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Celebrating students' research



Interview: Dr. David Morrison of NASA
NERD series on International Year of Astronomy

Insights in Water Treatment

Notes on Engineering Research and Development

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The Year of NERD

MUSINGS FROM THE EDITOR'S DESK

The fourth issue of NERD is in your hand. It has been a long, eventful journey since we started in May 2008 and an even longer run since May 2006 when the idea first appeared. In these four issues of NERD, we have been able to keep the promise of a quarterly magazine and we have stuck to the premise of publishing content created by students. With this issue, a new era has begun. We have gone beyond IIT Kanpur and have reached out to students of several other institutes of repute. As a result, three articles, one each from students of NIT Allahabad, NIT Nagpur and NIT Warangal feature in this issue. This number will go up in the forthcoming issues thus helping NERD acquire a national character—a natural evolution, one could say.

And although there is a certain achievement in expressing ourselves through NERD, the journey has been marred by mistakes – many of them. These mistakes, committed by a young, inexperienced team facing the challenge of publishing technical content four times a year, were unintended. They happened nevertheless. Sometimes layouts were non-uniform or there were grammatical mistakes that went unnoticed. Where the English was correct, attribