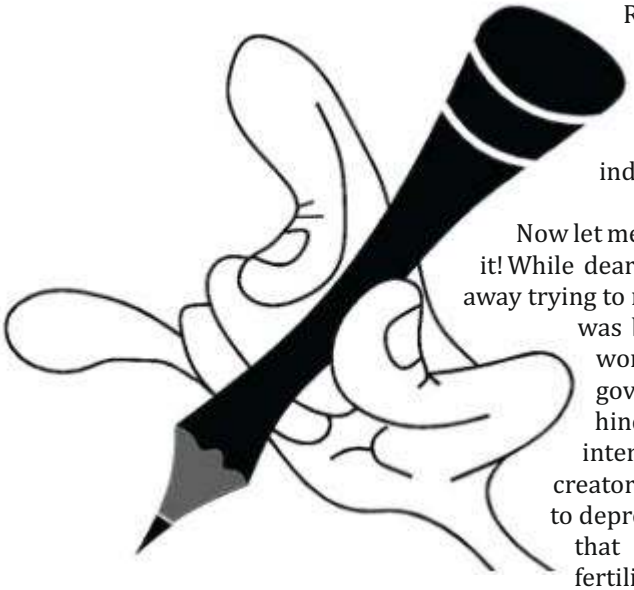


Kudos to Dr. Robert Edwards, the creator of first test tube baby! Dr. Robert Edwards from Britain has been recently conferred the prestigious Nobel Prize in Medicine by the Nobel Assembly at Sweden's Karolinska Institute for the work that has touched the life of millions of couples which suffer from infertility. Since the inception of his groundbreaking research, about 4 million individuals have been born, all credits to IVF (in vitro fertilization).

Now let me tell all of you something that hit me quite hard the first time I read it! While dear Eddy was working in his laboratory, a physician in India was toiling away trying to realize his dream of creating the first test tube baby. While Robert was being applauded in the scientific arena for developments in his work, the Indian physician was facing heavy opposition from various government agencies which declared his work as total hogwash! The hindrances didn't allow him to publicize his findings on the international level. Bengali doctor Subhash Mukhopadhyay was the creator of India's first test tube baby. Ultimately he committed suicide due to depression. Many authorities and medical scientists are of the opinion that he would have been recognized as the pioneer of in vitro fertilization, if he hadn't faced such stiff opposition.

I was completely unaware of the fact until I saw it on IBN Live. It made me very proud of Indian heritage in science and technology and filled me with disdain (at the same time) at the thought of such government which prevented the unsung hero from India from getting laurels for his work.

Well, talking about this issue of NERD, apart from the feature articles we include two newbie – Science Fiction Story and Science Poetry. These are the winner entries of Science Fiction Writing Competition and Science Meets Poetry which were organized in Takneek 2010. I hope that you enjoy devouring them as much as I did.

We are on the lookout for more science fiction writers and science poets. If you don't belong to that specie, why not try out once just for the heck of it?

Also, we have made (noticeable, I hope) changes in the layout and overall look of the magazine. We are looking for some illustrators who can make article-relevant cartoons for us and make them a lot more delicious.

Waiting for your feedback,

Regards,
Bhuvnesh,
Editor, NERD

P.S.: The contact info is given at the last cover page

Create,
Communicate,
Contribute !!!

Article

Learning with Supportive Vector

An Introduction to Support Vector Machines and their Applications

• Purushottam Kar

Support Vector Machines have acquired a central position in the field of Machine Learning and Pattern Recognition in the past decade and have been known to deliver state-of-the-art performance in applications such as text categorization, hand-written character recognition, bio-sequence analysis, etc. In this article we provide a gentle introduction into the workings of Support Vector Machines (also known as SVMs) and attempt to provide some insight into the learning mechanisms involved. We begin with a general introduction to mathematical learning and move on to discuss the learning framework used by the SVM architecture.

The Learning Methodology

Before we move into algorithms that learn, let us take a look at what mathematical learning (or machine learning) means and why is it an interesting field of study. Consider the following computational problems and try to see if one can write C++ programs (feel free to replace C++ with your favorite language) to distinguish between the following –

1. A correct and an incorrect Java program

2. A palindrome word (like ``detartrated'') and a non-palindrome word (like ``house'')

3. Graphs which have a Hamiltonian path and those which do not

One finds that for all these classification problems, one can write programs (however inefficient they may be). The set of problems given above are often known as Classification Problems. A classification problem is simply the problem of distinguishing between objects belonging to some fixed number of classes (viz. the class of palindrome words and the class of non-palindromes). Now consider the problem of distinguishing between the following –

1. An image of a handwritten 4 and a handwritten 9

2. A spam email and a non-spam e-mail

3. A positive movie review and a negative movie review

We find that apriori there does not seem to exist a set of well-defined rules that characterize the classes involved in the above tasks. Consequently one cannot simply sit down and write an algorithm to perform these classification tasks (the author feels that even standing might not help). Moreover in some of the tasks, the classification itself is not well defined (for example, the author might find all the e-mails from the deans to be spam-like but a good student might read them with due diligence). In such cases the best one can hope to do is try to inductively learn some of the latent (or hidden) patterns and rules that govern the classification. This learning one does when provided with Training Sets. For example, in the spam classification case, we provide our Thunderbird client (or in some woeful cases our Outlook client) with examples of e-mails we consider to be spam and examples of non-spam e-mails. The learning algorithms that come packaged with these clients then try to discover the pattern(s) underlying our choices using the training examples and use these learnt rules to classify a new e-mail as spam/non-spam. Thus the main objective in machine learning is to let the training data decide the eventual classification algorithm.

Linear Classifiers

In mathematical learning, these (unknown) underlying rules/patterns are abstracted as a mathematical function whose output on the objects of interest (images, e-mails, movie reviews etc.) decides their classification. Thus instead of trying to learn individual rules and patterns (which is the goal in a subfield of Artificial Intelligence called Inductive Rule Inference), we strive to directly approximate this unknown function as closely as possible. The simplest of such functions are linear functions. To understand this better, consider the simple case when our objects are vectors in a 2-dimensional Euclidean space and belong to either the BLACK class or the WHITE class as shown in the following figure. The example contains 14 WHITE objects and 14 BLACK objects which have been given to us as the training set. It can be clearly seen that the hyperplane drawn separates the BLACK instances from the WHITE ones and classifies the elements of the data set perfectly with no errors. Such a classifier is said to be consistent with the training set. Note that we may been given a dataset which no hyperplane is able to classify perfectly - such datasets are called *Non-linearly Classifiable*. However for now let us live in a simpler world where training sets are *Linearly Classifiable*.

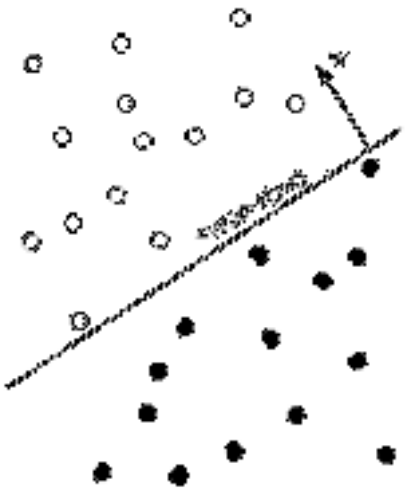


Figure 1: A Linear Classifier

In order to construct a mathematical representation of the classifiers, consider the linear function $f(\mathbf{x}) = \langle \mathbf{w}, \mathbf{x} \rangle + b$ (where $\langle .,. \rangle$ denotes the dot product and $b \in \mathbf{R}$). This function classifies a vector $\mathbf{x}'$ as BLACK if $f(\mathbf{x}') < 0$. Thus to be very precise we can say that our classifier is the function $g(\mathbf{x}) = SGN(f(\mathbf{x}))$, where SGN is the signum function. Notice that the hyperplane drawn is not the only one that is consistent with the dataset. In fact there are infinitely many hyperplanes which classify these 28 points correctly. This also shows us that a classifier that is error-free on the training set may make errors on new data points.

Such a problem (in this case that of finding a linear classifier) where there exist multiple solutions is said to be an ill-posed in mathematical literature. Ill-posed problems do not bode well for learning tasks because the outcome of a learning algorithm in such cases is typically sensitive to initial conditions. For example the Perceptron Algorithm [reference: Frank Rosenblatt. The perceptron: A probabilistic model for information storage and organization in the brain. Psychological Review, 65(6):386{408, 1958] is an algorithm that given these 28 training vectors, finds (``learns'') a linear hyperplane classifying these vectors correctly by starting with a (possibly bad) hyperplane and improving it iteratively to make it classify each vector correctly. However the hyperplane it ends up learning depends upon the hyperplane it started out with. Similar is the case with the Artificial Neural Networks framework [reference: Richard O. Duda, Peter E. Hart, and David G. Stork. Pattern Classi cation. John Wiley & Sons Asia Pvt. Ltd., 2006].

In such situations it is difficult to say anything about the learnt classifier with respect to its performance on new data (i.e. how frequently is it expected to make an error) which is what we are most interested in. In other words nothing much can be said about the Generalization Performance of the classifier on unseen data. The way out of this is to make the problem well-posed (i.e. have a unique solution) by way of Regularization. In very broad terms regularization entails assigning with each one of the (infinitely many) solutions, a goodness value and then searching for the best solution, i.e. the one with the highest value of goodness. Of course in order to be effective, the regularization step should be such that the best solution according to the goodness measure used is unique and has useful properties.

In the following section we shall study at the regularization step used to arrive at the SVM algorithm in some detail.

Large Margin Classifiers

Given a hyperplane $\langle \mathbf{w}, \mathbf{x} \rangle + b = 0$ and a vector $\mathbf{x}_0$, the Geometric Margin of the point (the reader is requested to bear with the definition of some technical terms - however it is assured that there will be few of them and that they will be properly explained) with respect to this hyperplane is defined to be the distance of the point from the hyperplane (actually this quantity is taken with sign but we shall ignore this technicality for the moment). A little bit of high school geometry shows us that this is given by the expression $|\langle \mathbf{w}, \mathbf{x} \rangle + b|/||\mathbf{w}||$ (where $||.||$ denotes the length of the vector). A point that is correctly classified by the hyperplane is said to have a positive margin of $+|\langle \mathbf{w}, \mathbf{x} \rangle + b|/||\mathbf{w}||$ whereas a misclassified point has a negative margin of $-|\langle \mathbf{w}, \mathbf{x} \rangle + b|/||\mathbf{w}||$

Now it is clear that any hyperplane correctly classifying all the points will have a non-negative margin with respect to all the points. Suppose we have a training set that is *Linearly Classifiable* i.e. there exists a hyperplane correctly classifying all the points. For any hyperplane let us take the minimum margin of that hyperplane on any training point as the regularization parameter (using the interpretation developed above, this the the closest any data point gets to the hyperplane). Now let us look for the hyperplane with the maximum value of this parameter (in particular we know that the maximum value will be positive since we know the data set to be linearly classifiable). It can be shown that there is a unique hyperplane with the largest value of this parameter. In the figure below (Figure 2) we take the same training set as in Figure 1 and draw the hyperplane with the maximum margin.

This unique hyperplane is known as the maximum margin

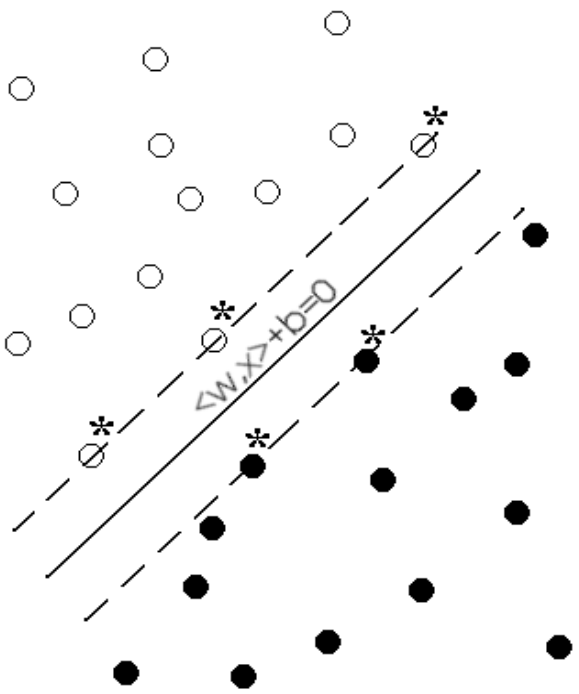


Figure 2: The Maximum Margin Linear Classifier- the starred points are support vectors

classifier of the training set and it possesses several interesting properties. The vectors which lie closest to this hyperplane (i.e. the ones having minimum margin) are called the *Support Vectors.* It turns out that the direction vector of the hyperplane i.e.**w** is simply a linear combination of the support vectors alone i.e. $\mathbf{w} = \sum_{\mathbf{x}_i \in SV} a_i \mathbf{x}_i$ where *SV* is the set the support vectors. This fact has important consequences for the classifier which we shall discuss briefly later.

The reason behind the name Support Vector Machines is that the support vectors actually support the hyperplane in the physical sense of the term. If one imagines that each support vector $\mathbf{x}_i$ is applying a force of a_i (its corresponding coefficient in the representation of **w**) on the hyperplane, then it turns out that the total force and torque on the hyperplane due to the support vectors is zero.

However this fact has little significance for learning. What does have significance is that if the margin of the maximum margin classifier is large then one is able to prove probabilistic bounds on the generalization error of the classifier. In other words one is able to make a mathematical statement of the following kind.

> Assuming that the training set was chosen randomly from some probability distribution on the Euclidean space, it is very unlikely that a training set will get chosen whose maximum margin classifier has a large positive margin but still makes gross errors on unseen points.

We have glossed over a lot of details (and introduced inaccuracies) while making the above statement but going into any of these details would require a full technical article on Vapnik-Chervonenkis dimension (strictly speaking even this would not suffice) and Probably-Approximately-Correct (PAC)

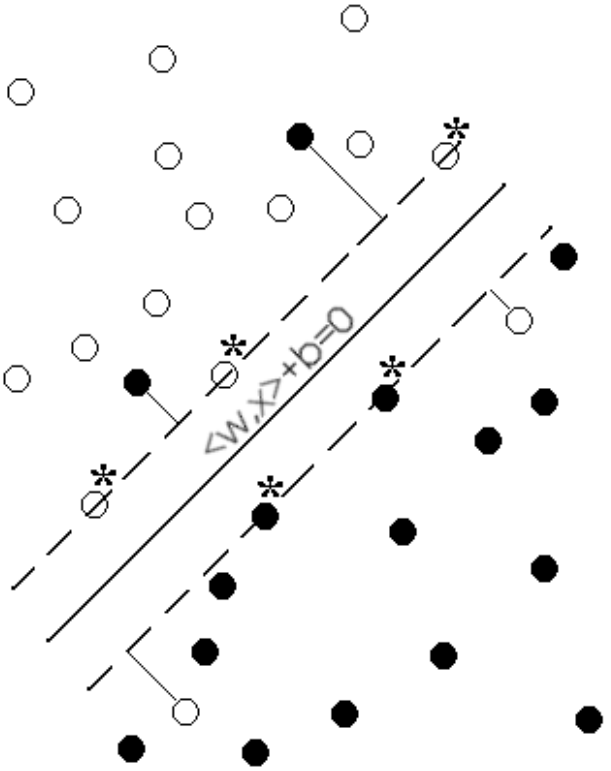


Figure 3: The Soft- Margin Linear Classifier- the starred points are support vectors

Learning. We provide pointers on these topics for the interested reader toward the end.

This basic SVM model can be tweaked to allow for situations where there is noise and a few outlier training points make it impossible for any linear hyperplane to classify the otherwise linearly classifiable data set. These models are known as Soft-margin SVMs (see Figure 3). The following figure is illustrative of such a situation. Again we choose not to go into the details of the topic.

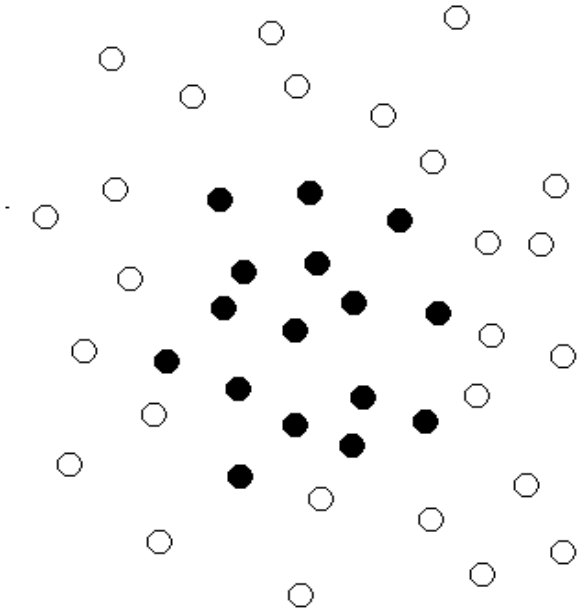


Figure 4: A Non-Linear Classification Problem

Learning the Maximum Margin Classifier

We briefly address the question of how to learn the maximum margin classifier given a training set of vectors in some Euclidean space (this might sound as a restriction for cases like spam detection where the objects are not real-valued vectors but we shall soon see how this drawback be elegantly overcome). Given a set of training vectors, we formulate a mathematical program (very much like formulations in the familiar linear programming paradigm) to express the problem of maximizing the margin. The program that gets formulated is a Linearly-constrained Quadratic Program and there are several efficient techniques available to solve the program. We give pointers to freely available solvers toward the end.

We now move on to the second most important feature of the SVM technique namely its adaptability to the *Kernel Trick.*

The Kernel Trick

An apparent drawback in the description of the SVM algorithm is that it seems to work well only when the data is linearly classifiable or nearly so. What, we may ask, happens when our problem is not so well behaved?

In such cases what we typically do is apply a non-linear transformation to the data (which usually maps the data to a higher dimensional space) to make it linearly classifiable or very nearly so. To appreciate this method let us consider the problem of learning the Boolean function XOR in a geometric setting. Recall that for two binary digits (or bits) a and b, **XOR**(a,b) = (a∧ ¬b)∨(¬a∧ b). Geometrically we can consider framing this problem in $\mathbf{R}^2$ and interpret the coordinate values as bit values. Thus we get the following classification problem with BLACK and WHITE denoting the two classes XOR = 1 and XOR = 0 respectively.

It turns out that this data set is not a linearly classifiable one as no line can separate the black points from the white ones. But consider the following non-linear map from $\mathbf{R}^2$ to $\mathbf{R}^3$. Φ : (x,y) \⟶ (x^2,y^2,√ 2xy). Figure 6 (next page) shows that this map makes the data linearly separable (for those worried about

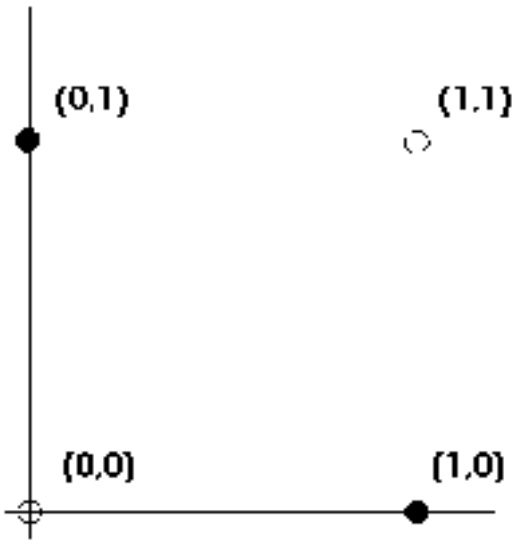
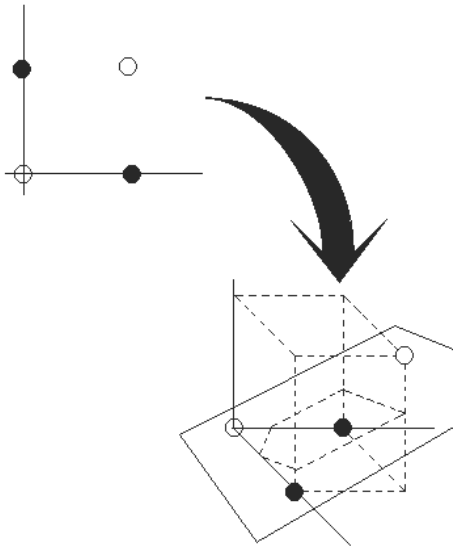


Figure 5: The XOR Classification Problem

whether this non-linear map would affect the generalization bounds, all it takes to fix things is a bit more involved theory from functional analysis).

Although there are infinitely many such transformations to linearize the data, this particular transformation is special because it corresponds to a Positive Definite Kernel also known as a Mercer Kernel. A detailed definition of this term is beyond the scope of this article but we can appreciate the uniqueness of this linear transformation by looking at how the dot product looks like in this transformed space. Given two vectors $\mathbf{x}_1, \mathbf{x}_2 \in \mathbf{R}^2$ one can easily see that $\langle \Phi(\mathbf{x}_1), \Phi(\mathbf{x}_2) \rangle = \langle \mathbf{x}_1, \mathbf{x}_2 \rangle^2$.



This innocuous looking technicality has great significance for the SVM algorithm because of the fact that the SVM algorithm can be expressed in a way that only requires dot products between the training vectors to learn the maximum margin hyperplane and not the training vectors themselves. This is most fortunate since we can now map our vectors to very (very) high dimensional spaces where they have a greater chance of becoming linearly separable but not incur the computational cost of performing the map. However as pointed out this is possible only if the inner product of the mapped vectors in the higher dimensional space can be easily expressed in terms of the original vectors as was the case with the map Φ.

This trick is known as the *Kernel Trick* and the measure $K(\mathbf{x}_1, \mathbf{x}_2) = \langle \Phi(\mathbf{x}_1), \Phi(\mathbf{x}_2) \rangle$ corresponding to a map Φ is known as a kernel. But what do we do when we get a new vector to classify? Here's where the fact that the direction vector of the maximum margin classifier is simply a linear combination of some of the training vectors (more specifically the support vectors - see Section 3) comes in handy. To see how let $\mathbf{w} = \sum_{\Phi(\mathbf{xi}) \in SV} a_i \Phi(\mathbf{x}_i)$. Hence (once again some technicalities have crept in. However these simply use the fact that the inner (dot) product is a bilinear map i.e ,

$$
\begin{aligned}
f(\vec{x}) &= \langle \vec{w}, \Phi(\vec{x}) \rangle + b \\
&= \left\langle \sum_{\Phi(\vec{x}_i) \in SV} \alpha_i \Phi(\vec{x}_i), \Phi(\vec{x}) \right\rangle + b \\
&= \sum_{\Phi(\vec{x}_i) \in SV} \alpha_i \langle \Phi(\vec{x}), \Phi(\vec{x}_i) \rangle + b \\
&= \sum_{\Phi(\vec{x}_i) \in SV} \alpha_i K(\vec{x}, \vec{x}_i) + b
\end{aligned}
$$

Thus the kernel measure is sufficient for classifying new points as well. What one usually does is instead of choosing a map, choose an appropriate kernel measure which (under some conditions given by a result in Functional Analysis called the Mercer's Theorem) is the inner product of vectors when subjected to some non-linear map and use that to learn a hyperplane via the SVM method - the high dimensional map is always made implicitly and never computed as such. However in many cases one comes up with a kernel by actually defining a map ψ and using the kernel $K(\mathbf{x}_1, \mathbf{x}_2) = \langle \psi(\mathbf{x}_1), \psi(\mathbf{x}_2) \rangle$.

Frequently one uses this trick to map vectors to infinite dimensional spaces (the Gaussian kernel measure $K(\mathbf{x}_1, \mathbf{x}_2) = \exp(-\|\mathbf{x}_1 - \mathbf{x}_2\|/\sigma^2)$, where $\|\mathbf{x}\|$ is the length of the vector $\mathbf{x}$ and $\sigma > 0$ is one such kernel). Some care has to be taken when dealing with infinite dimensional spaces but we do not go into those details in this article. The choice of the kernel is the most important one while using the SVM algorithm as this influences the quality of the learnt classifier heavily. However, apart from the choice of the kernel, the SVM algorithm is almost fully automated requiring almost no human intervention. This should be contrasted with Artificial Neural Networks which typically require a lot of manual tuning during the learning process.

It turns out that the kernel trick is more than a just neat way of getting the benefits of working in a high dimensional space without incurring the computational costs. It is also a neat way of handling non numeric data and allows the SVM algorithm to work in a variety of situations. This is because the kernel can be thought of as a measure of similarity (the trivial kernel $K(\mathbf{x}_1, \mathbf{x}_2) = \langle \mathbf{x}_1, \mathbf{x}_2 \rangle$ is indeed a measure of similarity between two vectors giving us the cosine of the angle between the vectors in case they are of unit length). Hence one can work with SVMs if one can find an appropriate measure of similarity between the objects concerned. For example when working with e-mails, one has to devise a way of finding out how similar two e-mails (spam or non-spam) are. In many situations, finding measures of similarity between two objects is a much more natural thing to do than converting objects like e-mails to numeric vectors. Of course the similarity measure we construct might not confirm to the Mercer's Theorem we mentioned earlier but even such non-kernel similarity measures are found to give good results in practice.

Applications of SVMs

SVMs have found widespread application in machine learning problems of which we survey two below. A more comprehensive survey is made impossible by lack of space.

Handwritten Digit Recognition

This application was mentioned in the seminal paper by Boser, Guyon and Vapnik that introduced the Support Vector Machine algorithm [reference: Bernhard E. Boser, Isabelle Guyon, and Vladimir Vapnik. A training algorithm for optimal margin classi ers. In International Conference on Learning Theory, pages 144{ 152, 1992]. The data set used was compiled by the United States Postal Service out of zip code numbers written on postal letters. This was a widely studied problem at that time and researchers had done a lot of work on Neural Networks and other algorithms trying to get better results on this dataset.

However the best they could do was achieve an error rate of around 12.7%. However Boser et al using simple polynomial kernels (where $K(\mathbf{x}_1, \mathbf{x}_2) = \langle \mathbf{x}_1, \mathbf{x}_2 \rangle^d$ for some integer $d \geq 0$), achieved an error rate of just 3.2%. This was taken as an illustration of the generalization error bounds at work.

Text Categorization

This is an example of how one can use the kernel trick to work with innovative similarity measures on the data. The problem was that of categorizing news articles from the Reuters-21578 collection into various topics (viz. sports, entertainment, politics). In this work Joachims [reference: Thorsten Joachims. Text categorization with suport vector machines: Learning with many relevant features. In European Conference on Machine Learning, pages 137{142, 1998], used insight from the field of information retrieval research to design similarity measures which gave significant performance gains. Earlier methods like Decision trees and Nearest Neighbor based algorithms were at best able to give accuracy rates of around 80\% on test data. The SVM based methods, on the other hand, were able to achieve accuracy rates of > 86%.

In many other fields like bioinformatics, image based object recognition and page ranking for Internet search, SVM-based techniques have been applied with great success. We conclude our discussion here and move on to give references to sources which discuss SVMs and related methods in greater detail.

Ponder Yonder

An excellent introductory text in SVMs is the following

> Nello Cristianini and John Shawe-Taylor, *An Introduction to Support Vector Machines*, Cambridge University Press, 2000.

The authors also maintain a website which has a lot of material on Kernel based methods including SVMs and links to freely available implementations of the SVM algorithm: http://www.support-vector.net/

For someone interested in learning more about concepts like PAC learning and the VC-dimension theory which allow SVMs to give generalization error bounds, the following is a good starting point

> Michael J. Kearns and Umesh V. Vazirani, *An Introduction to Computational Learning Theory*, The MIT Press, 1994.

Although not covered in this article, there are algorithms to perform regression and clustering that admit the Kernel trick. A good source to learn about these techniques is the following

> Bernhard Schölkopf and Alexander J. Smola, *Learning with Kernels*, The MIT Press, 2002.

About the Author

Purushottam Kar is a Ph.D. student with the Department of Computer Science and Engineering at IIT Kanpur working under the guidance of Prof. Harish C. Karnick and Prof. Manindra Agrawal. He is mainly interested in Learning Theory and Complexity Theory apart from having an avid interest in topics like Computational Geometry and Cognitive Science. He can be contacted at purushot@cse.iitk.ac.in

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Story

The Rebirth of Life

• Anjaney Kothari

The equation of your body in the general state does not permit us to increase your height, Piyush,' said Aseem, clearly incensed. 'and I have not spent three years, two months and one week making this device only to alter your height', he added, pointing at the coffin-like metallic device, twice the size of a human body in all aspects.

'Okay fine; as if I need to get any taller,' replied Piyush in a falsely exasperated voice. 'What does 'in the general state' mean, though? Makes me feel as if I am a complex theory of Physics,' he added, his hatred for Physics and its seemingly dull laws quite conspicuous on his face.

'The spatial equation of the human body, obtained when the body is totally vertical and still and the coordinate axes are such that the origin lies at the mid-point of the upper surface of pancreas, the z-axis is the vertical axis, x-axis is the horizontal axis parallel to the body and y-axis is the horizontal axis perpendicular to the body, is called the equation of the human body in the general state,' said Aseem in a pointedly soporific drone, adjusting his 'float-in-air' frame-less spectacles.

'Glad that you stopped before I began drooling in my sleep,' said Piyush, grinning. 'What have you made this coffin for, then?' he asked seriously.

'Well, the least it is meant to do is to make people invisible,' replied Aseem in a matter-of-fact tone. Piyush rolled his eyes. 'Invisible? That is the least, is it? How can you make people invisible with this?'

Aseem did not reply immediately. He started arranging the books strewn across his table on the glass shelves in his room (which had rendered the room much less roomy). Piyush allowed him his time. He had had nasty experiences when he had disturbed a pensive Aseem. So he got up and walked to the window. The thick curtains folded upwards immediately and the glass-window opened up quickly, allowing the last sunshine of the day to bathe the room. No one inside that room would imagine that a picturesque valley lay waiting for them outside the window. Piyush looked at the wonderful surroundings, utterly intrigued, but stopped at the sight of a complex network of glass tubes and spheres located far away. He thought for a moment. It was then that he realised, as he looked down, that he was seeing the valley through a large wall of glass and, as he now observed more closely,that a very large expanse of the ground was taken up by what looked like a magnificent glass-walled room. He moved his neck upwards to find the end of the glass walls. It seemed that the glass-walled room had a magnificent glass roof too. He had never seen this part of the C-AMBIENCE, although, being Aseem's brother, he had been into his room many-a-time. He looked back questioningly inside the room to find Aseem sitting on the chair and eyeing the coffin-like machine sombrely.

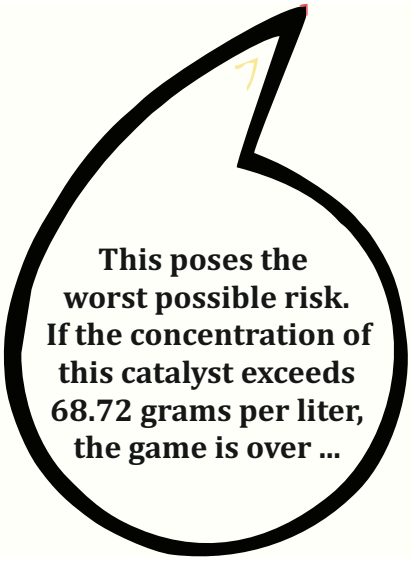
'The most I have assumed it to be able to do is...is to bring back each animal species which no longer exists on this planet', Aseem said suddenly with a heavy sigh and what was unmistakably a shiver.

Piyush forgot the glass-walled room. There was such an inscrutable expression on Piyush's face that it could not be fathomed whether he was more impressed, or more terrified by Aseem's new idea. 'How can you do that? You don't mean...do you mean that you can bring back... dinosaurs and mammoths and all those creatures... with this coffin of yours?'

'Yep,' Aseem said after a moment's pause, 'a very magnified version of the Urey-Miller apparatus is needed for this.' 'The Urey-Miller apparatus?' 'The one you just saw through the window.'

Piyush had always known that his brother would do something great in life, but never had he been so intrigued by an idea of his. While Piyush himself was a creative guy devoted to arts and literature, Aseem had the knack for thinking and implementing complex things which no one else normally tried to do. The Center for Advanced Mathematics and Biological Sciences, which was often called the C-AMBIENCE, was the only Laboratory in the world which had successfully brought together two very different sciences, Mathematics and Biology, and united them like two long lost brothers.

Aseem was the youngest person who had been offered a place at the C-AMBIENCE, three years ago, when he had submitted a paper on the



gene-number and how it could be used to determine the equation of the human body if the body were considered to be a curve in three dimensional space. In the past three years, Aseem had given the C-AMBIENCE a new thought. Before Aseem had joined the C-AMBIENCE, scientists there were at the verge of devising an advanced version of the Urey-Miller experiment.

'The Urey-Miller experiment, considered to be the greatest experiment on the origin of life on the earth, was conducted in the year 1952 by Urey and Miller.' Aseem said, in the tone of a dedicated teacher. 'It simulated the atmospheric conditions on the primitive earth in a glass apparatus and it was found that inorganic molecules like water, ammonia, methane and hydrogen yielded organic molecules like amino acids, used to construct proteins in the cells, and sugars and some essential components of nucleic acids.

'That.. was the actual experiment. But Richard and Anirudh, two of my colleagues here considered the possibility of recreating the entire process of evolution of life through this. They believed that continuing the experiment for a few months under strict experimental conditions might give rise to organisms that were..the first prokaryotes on earth..and if the experiment were continued for hundreds and thousands of years, we might see those organisms which have become extinct millions of years ago- that is we might actually witness the entire process of evolution, we might bring about..the rebirth of life.'

'That sounds great, with the only limitation that you would have to undergo several rebirths yourself to witness this rebirth of life,' Piyush said teasingly.

'That limitation is overcome by the use of KLL91, a catalyst compound which we have hitherto designed only on the computer, because it will be the strongest mode of a massacre if leaked. So we will be developing it inside the apparatus during the experiment. Then there are also three complex proteins which we would use. These are present in all the members of the animal kingdom and their formation by the natural evolution process would take thousands of years.'

There was a minute's pause in which Aseem gulped down two glasses of water, while Piyush looked thoughtful for the first time that evening. 'Will this not affect the species that are formed in the beginning? I mean, the proteins that were supposed to be formed years after the evolution of the first species have been formed before, so will this not affect the process and lead to better species than the actual ones?' said Piyush, looking outside the window.

'Yes, that is the first element of risk,' replied Aseem, mildly surprised by Piyush's thoughtfulness.

'Why does it pose a risk? We would be able to see new creatures, maybe..but how much time will it take exactly, and how will you control this process?'

'So many questions at once! You are becoming scientific Piyush. Well...It poses a risk, a lethal risk, because we cannot yet predict the changes the creatures at any stage of evolution will undergo because of the early availability of these proteins.

'The time this process will take depends on the amount of KLL91 used. This poses the worst possible risk. If the concentration of this catalyst exceeds 68.72 grams per liter, the game is over because our glass apparatus would develop leakage beyond that concentration and if a single molecule of this compound comes in contact with any part of your skin, you die...and a painless death for that.

'The process will be controlled by the software used in this device, this coffin', ended Aseem, a smile sprawling slightly across his face, 'If Iget the equation of the body of the extinct organism I wish to recreate, I would feed this information to the software in this device.'

'What would that do?'

'The software actually stops the machine when the body of the entered equation is obtained. It also allows you to modify the size of the organism proportionally by changing the coefficients of the terms containing x, y and z raised to fractional exponents by a multiple of the genomic ratio...Wait a moment.'

A call on Aseem's phone disturbed the Q&A session.

'Richard's call. The apparatus is complete, after all these months of hard work. We must inspect it today. You can come with me if you like', Aseem said after having attended the call.

'Of course! Lets go', Piyush said interestedly.

They reached the ground floor of the C-AMBIENCE and found it packed with a throng of people, most of whom were assembled near the screen which was showing the Urey-Miller apparatus set up outside.

'You guys really love glass', Piyush said, reminded of the glass-walled room as they walked through the magnificent glass doors of the C-AMBIENCE building.

They found Anirudh and Richard waiting for them outside. 'Hi, Piyush. You coming with us?' said Richard, shaking hands with Piyush, who nodded excitedly. 'I had never thought I would get this close to my dream project', said Aseem. 'Yeah, its great, isn't it?' said Anirudh, 'Eric said that the equations that both of you have been developing for the Seismosaurus body are ready, but he is not sure about the n/m genomic ratio.'

'I have worked that out. The n/m is .267. I have checked it from the palaeontologic data.'

They had now reached the rear side of the C-AMBIENCE, the one which Piyush had seen from the window. The glass-walled room would have given anyone this close to it the megalophobic feeling of the glass falling over him.

They walked over to where the glass tubes and spherical structures were arranged.

‘Hi, Eric. I have checked out the n/m from palaeontologic data. And if we want a one meter version of the fifty one meter tall dinosaur, the coefficients of all the terms involving x have to be 0.812', Aseem said to a blonde long-haired man who was doing something on the computer interface attached to the glass apparatus.

‘That's great, Aseem', said Eric cheerfully, still working on the computer,'and I have set the KLL91 pressure on this software. Only after it begins to form, and the supply of ammonia and methane begins, we will pass the electric current, what do you say?’

'Yeah, I think its better of the two ways.’

'Have you decided upon a name for this experiment yet, Aseem?' asked Anirudh.

'No, actually I could not think of a name that would form a good acronym’

'How about the ROLE...the Rebirth of Life Experiment?' said Piyush after a minute.

'That is an awesome name, Piyush' said Richard.

'Yeah. Really great. People would ask us- "What was your role in the ROLE?"' said Eric, grinning.

'That is done, then. So, if all is done, should we conduct the experiment on the day after the next? After we have re-evaluated a few data so that nothing can go wrong in the experiment?' asked Aseem.

'Yep,' said the others.

On the day of the experiment, only the six members of the ROLE crew were allowed at the site, although Piyush was permitted in.

With a sanguine note, Eric and Aseem started the experiment. He entered the n/m, the KLL91 pressure so as to keep the concentration less than 68.72 grams per liter, the gas concentrations, the modified equation of the Seismosaurus and other data. A loud rumbling noise began as soon as electric current was passed through the gases in the apparatus. Piyush was gazing at the center of the apparatus dreamily while they waited for half an hour and kept observing the computer screen to monitor changes.

'Aseem, Aseem, the n/m value has entered an increasing loop.' Eric cried in a loud voice.

'What is going on? We will get a much larger sized creature then.' shouted Richard

'This is impossible. How could we go wrong with the software?' Aseem said, panicking. After a minute of checking on the computer, he shouted amid the rumbling noise,'We have lost control of the system...The n/m is increasing of its own accord.The size of the Seismosaurus will reach larger than even its actual size then..'

'We must inform the C-AMBIENCE. The experiment has turned out a fiasco.' said Anirudh

'We don't have much time to us,' screamed out Richard.

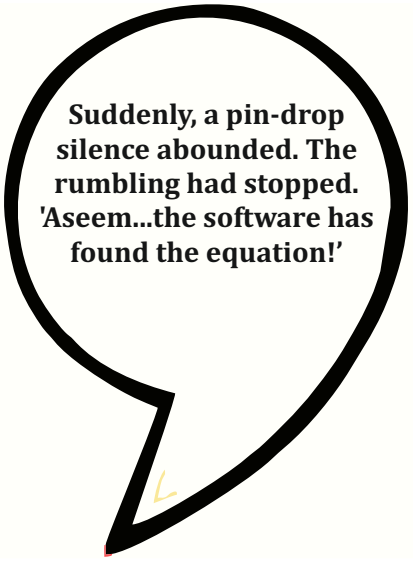
Suddenly, a pin-drop silence abounded. The rumbling had stopped. 'Aseem...the software has found the equation...We..We will have the Seismosaurus in a minute,' said Eric quietly.

'What are you waiting for?' Aseem shouted through a sore throat,'RUN!!'

'RUN!' shouted Eric and Richard together. Piyush was still eyeing the centre of the glass-walled room, totally intrigued. He might have just woken up from a slumber.'PIYUSH...' the loudest shout so far came from Aseem,'WHAT ARE YOU DOING? COME WITH ME!' Startled by the shout, Piyush absorbed the tense aura around in a moment and started running behind the others.

Aseem had no time to think about where they had gone wrong, and really, there was no need. The Rebirth of Life Experiment was definitely going to render them all dead. He was still waiting for the worst...

And it came soon...An ear-splitting crash behind them recited the result of the biggest and the most dangerous experiment on earth...



As Aseem, Piyush and others turned around, they only had time to capture the glimpse of no less than four 100 meres tall creatures which they had only imagined in their dreams probably. They were too large for the glass-walled room. Large chunks of glass fell upon them like heavy quills.

But that was not the worst. In an instant, each one of the people around began to drop on the ground, as if the threads of various puppets were cut off at the same time. The leaked KLL91 had done its job in an instant. There could not have been a worse sight. And then, as if it were needed, a tremor like an earthquake of the utmost magnitude, rocked the C-AMBIENCE. At the drop of a hat, the ambience of the C-AMBIENCE was death...

Thousands of bodies, of the staff that worked at the C-AMBIENCE, papered the ground, making it a violent red graffiti. This was going to be the end of human life on earth, because there was no stopping the spread of the leaked KLL91 and its contaminated resources.

Something had gone drastically wrong. They had ignored the fact that no experiment in the world could be absolutely perfect, and that no experiment in the world could have been more

devastating than this one. They had not heeded that tampering with the flow of time will only reduce your life-time...They had not realized that the universe was good as it was, with its mysteries veiled...

Life had ended for the humans in this slot of time, but nevertheless, Life had taken Birth again...

About the Author

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Poem

Psychology and Genetics

• Amit Saraswat

The day it seems was quiet before,
When psyche and genes were neither and nor;

Psyche decreed genes was a waste,
Genes snapped psyche had a haste;

For both had claims on how we behave,
The etiquette between them had come to a shave;

Psyche found its strength in stimulus-response,
And became more sound with Freud's rebound;
Genes though slow were trying every day,
The 'smart gene' when found gave them a way;

But blessings and blessings to Freddie and Crinque,
For one was a geneti and other a shrink;

They were both determined to neglect the fight,
And worked along to achieve the might;

The genes they say are quiet innocent,
They just want peace or might resent;

For if one is continually punished,
The gene of aggression may get diminished;

But if repeated and repeated punishments occur,
The gene may return with quiet vigour;

The same was the theory of Freud's unconscious,
Where instincts drive us to get mischievous;

Activation recession of a particular gene,
May make a child Curie or Chaplin;

For there are orders of DNA helix,
Which govern memory and power of gimmicks;

And as for green eyed mom and brown dad,
The game is purely on the fate of the lad;
But still the green is more probable,
Since brown has been on quiet a recession;

And this opens the doors for cures ajar,
Diseases of brain can be sort apart;

A Wilson's disease can be controlled to roar,
And Psychotherapy would be the sole to oar;

As the poetry now ends I must conclude,
Harmony is the only way to make solitude;

Progress at stake of fight never gains,
Try join hands and you won't have vanes.

About the Poet

Amit Saraswat (10079, amitsar@iitk.ac.in) is a first year undergraduate student in the Department of Mechanical Engineering. He is interested in reading advanced physics, finance and biology. He also enjoys reading novels.

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The Sci-Fi Story 'The Rebirth of Life' and the Science Poem 'Psychology and Genetics' are the winners of the Sci-Fi Story and Science Poem writing competitions held in Takneek 2010, the intra-IITK technical festival, respectively. The NERD Team congratulates the author and the poet for their achievement and appreciates their work.

Article

Nanostructured Materials

• Brajendra Singh

1. Introduction

Albert Einstein, as part of his doctoral dissertation, calculated the size of a single sugar molecule from experimental data on diffusion of sugar in water. His work showed that each molecule measures about a nanometer in diameter. At the billionth of a meter, a nanometer is the essence of small. Almost 100 years after Einstein's insight, the nanometer scale looms large on the research agenda. With the emergence of nanotechnology and nanoscience, the investigation and application of nanostructured materials is growing rapidly. By definition, nanostructured materials have at least one dimension that is less than 500 nm, typically having 10 2 to 10 4 atoms / clusters of atoms as shown in the figure below.

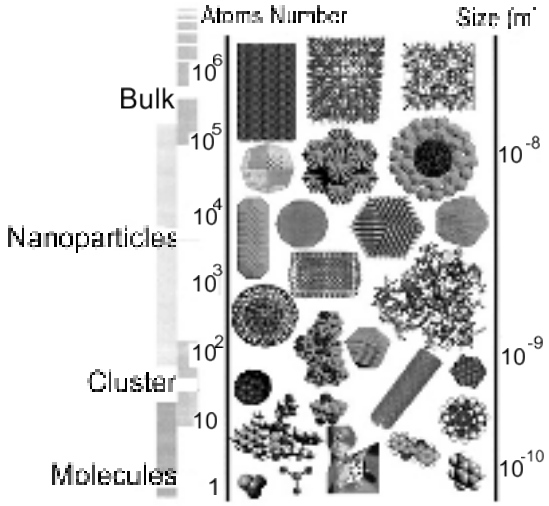


Figure 1: Diagram of the range in which nano particles are present [8]

Nano-structured materials have become the central subject of materials research during the last decade in the past twentieth century owing to the novel magnetic, electronic, optical and catalytic properties observed in such materials. 'Nanomaterials' are not simply another step in miniaturization, but lies midway between the scale of atomic and quantum phenomena, and the scale for bulk materials. Conventionally nano-materials have been obtained using the 'top-down' approach employing techniques like photo and electron-beam lithography which provide a tool for etching surfaces to provide structures on the nanometer scale. However the structural dimensions of the nanomaterials currently require large-scale production of parts that are significantly smaller than 100 nanometers. The Nobel physicist Richard Feymann pointed out more than 40 years ago " There is plenty of room at the bottom" and thus today's nanotechnology research puts a great emphasis on the development of 'bottom-up' strategies (enlargement strategies), which concern the self-assembly of atomic building blocks to create larger functional devices.

Nanoparticle systems, including monolayer-protected clusters (MPCs) and mixed monolayer-protected clusters (MMPCs), bridge the gap between lithographic and synthetic methods. Bottom-up methods using the techniques of organic and inorganic synthesis furnish a means of fabricating molecular systems such as devices and sensors that are on the 0.5-2.5 nm scale with complete control of three dimensional structures. On the other hand, Sono - chemistry is one of the bottom up methods which offers a viable route to realize bulk nanomaterials wherein complementary reactivities, geometries and/or physical properties between reaction components direct the assembly from the 'bottom-up' with specific implications on the magnetic and electronic transport.

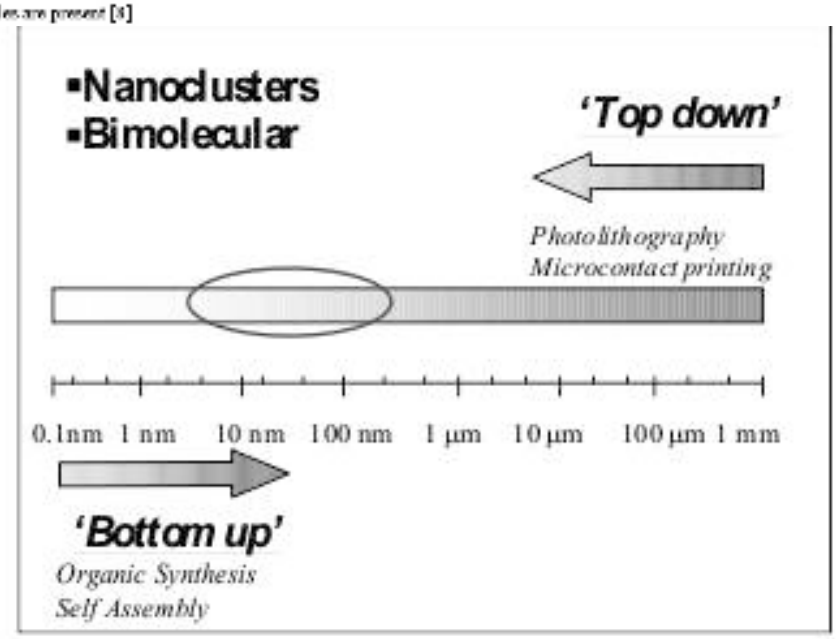


Figure 2: Showing *'top – down'* and *'bottom – up'* approach to realize nano materials[8]

Apart from the bulk nano structures, In the late 90's, it was discovered that layers of extremely thin (a few atomic layers thick - nano) films of magnetic material exhibit magnetic and electrical properties that can be very different from the properties exhibited by the bulk forms of these materials.

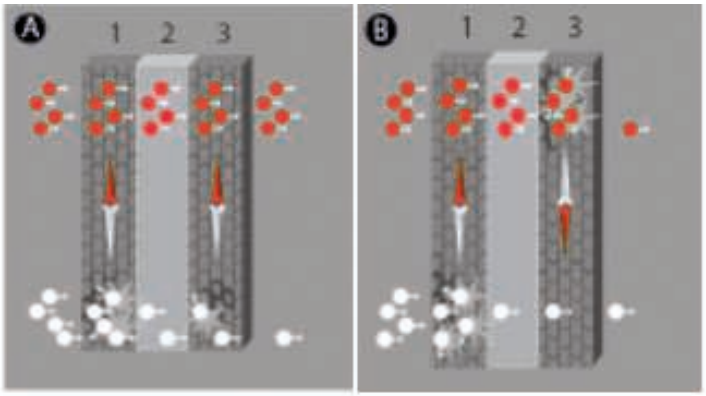


Figure 3: (A) If the direction of magnetization is same in both magnetic layers, the electron with parallel spin (dark) can pass through the system with out problem. (B) If the direction of magnetization in the two magnetic layers is opposed, all the electrons will have antiparallel spin in one of the layers and will therefore scatter a great deal. [9,10]

Giant Magneto Resistance (GMR)

In particular, the electrical resistance in these materials can be extremely dependent on the ambient magnetic fields. This enhanced sensitivity of the electrical resistance to magnetic field is called "giant magneto resistance" GMR [figure-3, next page]. GMR effect has been used in all common hard discs to read magnetic bits and bytes. The effect is based on the quantum-mechanical combination of electron spins in the nanomaterial layers. In only ten years, the GMR effect has made its way from the laboratory to the consumer as a computer hard disks and read heads and is now used daily a billion of times.

2. Sonochemical synthesis of nanomaterials

2.1 Sonochemical process

Sonochemistry is the application of ultrasound to chemical reactions and processes. Ultrasound is the part of the sonic spectrum which ranges from about 20 kHz to 10 MHz, and can be roughly subdivided into three main regions: low frequency, high-power ultrasound (20–100 kHz), high frequency, medium-power ultrasound (100 kHz–1 MHz), and high frequency, low-power ultrasound (1–10 MHz). The range from 20 kHz to around 1 MHz is used in sonochemistry, whereas frequencies far above 1 MHz are used as medical and diagnostic ultrasound. Ultrasound offers several potential advances compared to the more traditional synthetic routes. These include:mild ambient temperatures, Enhanced mixing and transport properties, ability to generate unique high-energy intermediates, decrease of reaction time and /or increase of yield, lower reaction temperature, switching of reaction pathway, Use of fewer or avoidance of phase transfer catalysts.

The origin of sonochemical effects in liquids is the phenomenon of acoustic cavitation. Acoustical energy is a mechanical energy, that is, molecules do not absorb it. Ultrasound is transmitted through a medium via pressure waves by inducing vibrational motion of the molecules, which alternately compress and stretch the molecular structure of the medium due to a time-varying pressure. Therefore, the distance among the molecules varies as the molecules oscillate around their mean position. If the intensity of ultrasound in a liquid is increased, a point is reached at which the intramolecular forces are not able to hold the molecular structure intact. Consequently, it breaks down, resulting in the formation of a cavity. This cavity is called the cavitation bubble, as this process is called cavitation and the point where it starts the cavitation threshold. A bubble responds to the sound field in the liquid by expanding and contracting, that is, it is excited by a time-varying pressure (figure – 4). Two forms of cavitation are known: stable and transient. Stable cavitation means that the bubbles oscillate around their equilibrium position over several refraction/compression cycles. In transient cavitation, the bubbles grow over one (sometimes two or three) acoustic cycles to double their initial size, and finally collapse violently. The size, lifetime, and fate of a cavitation bubble depend on the following parameters: frequency, intensity (acoustic pressure), solvent, bubbled gas, and external parameter (temperature, pressure).

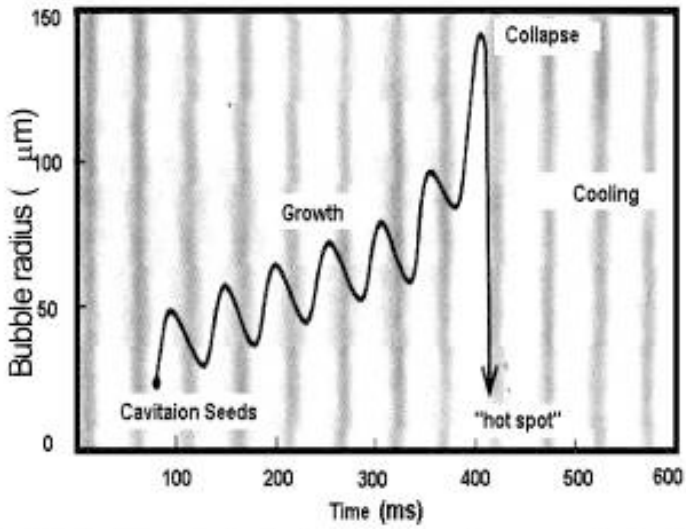


Figure 4 : The initial bubbles absorb dissolved gas from the surrounding liquid and grow. Once large enough, the bubble resonates and absorbs acoustic energy. It quickly grows over the course of one acoustic cycle until it cannot sustain itself and it implodes.[8]

2.2 The Sonochemical Cell

A schematic of the sonochemical apparatus is illustrated in figure - 5. The heart of the sonicator is an element called the transducer. This is a ceramic disk whose crystal structure has a specific direction (in this case, in the vertical direction) in response to an applied ac voltage. In most high-intensity experiments, the transducer is being displaced 20,000 times a second (20 kHz).

2.3 Nanomaterials employing ultrasound

As a general approach to Sono Chemical synthesis of nanophase materials, extreme conditions of cavitation produce a variety of nanostructures and often amorphous metals, alloys, and carbides. Volatile organometallic compounds decompose inside a collapsing bubble, and the resulting metal atoms agglomerate to form nanostructured materials. The sonochemical synthesis of nanostructured materials is also extremely versatile; simply changing the reaction medium can generate various forms of nanophase materials. When precursors are sonicated in low volatile alkanes, nanostructured metal powders are formed. If sonication occurs in the presence of a bulky or polymeric surfaced ligand, stable nanophase metal colloids are created. Sonication of the precursor in the presence of an inorganic support (silica or alumina) provides an alternative means of trapping the nanometer clusters. Figure – 6 shows the Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) images of nanostructured materials prepared using sonochemical method.

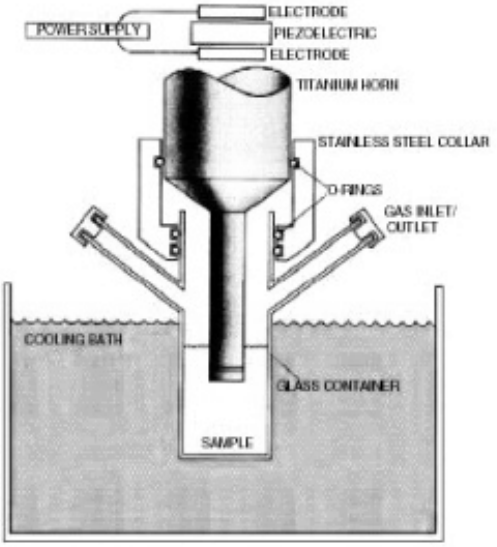


Figure 5: Schematic of the sonochemical apparatus used for carrying out reactions. The titanium horn immersed in the reaction liquid is driven by a piezoelectric, which vibrates when subjected to an alternating electric field. The common piezoelectric ceramic used is PZT, a lead zirconate titanate material.[8]

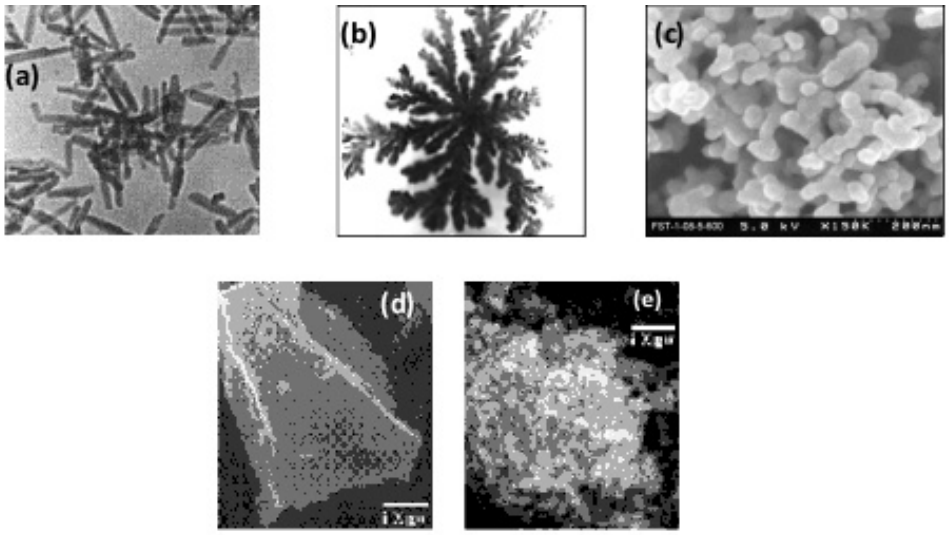


Figure 6: Sonochemically prepared (a) magnetite nano rods (b) Tungsten oxide nano particle showing dendrite morphology (c) $LaCoO_3$ and MoS_2 prepared by (d) conventional and (e) sonochemical method.[8]

3.1 Chemical synthesis of nano materials

Chemical process of synthesis of nano materials involve either rapid injection of reagents into hot surfactant solution followed by aging at high temperature, or the mixing of reagents at a low temperature and slow heating under controlled conditions. Spherical cobalt nanoparticles with various crystal structures have been synthesized by thermally decomposing dicobalt octacarbonyl or by reducing cobalt salts. Nanoparticles of Fe–Pt and other related iron or cobalt containing alloys have been made by simultaneously reacting their constituent precursors. Many different ferrite nanoparticles have been synthesized by the thermal decomposition of organometallic precursors followed by oxidation or by low-temperature reactions inside reverse micelles. Rod-shaped iron nanoparticles have been synthesized from the oriented growth of spherical nanoparticles, and cobalt nanodisks were synthesized from the thermal decomposition of dicobalt octacarbonyl in the presence of a mixture of two surfactants.

3.2 SEM and TEM images of Nano Materials synthesized by Chemical methods:

(see next page, Figure - 9, 10, 11)

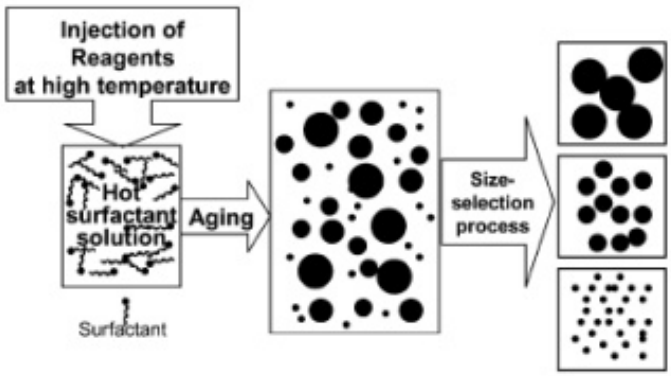


Figure 7: Generalized synthesis of monodisperse nanoparticles by the injection of reagents into hot surfactant solution followed by aging and size-selective process.[11]

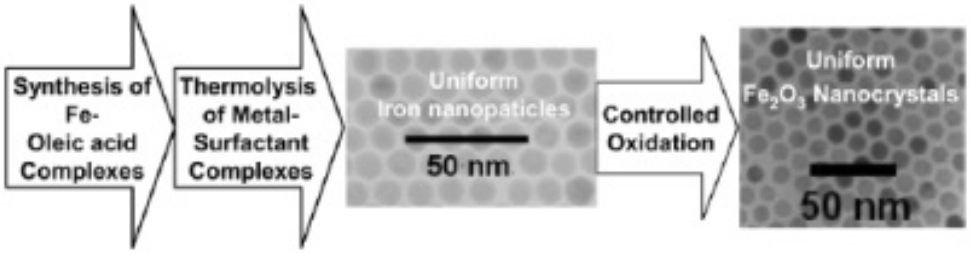


Figure 8 : Synthetic procedure for monodispers γ-Fe_2O_3nanoparticles.[11]

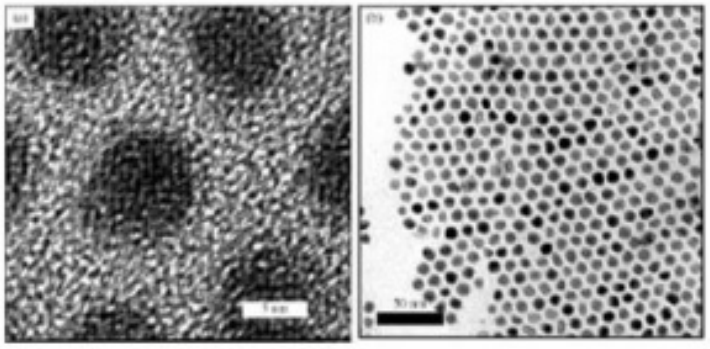


Figure 9: (a) High-resolution TEM image of 7 nm hcp Co NCs revealing subtle lattice imaging of the NCs. (b) Low resolution TEM images of an ensemble of 10 nm hcp Co NCs.[11]

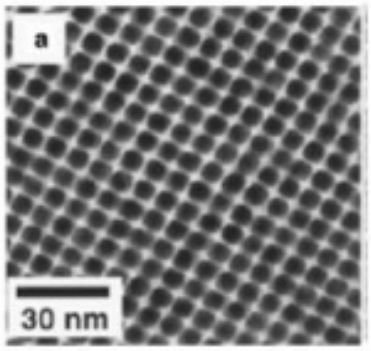


Figure 10: (a) TEM micrograph of a 3D assembly of 6 nm $Fe_{50}Pt_{50}$ sample after replacement of oleic acid/oleylamine with hexanoic acid/hexylamine.[11]

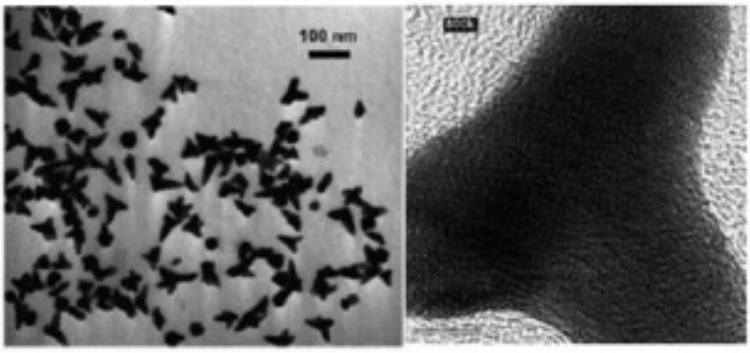


Figure 11: TEM image of branched gold nanocrystals and HRTEM image of an individual gold nanocrystal.[11]

3.3: Applications of Nanostructures :

Nanostructures have been used by nature for millions of years: birds and magneto tactic bacteria use magnetic particles for essential navigation purposes. Nature has optimized a compass within these living species that each magnetic particle is as large as it can be without being multi domain. If present as single particles, they would be super-paramagnetic, and would thereby loose their ability for orientation purposes. The particles are ordered in a row so as to maximize the sensitivity of the compass and to avoid switching of the direction of magnetization. Now-a-days, nano particles and nanostructures are being used in many areas and many materials are designed to provide unique properties not achievable by conventional materials. Areas of application of nanoparticles and nanostructures are magnetic tapes, magnetic fluids, catalysts, and mechanical hardening of alloys, sensors, as well as high-performance soft and hard magnets. Amorphous alloys are used in most theft-protecting systems where the interplay between magnetic and mechanical properties are employed. Amongst many other applications, they are used for detection and precise measurement of ultra-small magnetic fields e.g. Oersted satellite, which is mapping the magnetic field around the Earth.

4. Fabrication of nano structured thin films

4.1 Pulsed Laser Deposition Technique

Pulsed laser deposition (PLD) is a technique used for creating nanostructured thin films. It has gained a great deal of attention in the past few years for its ease of use and success in depositing materials of complex stoichiometry. It was shown that the non-equilibrium thermal evaporation process preserves the stoichiometry of the target material in the film under material-specific window of laser energy density and collection angle of the evaporant. Preservation of target stoichiometry, a unique feature of PLD, is considered to be a result of the following two important factors:

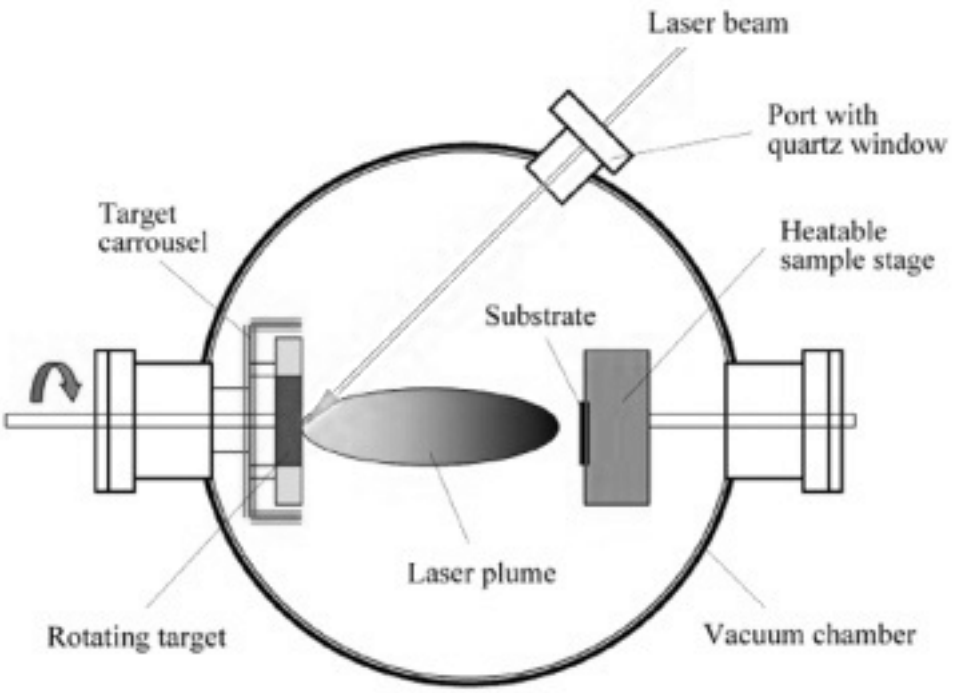


Figure 13:. General diagram showing Pulsed Laser Deposition process.[8]

1. The time scale of the evaporation process and the heat transfer to the target is short compared to the time scale in which the surface and bulk atomic species intermix.

2. Due to high evaporant density at the target surface, collisional process dictate the angular distribution of the ejected species (atoms, neutrals and ions) and up to a specific distance from the target, the trajectories are species independent. This distance is specific to a target material, laser energy density and the deposition pressure.

The principle of pulsed laser deposition, in contrast to the simplicity of the system set-up, is a very complex physical phenomenon. It does not only involve the physical process of the laser-material interaction of the impact of high-power pulsed radiation on solid target, but also the formation plasma plume with high energetic species and even the transfer of the ablated material through the plasma plume onto the heated substrate surface. In the PLD process, due to the short laser pulsed duration (~10 ns) and hence the small temporal spread (<=10 ms) of the ablated materials, the deposition rate can be enormous (~10 mm/s). Consequently a layer-by-layer nucleation is favored and ultra-thin and smooth film can be produced. In addition the rapid deposition of the energetic ablation species helps to raise the substrate surface temperature. In this respect PLD tends to demand a lower substrate temperature for crystalline film growth. Unlike thermal evaporation, which produces a vapor composition dependent on the vapor pressures of elements in the target material, the laser-induced expulsion produces a plume of material with stoichiometry similar to the target. It is generally easier to obtain the desired film stoichiometry for multi-element materials using PLD.

4.2 Pulsed Electron Deposition Technique

One of the exciting developments to occur over the last decade has been the emergence of a novel pulsed electron source based on a pseudo spark capillary source. Pulsed Electron Deposition is a process in which a pulsed high power electron beam is incident on the surface of a target, penetrates approximately 1-2 μm resulting in a rapid evaporation of target material. The energetic beam of pulsed electrons is created in a low-pressure gas discharge known as “Pseudo-spark” or “Channel-spark” in the literature. The ablation process lasts about 100 ns leading to non-equilibrium heating, which in turn facilitates stiochiometric preservation of the target composition in the deposited film. The main feature of the PED is to generate high power of density of about 108 Watt/cm2 at the target

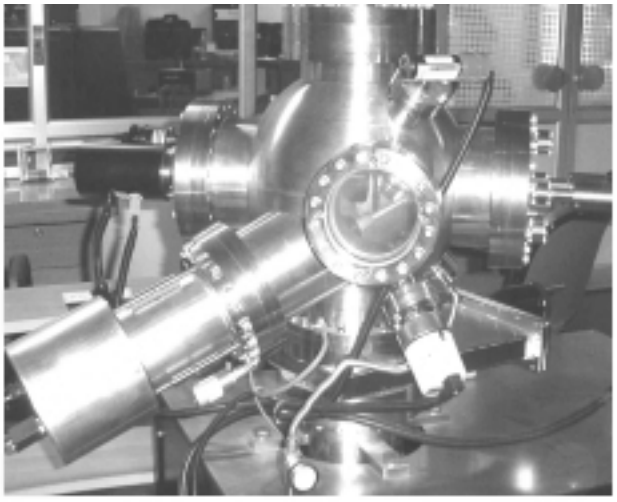
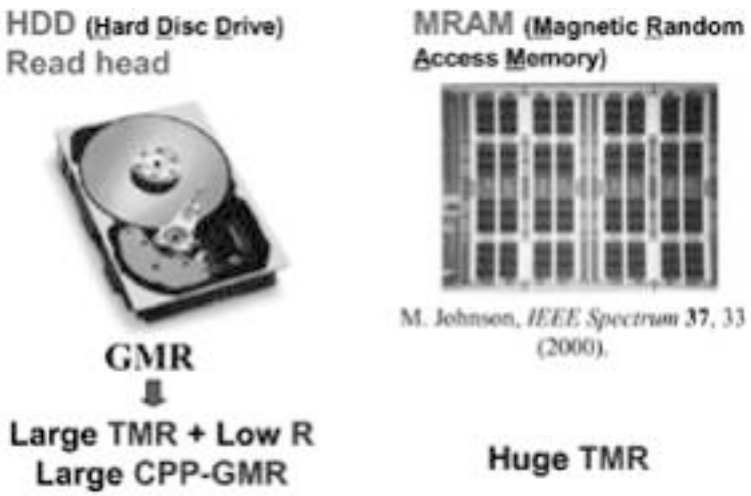


Figure 14: Pulsed electron deposition facility at IIT Kanpur[8]

Minimum discharge voltage	20kV
Electrical efficiency	30%
Stored Energy	3J
Gas Pressure	~30 mTorr
Discharge time	~80-100 ns
Repetition time	1-100 Hz
Electron energy in the beam	=15keV
Electron current	15kA
Electron beam diameter	~2-3 mm
Beam current density	$=10^7 A/cm^2$
Power in the beam	=15MW

surface as a result thermodynamic property such as melting point and specific heat become unimportant for the target material. PED is not critically dependant on the optical absorption coefficient, therefore ablating SiO2 which has large optical band gap of 10 eV can be achieved at ease. All solid state materials-metals, multi-component metal oxides, complex alloys novel polymers, semiconductors and insulators, can be deposited as thin films with PED. Metal – Insulator – Metal tunnel junctions can also be realized which other wise difficult to achieve with other deposition techniques.

The high Temperature super conducting (HTS) YBCO (and GdBCO) films, Para electric (Ba – SrTiO3) films, Metallic – oxide (SrRuO3) films, Insulating glass (SiO2 – based) films and Al2O3 films and PTFE films are some of the materials which have been explored using Pulsed Electron deposition technique.



5. Applications of nano structured thin films:

Thin films of a nanometer thicknesses routinely fabricated using pulsed electron deposition, pulsed laser deposition, molecular beam epitaxy etc. The discovery of GMR was to a great extent due to the significant progress in thin-film deposition techniques, which made it possible to fabricate layers of various materials with nearly a monolayer precision. The discovery of Giant Magneto Resistance (GMR) effect (figure 7) in Fe/Cr magnetic multilayers in 1988 has initiated a tremendous research effort on layered magnetic systems. GMR effect originally observed in the Fe / Cr sandwiches and multilayers was also found in many other magnetic multilayers systems like Co/Cu, Co/Ru, Ni/Ag, and Co/Au. Figure-15 shows some of the applications of thin film devices where GMR and TMR effects have been utilized.

6. Research work at IITK:

(I) SEM and TEM images of bulk nano particles synthesized by Sonochemical and Wet chemical methods (Figure - 16 to 20):

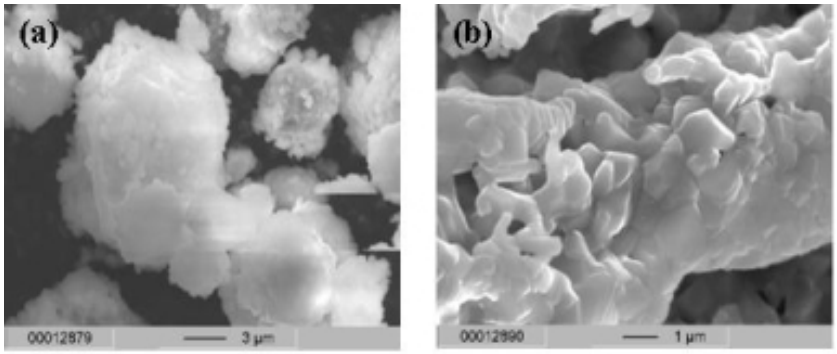


Figure 16: Scanning Electron Micrographs of sonochemically prepared cobalt nano metal powder **(a)** as prepared and **(b)** heated at 900°C.[8]

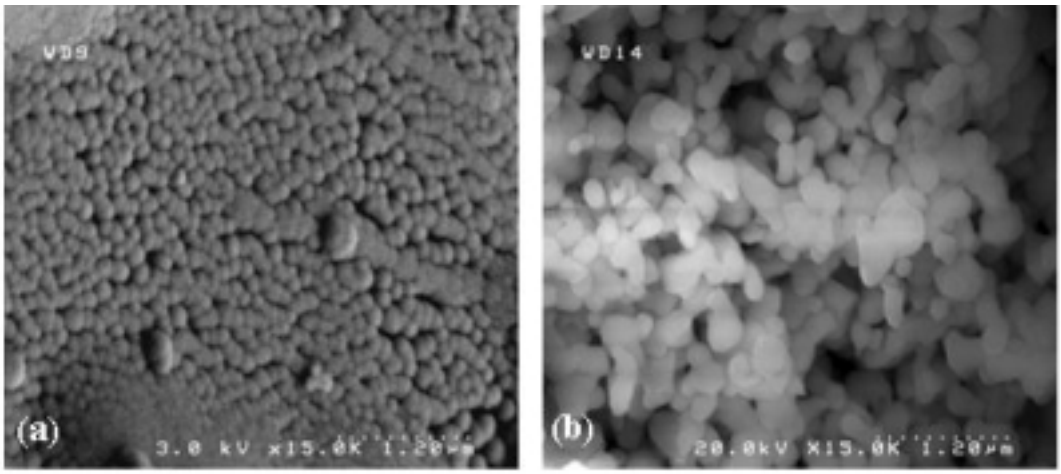


Figure 17: Scanning electron micrograph of sonochemically prepared chromium metal powder **(a)** 'as prepared', showing room temperature sintering effects **(b)** heated at 900°C.[8]

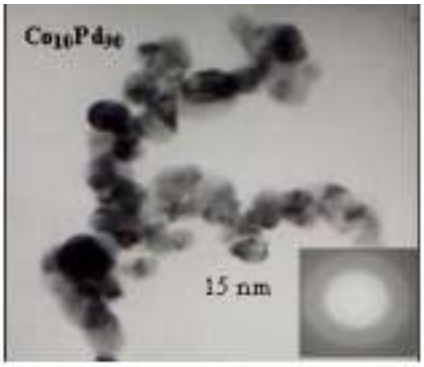


Figure 18: Transmission electron micrograph (TEM) of the $Co_{10}Pd_{90}$ particles prepared via $NaBH_4$ route. The particle size estimated is about 5-8 nm. The inset shows the weakly crystalline nature of the as-prepared powders.[8]

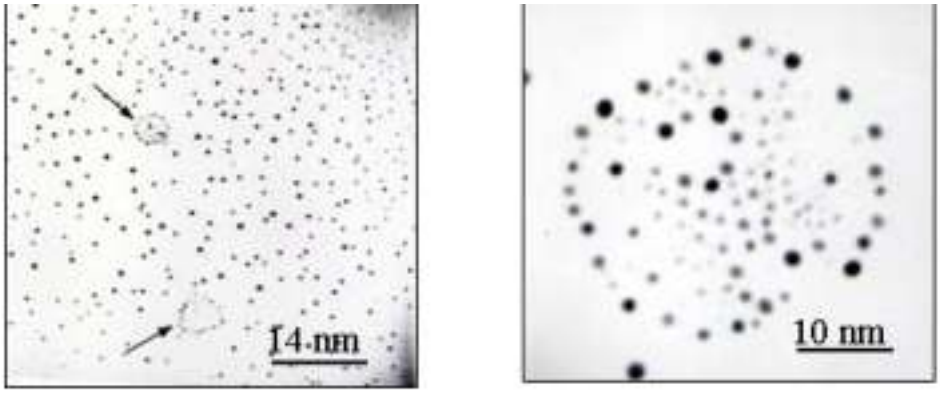


Figure 19: TEM of 'as prepared' Fe-Pt nano-alloys showing nominally spherical, monodipersed particles that self assemble to form closed ring-like structures driven by the balance of surface tension, van der Waals forces, magnetic interactions among super paramagnetic (SPM) or ferromagnetic (FM) particles.[8]

(ii) Tunneling Magneto Resistance (TMR):

Among several facets that characterize new generation Spintronic devices, magnetic tunnel junction (MTJ) is the simplest multi-layer configuration consisting of two ferromagnetic (FM) layers separated by a nanometer thick insulating barrier. The choice of the insulating layer (organic or inorganic) and the thickness of this barrier determine the spin dependent tunneling to provide high and low resistance states.

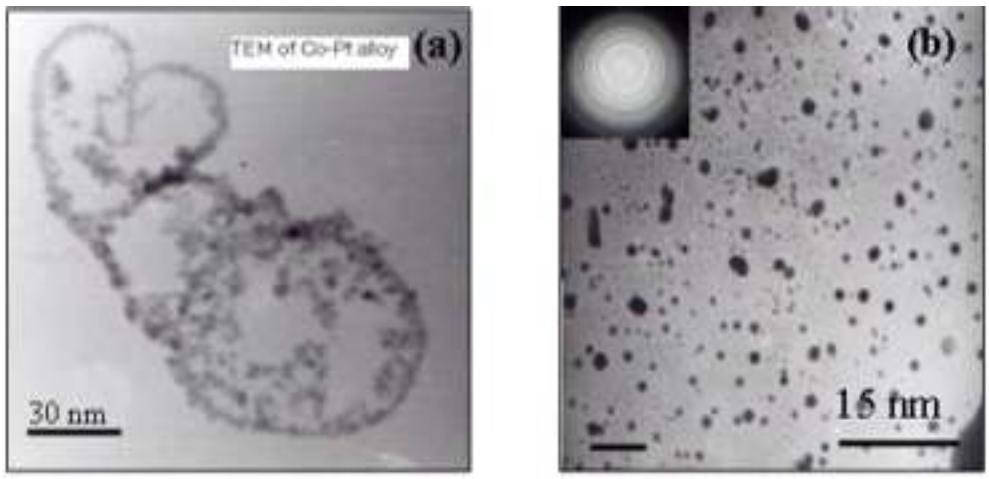


Figure 20: (a) Transmission Electron Micrograph of $Co_{50}Pt_{50}$ 'as prepared' alloys forming self assembled nano chains of ~3000Å in length **(b)** Tem of the dispersed particles with average diameter of 4 - 5 nm. Inset shows the SAED pattern confirming the amorphous nature of the alloys.[8]

The tunneling characteristics are dependent upon the dielectric constant () of the insulating film; the smaller the value of the lower the resistivity. Inorganic oxides such as Al2O3 and MgO show ~9-11, whereas for PTFE (~2) a considerably thick barrier is permissible. Hence, choice of PTFE (hereafter referred as Teflon) can bring down the criticality of barrier layer thickness and issues related to pin hole formation. Teflon is thermally stable (Tg = 325oC), crystalline and has a very high band gap (8.5 eV). Pulsed Electron Beam deposition (PED) technique employed to deposit the Teflon films. Further, as a synthetic strategy, bottom Fe electrode deposited at 250o C to obtain a nearly flat film and to decrease the coercivity with respect to the top Fe electrode.

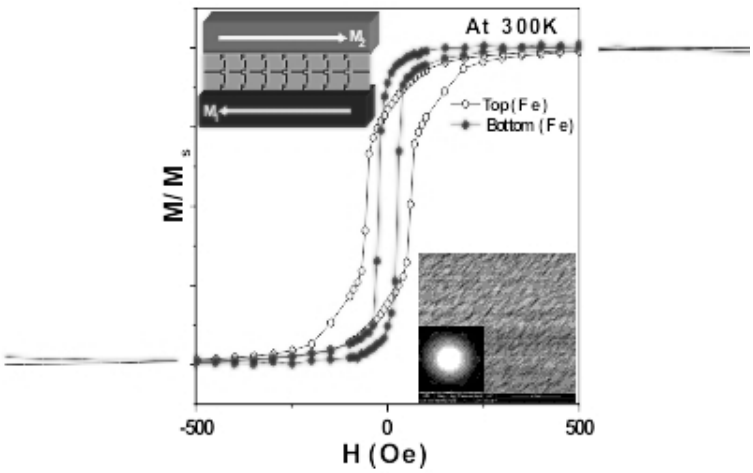


Figure 21: Magnetic Hysteresis loops of the top and bottom Fe electrode measured separately at 300 K. Note coercivity difference between bottom & top electrode that is necessary for spin valve device. The bottom inset shows SEM image of the Teflon film and the SAD pattern shows weakly crystalline nature. The top inset shows Fe/Teflon/Fe interface work as spin valve.[8]

The magnetization measurements were performed using variable temperature VSM, separately for the bottom and top Fe electrodes, applying field in the plane of the film as shown in Figure 21. These measurements indicate that at 300K, the coercive field, Hc of the bottom Fe electrode is ~25 Oe whereas Hc ~54 Oe for the top Fe electrode. The bottom inset shows the SEM image of teflon film showing predominantly flat surface desired for depositing the over layer and the selected area diffraction shows crystalline nature of the Teflon film. The top inset shows the schematic representation of the trilayer device, (-CF2-)n chains playing the spacer role.

Figure 22a shows the M-H loop of the Fe (100 nm) / Teflon (6 nm) / Fe (100 nm) device measured at 300 K with the field in the plane of the film. When the external magnetic field H is varied between 25 and 54 Oe, the magnetization directions of the two FM electrodes are anti-parallel to each other; whereas for H > 54 Oe the magnetization directions of the electrodes are parallel to each other. This is clearly observed in the M-H loop for the device, where magnetization transition is reverses via a two-step loop. In the case of coupled system ,the coercivity of the single loop will come between coercivity of the top and bottom electrode. The top inset in Fig.18 shows the device structure of the size 5 x 5 mm2 employed for MR measurement.

In Figure 22b, a typical MR loop of the magnetic tunnel junction at zero biasing voltage is shown. The electrical resistance, R in the anti-parallel magnetizations alignment (RAP) is greater than that in the parallel alignment (RP). The maximum relative MR is given by Julliere's Model, TMR = (RAP - RP) / RP = 2 P1P2 / (1 - P1P2), where P1 and P2 are the electron spin polarizations of the two electrodes, is found to be 0.06 % at 300K. In summary, a two step hysteresis loop proving a trilayer device to show MTJ performance using Teflon (organic molecule) barrier layer thickness around 6 nm demonstrated.

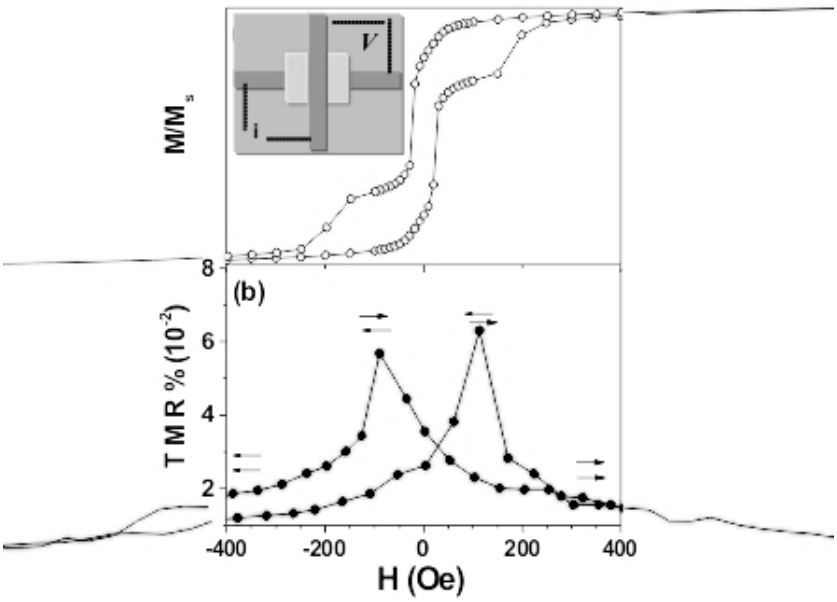


Figure 22: (a) The magnetization hysteresis loop measured at 300K with magnetic field applied parallel to the plane of the film for the Fe (100 nm) / teflon (6 nm) / Fe (100 nm). (b) Magneto-resistance (MR) curve for the Fe (100 nm) / teflon (6 nm) / Fe (100 nm) with magnetic field applied parallel to the plane of the film. The top inset shows device structure of the size 5 x 5 mm^2 for MR measurement.[8]

Ponder Yonder

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Brajendra Singh (brajendr@gmail.com) joined for the research program at Department of Chemistry, Indian Institute of Technology Kanpur, INDIA in the year 2002 after qualifying CSIR - JRF/SRF fellowship from Council of Scientific and Industrial Research (CSIR), INDIA. He has been awarded Ph. D. degree in 2008 in the area of Solid State and Materials Chemistry. Currently, he is working as assistant professor in Centre of Material Sciences, University of Allahabad, Allahabad.

TIME TO SHOOT

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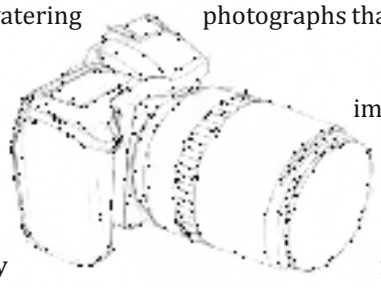

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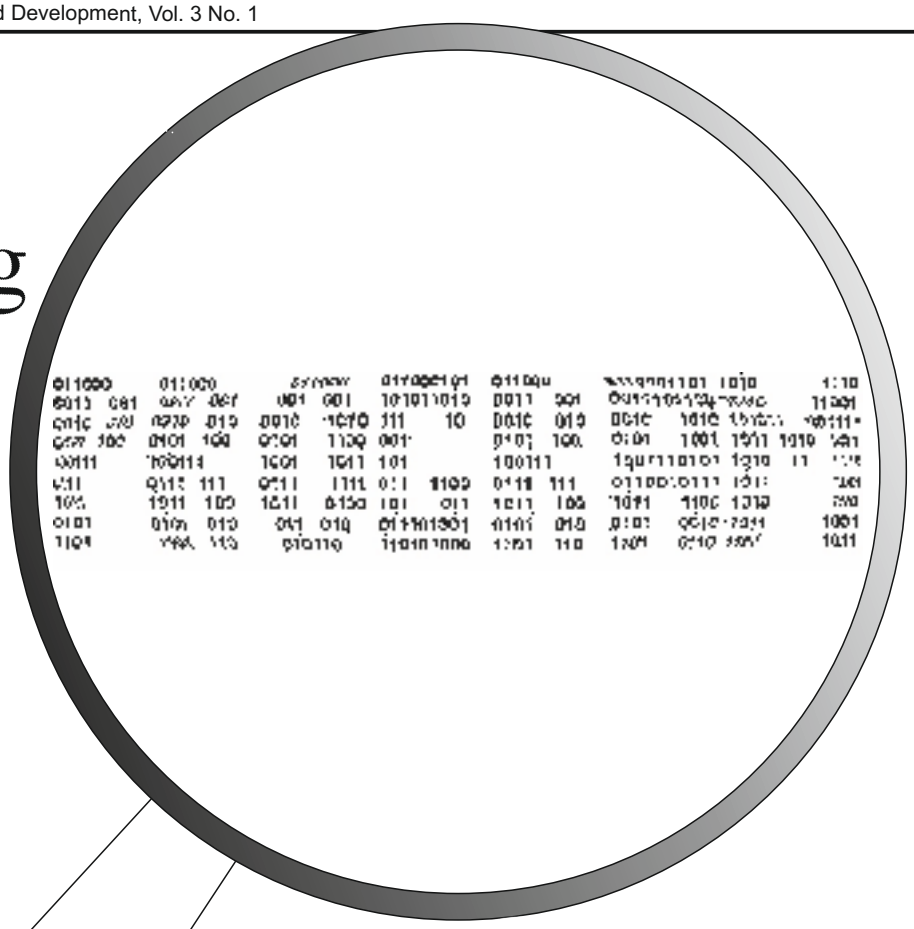
Article

Writing Smallest

• Manjish Pal



Most of us have written computer programs at some point of time. Some of us are in fact fond of writing programs. So, this article will really bring something fascinating about computer programs for them. Let me start with an informal definition of a program. A computer program is a kind of black-box that on some input produces an output. A correct program will always output the desired output (for which the program is written) on the given input. If somebody is asked to check whether the program is correct or not without looking inside the black-box, then in principle he will have to give infinitely many inputs.

After this brief introduction let say we are in the following situation: Somebody has come to us with a problem related to integer arithmetic (say, testing whether a given number is prime or not!) and asks us to write a program that solves the problem i.e. it always outputs the correct answer on any input. Till now for a computer programmer there is not much to worry about. The person now asks us to write the program in the most efficient way possible. It is natural to ask him the sense of efficiency in this case. That is, whether the program has to be efficient in terms of processing time or memory required et cetera. Now the answer we get is this:

"Write the smallest (with respect to the size of the program when converted into 1's and 0's) possible program to solve this problem."

Let this length be called the "binary-length" of the program. This really is a daunting task for us as we really do not know whether the program we are going to write to solve the problem is going to be the "smallest" one or not. That is, if we consider all possible correct programs our program should be the smallest one to give the same output for the same input. Let us call programs with such property to be "elegant".

Suppose we write a program for him and we feel that this in fact is the elegant program for the problem. How are we going to convince him?

One way out is to give a mathematical proof that indeed our program is elegant. Let us say our mathematics is not good enough to do this. What if we have a proof checking program PC for the formal axiomatic system related to the problem which, given a statement, can go through all possible proofs in the axiomatic system and output "yes" if the statement is true in the system? Well, what is a formal axiomatic system? Informally, a formal axiomatic system can be thought to be a set of statements that can be derived using some fixed statements called axioms which are assumed to be true. Number theory, geometry etc. are examples of formal axiomatic system.

Coming back to our problem, how can PC help us? What we can do is to run PC with the input statement being "P is elegant", where P is the program that we have written. If P is in fact elegant, then this method is surely going to work and we would successfully convince our problem-provider but if it is not then we can't say anything. Why? Because the axiomatic system can have infinitely many true statements and hence if we give a non- true statement as input to PC then PC will never be able to conclude that the statement is false and will never halt since that particular statement is not a part of the axiomatic system.

It seems that we are done, but there is a slight problem. It turns out that it is possible that our P is in fact elegant but PC can't see it. This

might seem absurd but it can be proved that PC can't be used to prove the elegance of programs with size greater than some value. In the rest of the article I would like to give a very rough sketch of this proof, which is due to Gregory J. Chaitin, who has given a rigorous description of the proof using LISP (short form for "LISt Processing"), which is a functional programming language. In a functional programming language each and every computation can be represented as an evaluation of a mathematical function [readers may also refer to lambda calculus for more information]. But I won't go into functional programming language and LISP details here. Note that Chaitin is well known for his contributions in algorithmic information theory and philosophical mathematics.

Now, the crux of the proof lies in constructing a program R that returns the following:

The value the smallest program, larger than R, that can be proved to be elegant using PC.

There seems to be a few ambiguities in the above statement. First of all what I mean by the value of a program? As I mentioned above, in a functional programming language (like LISP) every program is an expression that has a mathematical value. In the above statement I am talking about this value only. The return value of computation will be same as the value of the expression. The size is again the length (or the number of characters) of this expression. If we represent each character in 8 bits in our computer, then smaller expression in LISP will correspond to a smaller binary length of the program that we talked about earlier. It turns out that we can write the program R in LISP. If the size of the program PC is S, then the size of the program R turns out to be S+N, where N is a fixed constant (which is actually 356) in LISP. Now the most important part is how this program is constructed. The rough idea is as follows:

R has a fixed part of size N and part containing the program PC that is of size S. In the fixed part R determines its own size as S+N and makes a function call to PC to run through all the proofs of the axiomatic system and in increasing size, until it finds a proof that some program say Q is elegant and size of Q is more than S+N. If such program Q is found then R returns the value of Q. Assume that any program which is looked upon by PC has input coded within it (if any) and hence so has Q. This program R is not too difficult to write in LISP.

Now, if we look carefully we are in a state of contradiction as Q is elegant and we have found a program that is R which has a size smaller than Q having the same return value as of Q, which is contrary to the definition of "elegance". So, what do we conclude? We conclude that either PC proves false statements i.e. some of the proofs that are wrong are considered correct by it (which we definitely do not want as then our entire axiomatic system will turn out to be inconsistent and will collapse) or that PC cannot prove the elegance of elegant programs of size more than S+N. This conclusion in some sense indicates that our formal axiomatic system is incomplete. The notions of incompleteness are not new in mathematics as such an idea was first put forward by Kurt Gödel in 1931 in which he proved the existence of non-provable true statements. Subsequently, A.M.Turing in 1936 proved a similar result on computers using the celebrated "Halting Problem".

So, it is possible that for some problems we will never be able to convince our problem provider that the program we have written is in fact an elegant one and finally we might have to settle down with programs that are not actually elegant or smallest in binary length.

Ponder Yonder

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2. List of publications of G. J. Chaitin at http://www.umcs.maine.edu/~chaitin/complete.html

About the Author

Manjish Pal is an active contributor and editor at The NERD (the NERD website, http://thenerd.in), who graduated from IIT Kanpur in May 2009 and is pursuing doctoral research at Princeton. He is currently taking a break and is a Visiting Faculty member at LNMIT, Jaipur (India).

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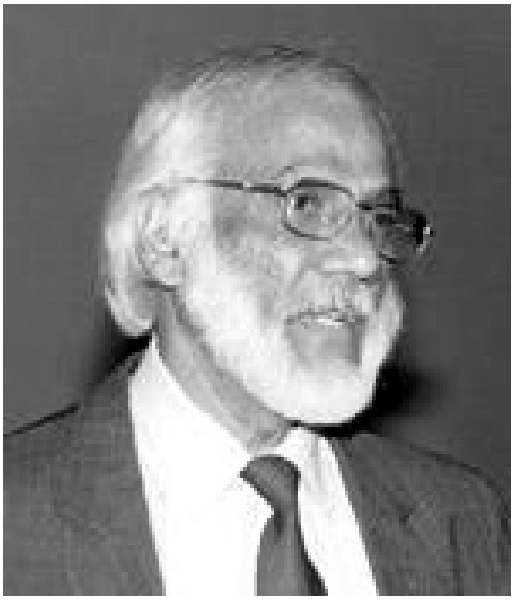
Interview

Dedication personified: Interview with Dr. G. Padmanabhan (ex-Director, IISc Bangalore)

• Pushkar Aggarwal and Mohit Kumar Jolly

Dr. G. Padmanabhan, the recipient of Padma Shri and Padma Bhushan, is a renowned biochemist and a pioneer in Indian biotechnology. He served as the Director of Indian Institute of Science (IISc) Bangalore from 1994-1998. Science is everything for him, and he continues to do research as an honorary professor in the Department of Biochemistry at IISc. Popularly known as GP and a completely home grown scientist, he has never been to a shop or bank for the last 30 years. A NERD team member interviewed him in the leafy campus of IISc Bangalore. Here are some of the excerpts from the same.



NERD: You have been associated with IISc Bangalore for last 4 decades. You also served as the Director of the Institute. As IISc celebrates its centenary year, please tell us something about the growth of the institute and its current standing in worldwide state-of-art research.

Dr. Padmanabhan: IISc was setup through the vision of Jamshedji Tata. He had wanted to contribute in three major sectors in India- steel, power and higher education. He even considered Lucknow among many other places to set up IISc. In the end, he was given free land in Bangalore by the erstwhile Maharaja of Mysore. Initially opposed by the British who did not think there was a need of such an institution in India, IISc started in 1909, with two departments, Electrical Technology and Applied Chemistry. Today, there are 40+ departments. The decision to start IIT's took place in the institute. Every technological development in the public sector in the country had a linkage here example NAL, BEL, CPRI etc. We had luminaries like Homi Bhabha, Vikram Sarabhai, and of course C.V. Raman.

In the first 50 years of its existence, IISc answered to the demands of society. It was involved in projects of applied nature. For example, during the Second World War, it was involved in extracting solvents from flowers to be used in manufacturing different goods. In 1921, the department of Biochemistry, one of the first in the world, was set up in IISc. However, unlike today, it was focused more on practical problems, like methods of sewage treatment, nutritional foods etc. In the second phase, the focus shifted to publishing papers and basic research. Now, a large number of high-quality papers come out of IISc. In my opinion, although good basic research is vital for the country, science without an element of application to human welfare is sterile. One application which benefits society means more to me than several publications.

IISc suffered because of the first nuclear blast, and we were projected as the think tank behind the effort by vested interests and sanctions were imposed on the institute. This caused a lot of problems, since materials for research were not allowed to be imported. However, the institute found different ways of coping through these, and carried on with research activity. I wrote a letter against these sanctions to Science, which they were kind enough to publish.

IISc suffered because of the first nuclear blast, and we were projected as the think tank behind the effort by vested interests and sanctions were imposed on the institute.

Despite these hurdles, we have published a large number of papers in several fields including Bio-Sciences. Earlier, there was no concept of intellectual property, since as a public-funded institution, all the work we did was supposed to be meant for public consumption. The concept of patents came much later.

The institute has done great things, but in today's scenario no one can afford to rest on their laurels. IISc needs to reinvent itself

.

NERD: As Director of IISc, you strived hard to promote industry-academia collaboration. Please detail about some of your related initiatives. What is the current scene in India? What major changes would you suggest to improve it?

Dr. Padmanabhan: In biotech, an approach to application oriented research has been only there in industry in the last 10 years. I was involved in setting up the Society for Innovation and Development (SID) for long term industry interaction. The Centre for Scientific and Industrial Consultancy (CSIC) already existed in the Institute. A new Innovation Centre has come based on the success of SID. Right now, in IISc, industry approaches IISc in two different ways. First, they are looking for a solution to a particular problem, which is generally not too difficult to find. The institute takes it up not for money, but only if the problem poses an intellectual challenge. A second option for the industry is to establish its own lab in the campus.. The engineering departments have always had an interaction with industry and national agencies, but today even in science departments there must be about 40% of faculty with industry relations. This would not have been more than 5% 10-15 years ago. The greatest virtue of the institute is the academic freedom it gives to its faculty and over the years this has helped to make the institute unique.

NERD: You are known as an icon in the field of anti-malarial drugs. What got you interested to work in this field? Please elaborate upon your contribution in the field. What is the latest breakthrough research in these anti-malarial drugs?
Dr. Padmanabhan: I am basically a biochemist/molecular biologist. I was working on the gene-basis for drug metabolism in liver. When, I was interacting with AstraZeneca in the early 80's, we had started projects on TB and malaria among others for the company. I got interested in malarial parasite biology during this, and ARC funded my research for almost 10years. There is no vaccine available against malaria; the parasite can be combated only through drugs. The parasite however, develops resistance against drugs. The biggest challenge is to discover new drugs. There is only one drug of Chinese origin (artemisinin) which is really good. So far there has been no resistance to it, because it was used only in emergencies. Now that other drugs don't work it is used as a frontline medication against the parasite and it has started developing resistance even to this drug.

My research targets the metabolic chains in the parasite as possible drug targets. In addition, we also look at natural compounds for anti-malarial activity. For example, we have found that Curcumin present in turmeric possesses such properties. Combination of two drugs reduces or delays resistance development. We tried a combination of Curcumin with the drug mentioned before, and it has given a breakthrough in the animal malaria model, completely killing the parasite with no recurrence. Curcumin is a preferred compound because it is non-toxic, cheap and without any history of resistance development. We are now starting clinical trials for the drug combination.

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NERD: You are a home-grown scientist. What was the scene of conducting research in biology four decades ago when you joined the line?
Dr. Padmanabhan: It was gross, and not at the molecular/cellular level. Partly because no instruments were available to do such kind of research. In IISc, there was some work on enzymes, but that was about it. There were some visionaries like Dr. P S Sarma, my guide, who established areas such as molecular biology and immunology in this department in the 1960s. It was standard practice, and I believe it is true today as well, that students go abroad after their PhD's. I was an exception and at that time it was considered as misplaced patriotism!

I stayed at IISc for three years after completing my PhD as a Pdf (post-doctoral fellow).But, I was, perhaps, a unique case, appointed as Assistant Professor at that time without a post-doctoral experience abroad. It was all because of the vision of Dr. Satish Dhawan, the then director.

I went to Chicago later, as a Senior Fulbright Scholar, to Prof. Murray Rabinowitz's laboratory. He was a remarkable person. He was confined to a wheelchair due to muscular dystrophy. He still came to lab five days a week, conducted lab meetings and published papers. He invited me to stay back in his lab, but I declined since my heart lay back in Bangalore. He graciously offered me his lab whenever I wanted it. I visited his lab 10 times between 1975 and 1986. But, I never took any of my projects there. I worked on their projects and learnt the technology and established the procedure. I then brought this expertise back to India, and used it for my projects. We never gave up no matter whatever are the hurdles we faced.

NERD: You were involved with the setting up of National Biotechnology Board in 1982 and upgrading it to Department of Biotechnology (DBT) in 1986. How have you witnessed the change in the Indian R&D scenario in biology since the setup of DBT?
Dr. Padmanabhan: The DBT has made a very significant impact in Life Science R&D in the country. There is a significant improvement in the quality of research. DBT has established infrastructure to support research in the field. It has provided opportunities for training, and also established several new institutions in the field of life sciences. Along with DST support, significant improvements have taken place in this area of research.

NERD: Your initial research focused on transcriptional regulation of Eukaryotic genes. Can you please put that in simpler terms and explain about your related work?
Dr. Padmanabhan: My research was on genes involved in metabolizing drugs. Drugs induce genes involved in their own metabolism in liver. This subject has become very important in the human and goes under the name of pharmacogenomics.

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NERD: You are understood to be the one who brought cloning and recombinant DNA technology to India in the early 1980's. Kindly tell us about your related research contributions.
Dr. Padmanabhan: I used it mainly as a tool. During my research, I needed to characterize genes, to better understand their function. We needed adequate quantities of genes and the protein product and so cloning became essential.

As I already mentioned, I went to Chicago, to learn experimental techniques there and then bring them back to India. This branched off into malaria research, where we cloned, sequenced and expressed proteins of the heme-biosynthetic pathway in the malarial parasite. We discovered this pathway during the course of this research.

NERD: How do you find the rate of growth of biotechnology industry in India? How do you envision the growth of it in 2020?
Dr. Padmanabhan: If you compare it with earlier times, there is now a lot of awareness about the biotech industry. There is also a lot of hype associated with it. Positively, the hype has attracted not only investments but also students. On the flip side, people tend to take biotech education as a business. Too many institutions have come up, which produce poorly trained students having degrees in biotechnology. It has become a very sad situation; there is negative feedback, and due to lack of opportunities for students, intake into biotechnology courses would decrease. The reason for this is twofold. The students are poorly or not adequately trained. Secondly, the industry has not grown to that level to accommodate everyone.

Earlier, biotech industry in India was concerned with production of bio-similar; it was similar to the effort in the drug industry. This is very essential for the country, but often would lack innovation. In the last five years, there has been a sea change. There is a newer brand of entrepreneurs. Now, qualified people, PhD's start their own companies. Now many young

people are interested in going into the industry.

2020 – I am a chronic optimist. One thing about India is that the entrepreneurial skills of the people are amazing. For example, I know of this new company, Yash Raj biotech. Run by a banker and a financer, it is a diagnostic company and still these people know every cutting-edge detail about the field. They pick leads from leading international meetings and conferences.

The future looks very bright, but I am a little worried about the agriculture sector. I am a great believer in transgenic crops. They can be of vital use to the country. However, with the current controversies surrounding them, the efforts of scientists are stagnating in glass houses.

NERD: There has been an unprecedented rise in bio-entrepreneurship in India, and Bangalore is said to be the 'Biotech Hub' of India. What advice would you like to give to prospective entrepreneurs?
Dr. Padmanabhan: Firstly, they have an obligation to upgrade the competence of students and not just sit back complaining about the lack of skilled personnel in the field. For example, DBT has started industrial training programs. Industry should also take such initiatives. Secondly, India needs bio-similars, because it requires cheaper products. However, there is also need for innovation. There, initiatives like SBIRI (small business innovation research initiative), BIPP (Biotech Industry Participation Program) started by DBT to promote innovation in the field in India will pay dividends.

Being a member of various boards, I have the opportunity to go through hundreds of projects, and it is heartening to see that people are trying to innovate now. Patent laws changed in 2005. As a result of these reforms, earlier professors had to chase industry for projects, now it is the other way round.

We still lack in some major areas, mainly Translational Research e.g. lab-to-land transfer of technology, scale up of production, clinical trials etc. Things are now slowly changing for the better.

I am a great believer in transgenic crops... However, with the current controversies surrounding them, the efforts of scientists are stagnating in glass houses.

NERD: Indian biotechnology industry predominantly consists of pharmaceutical companies. Terms like Biomedical engineering are not yet heard in India. What are the reasons for the same? Is that because of the fact that the industry is yet in a nascent stage?
Dr. Padmanabhan: We need people with a different background. Biologists would make poor engineers, but engineers can easily learn biology. The reason is also due to lack of infrastructure that is needed for fields like biomedical engineering to operate. However now things are changing For example, there is a bio design program between IIT Delhi and Stanford supported by DBT.

NERD: What are the major challenges/concerns before the Indian Biotech or BioPharma industry? What is its current world wide standing?
Dr. Padmanabhan: The main challenge is innovation. Also, the industry needs to keep pace with others worldwide. For example, while we move to establish serum proteomics as a tool in diagnosis, the world has already moved to Saliva Proteomics! Still, one's environment and country's need also should be kept in kind. We may need to opt for a less advanced technology in India just because it is cheaper. It is always a balancing act.

NERD: You have been a great teacher as well. What pedagogical techniques do you use? Please share with us some experiences.
Dr. Padmanabhan: I always want to give excitement to students in whatever I teach. Too many facts just make the subject boring. I also like to point to the possibility of research questions in whatever I am teaching. This is because students take the text book as gospel. It is necessary to highlight the gaps in knowledge.

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NERD: Tell us something about your student life. Were you always dedicated to pursue research as your career?
Dr. Padmanabhan: Yes. I was the topper in IARI (Indian Agricultural Research Institute) during my masters; however I could not get into PhD there. I came to IISc. During my school days, I wasn't a great student but a sportsperson. The inspiration for research comes from the role models. In Presidency College, I had a Chemistry teacher who was greatly committed to research. At that stage, one thinks it is something great, and an aura develops around the person you admire. I believe students are guided by the role models they look to.

NERD: What would you have been if not a scientist?
Dr. Padmanabhan: I might have been a musician. I have always been a backbencher. I am shy and do not want to come into the limelight. However, music and cricket, which I was good at, saved me.

NERD: We have heard you have not been to any shop or bank for the past 30 years. We have seldom seen such dedicated scientists, and you have always been a role model for all of us. What final message would you like to give to students?
Dr. Padmanabhan: In India, we don't go deeper into research. We are not bold enough. I presented in a seminar the idea of gene therapy early in my career, which came up in a big way later, but people laughed at me. I did not have the courage to pursue. Many people just give up and quit due to lack of infrastructure. Scientists in developed countries are much more adventurous than us here. People switch fields easily, but we get stratified early in our so called specializations. Every profession has its own merit and people should be able to pursue whatever interests them.

I believe students should enjoy life. They should explore and do whatever they enjoy and find it worthwhile. Of course, they have an obligation to the Society in which they live.

NERD: Thank you so much Sir for your time and attention!

About the Interviewers

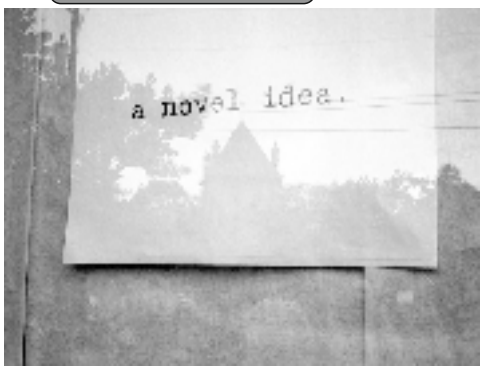
Pushkar Aggarwal (pushkar.aggarwal@gmail.com) is a alumnus from IIT Kanpur. He graduated from the Department of Electrical Engineering. He is interested in learning about semiconductor devices and circuits, and biomedical instrumentation.

Mohit Kumar Jolly (mkjolly@iitk.ac.in) is a first year M.Tech. student at IIT Kanpur. He is interested in science journalism and communication, and is one of the founders of NERD.

Article

Monolithic Reactor: a Novel Reactor for Chemical

• Aditya. S. Sandupatla



In the chemical industry, many times we encounter a three phase reactor system- solid, liquid and gas phases inside a reactor- wherein mostly gas and liquid are reactants and solid is a catalyst, a substance which increases the rate of reaction without itself undergoing a change.

One of the simplistic traditional approaches to build such a three phase reactor system has been to load the solid catalyst inside the cylindrical enclosure and pass liquid and gaseous reactants over it. In chemical engineers language, we call it a "trickle bed reactor' (Fig.1). The conversion of reactants to the desired products depends on various factors such as catalyst structure, catalyst composition, temperature, pressure, the time that reactants spend inside the reactor and the flow pattern of the reactants. Out of these, catalyst structure, residence time of reactants and flow pattern of reactants change with change in the type of reactor. From an industrial point of view, we want better heat and mass transfer rates, lower pressure drop and narrow residence time distribution of reactants across the reactor bed. To improve the performance in comparison to the trickle bed reactor, use of structured reactors has been proposed.

Monoliths are one type of structured reactors (Fig.2). An example of use of a monolithic structure is the catalytic exhaust converter attached to most automobiles these days (Fig.3). It is a ceramic structure consisting of thousands of parallel, one millimeter square channels. It is ordered, self repeating structure that is capable of withstanding the rapid temperature changes that occur in automotive applications. The channel walls are coated with a layer of catalyst which converts the noxious particles in the exhaust gases into less harmful substances. This makes the monolithic catalyst used in the automobiles one of the most widely used chemical reactor, although it is a gas/solid reactor and not a three phase reactor. The main advantage is its regular well defined structure. Hence, the scale-up of such reactor is relatively easier. Moreover, use of monolithic reactor for multiphase reactions has not been fully explored.

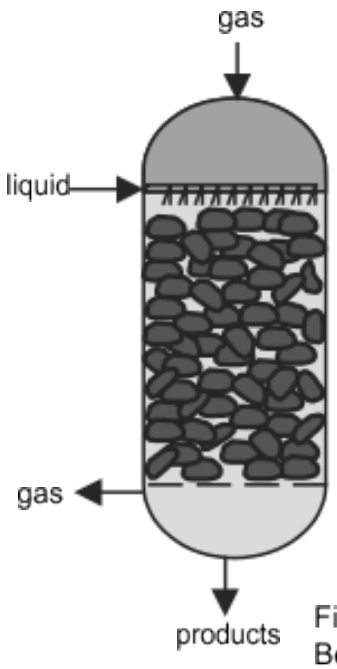


Fig.1:Trickle Bed Reactor

For a three phase reaction to take place, gas and liquid have to find their way into solid catalytic porous material. The effectiveness by which these come in contact depends on flow pattern inside monoliths. Depending on the relative gas and liquid velocities in the monolithic channel, different flow regimes can exist. At a constant liquid velocity, with an increase in gas velocity, the flow regimes shifts from bubble flow (Fig.4a) to slug flow (Fig.4b) and then to annular flow (Fig. 4c). Amongst these, slug flow is desired in which large gas bubbles are separated by liquid slugs. Due to the liquid circulation in the slugs and small thickness of the thin film separating the gas bubbles from the catalyst, the overall heat and mass transfer rates are much higher than in conventional reactors. Moreover, the thickness of the catalyst layer is small resulting in better utilization of the catalyst.

Recent work by a PhD scholar in the Department of Chemical Engineering has shown the advantages, such as lower pressure drop, higher effectiveness factor and higher productivity, when monolithic reactors were used for hydrogenation of -methyl styrene. This reaction was

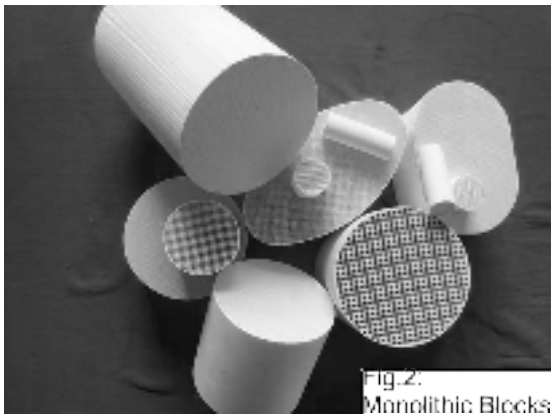


Fig.2: Monolithic Blocks

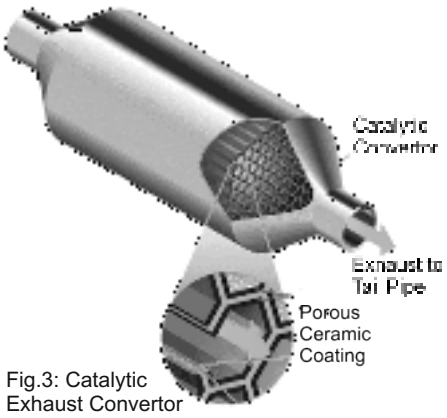


Fig.3: Catalytic Exhaust Convertor

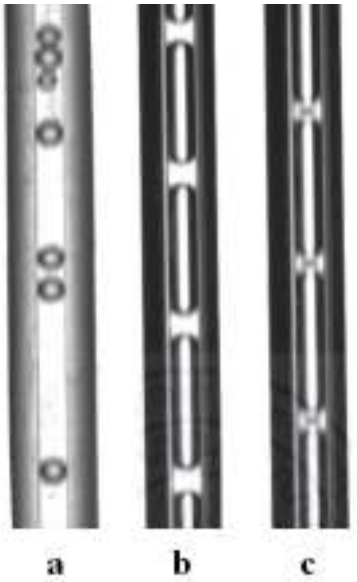


Fig.4: Flow Pattern inside

conducted at low temperature (40oC) and atmospheric pressure. Encouraged by the results, Chevron Corporation, U.S.A. has sponsored a project with Prof. D. Kunzru, Department of Chemical Engineering to investigate the possibility of using monolithic reactor for hydrodesulphurization of petroleum fractions. This reaction is being studied at high temperatures (350oC) and high pressures (60-100 atm). The bench scale reactor set-up is shown in Fig.5. The results from the study would be used to build up the commercial scale reactor.

Fig.5: Bench Scale Reactor

About the Author

Aditya S. Sandupatla (adiss@iitk.ac.in) completed his Masters in Chemical Engineering working on Hydrogen production using Micro-Structured Reactors. Presently, he is working on Monolithic Reactor, as a Senior Project Associate, with Prof. D. Kunzru, Chevron Chair Professor, Department of Chemical Engineering, IIT Kanpur. His research interests are catalysis and process intensification.

NERD INITIATIVE RECOGNIZED

"Catching them young: Inspiring budding researchers for better science communication"

a paper by two NERD members, Bhuvnesh Goyal and Mohit Kumar Jolly has been selected for publication in the proceedings of 11th International Conference on Public Communication of Science and Technology 2010. Please visit http://www.pcst-2010.org/for more information on the conference.

NERD team wishes both of them luck for the same!

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Illustration of NERD Boy by Prabha Malya and the trophy is taken from Microsoft Clipart Gallery
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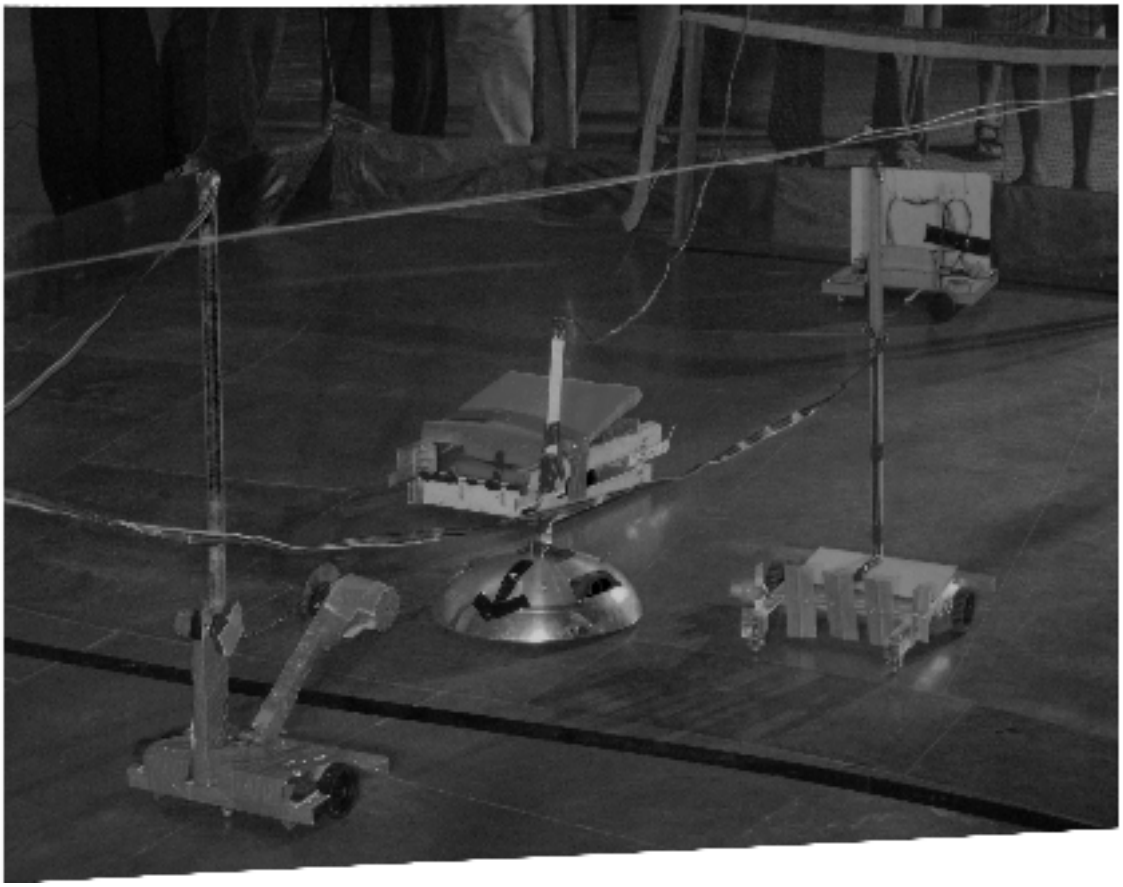

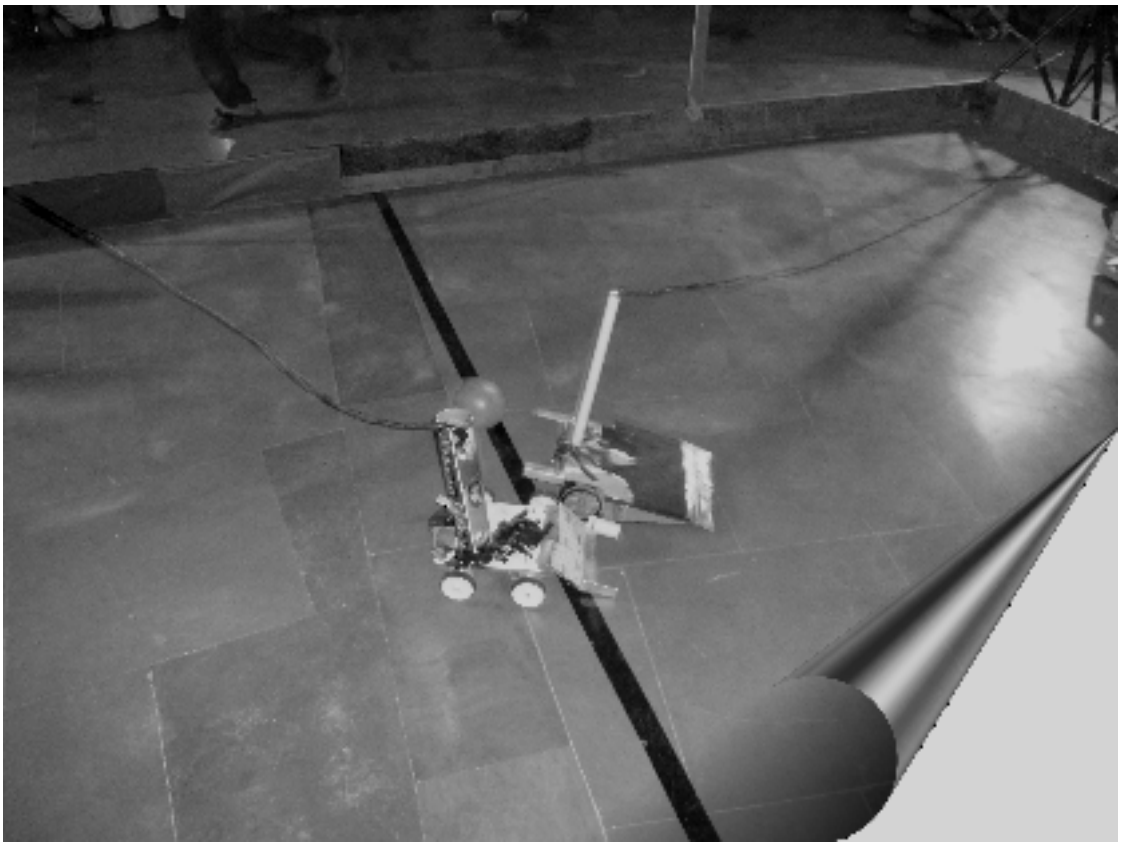


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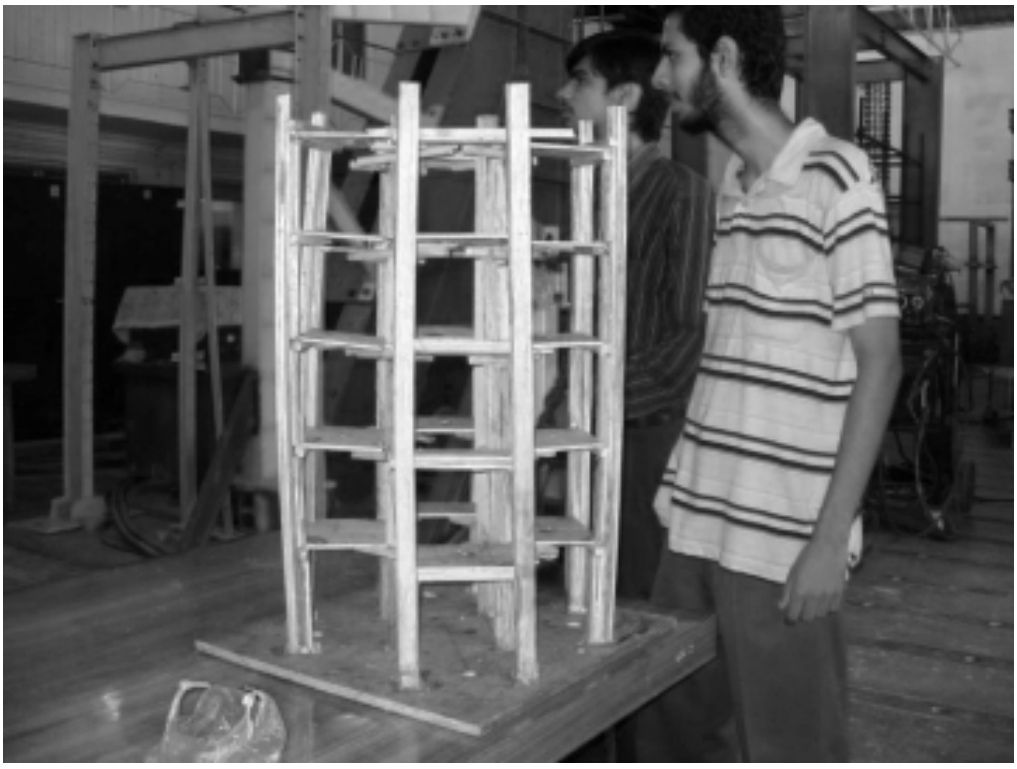


We build our own world...

Tamaghna Hazra and Swapnika Reddy tell us about a group with a difference: NERD Research.

It was just after the first mid sems. Around the time when everybody around me seemed engrossed in Counter Strike, AoE and other such inane addictions.

Through the grapevine I heard about a fledgling initiative for science discussion. Mildly interested and somewhat sceptical (hadn't this sort of idea been kindled and flickered out too many times already?), I met up with one of the members to find out more.

"Basically we are just a handful of folks who are passionate about science. A few journals from the Library and some very interesting video lecture have been fished out. We've been reading articles that interest us. . Every fortnight, we will get together and discuss what we have read." said..... (Drum roll!!)... Ish Dhand, who took the initiative to start this group and has been coordinating the effort with Pranjal Nayak.

Why?

- "Let's learn more about the areas that interest us.
- Let's find new areas that might interest us.
- Let's improve our understanding of what we read by discussing the same.
- Listen to others and let new ideas flow!
- We intend to involve some professors to guide us every now and then."

A closed group with everybody contributing... now, this idea might just work out!!! I was hooked :P
Since then we have met regularly and it's a real pleasure to have 'cerebral' discussions with like-minded people who're now some of our closest friends. We have discussed stuff like:

- Why there is a very strong reason to believe that genetics is taking us to a male-less society.
- Everyday science like the stability of a bicycle and the mirage phenomenon, where we found that the textbook explanations had gaping holes in them.
- Drinking bird; a home decor that appears to be a perpetual motion machine at first sight.
- Handicap principle which explains why a peacock's long tail has survived natural selection.
- Types of supernovae and why they are formed.
- Understanding the brain and neural networks

This coming semester, we'll continue to meet under the soft shade of the white board to ask questions to nature and seek answers. If you are the type who finds the world around us more interesting than our courses allow us to believe, drop in a mail to ishdhand@gmail.com.

The team thats been there since the inception of the group:

Gitesh Dawer, Ish Dhand, Kapil Singh, Kavya sudha, Kumar Ritikesh, Mounica Bodapudi, Pranjal Nayak,Prashant Kumar, Ruhi Dang, Sayan Basak, Shreya P Kumar, Sourav Raha, Sthitadhi Roy, Swapnika Reddy, Tamaghna Hazra, Tanmay Mudholkar

And the latest 'seek'ers from Y10:

Abhinav Deshpande, Abhiroop, Abhishek Jindal, Akshay bansal, Anubhav Dwivdi, Anupam, Arindam Pramanik, Ashish Sharma, Ashudeep Singh, Atulya Shivam Shree, Dhuv Lakhani, Gaurav Vijayvargia, Harsha Mulchandani, KapilDev Advani, Karn Vohra, Kevin Valson Jacob,N Srujan babu, Nitica Sakharwade, Nikhil Jha, Pankaj Prateek, Paridhi Kabra, Prasoon Suchandra, Prenit Wankhede, Prudhvi, Sahil Bhandhari, Sayak Dasgupta, Shashank Pisupati, Shaurya Shriyam, Shoubhik Gupta, Shriman Narayan, Siddharth Rawat , Surajit Mondal, Vatsal Sharan, Vibhav Agarwal, Vignesh R.

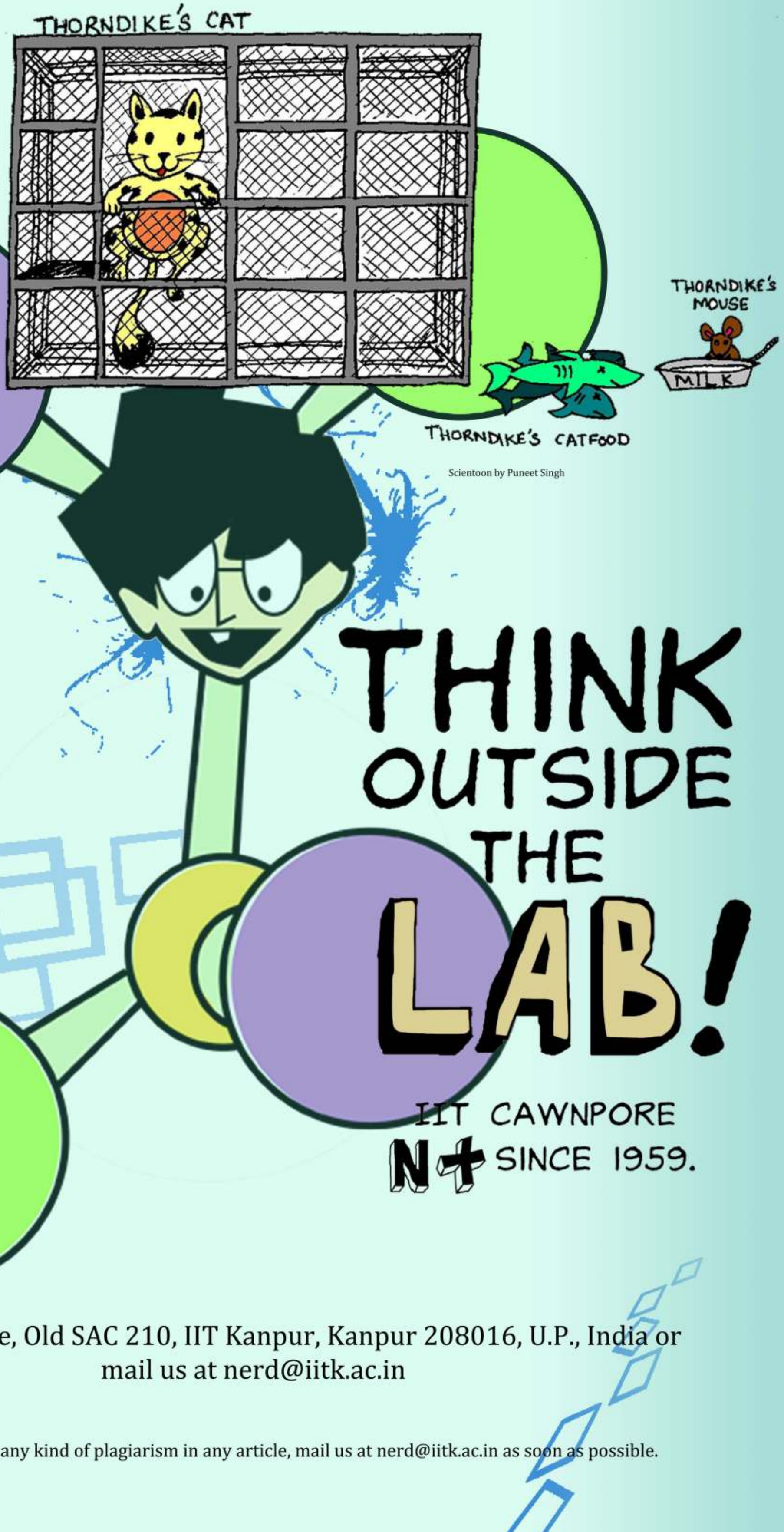
Core Coordination Committee:

Bhuvnesh Goyal, Pranjal Nayak, Utsav Kesharwani.

Other Team Members:

Aayush Gupta, Anjanrey Kothari, Divija Rao, Gaurav Krishna, Mohit Kumar Jolly, Puneet Singh, Punit Kumar Singhal, Prateek Mittal, Shubham Deva, Sumit Gupta, Vardhan Shrivastava.

Edward Lee Thorndike conducted an experiment where he put a cat in a cage with a latch on the door and a piece of salmon outside of the cage. After first trying to reach through the cage and then scratching at the bars of the cage, the cat finally hit the latch on the door and the door opened. With the repetition of this experiment, the amount of time and effort spent on the futile activities of reaching and scratching by the cats became less and the releasing of the latch occurred sooner. Thorndike's analysis of this behavior was that the behavior that produced the desired effect became dominant and therefore, occurred faster in the next experiments. He argued that more complicated behavior was influenced by anticipated results, not by a triggering stimulus.



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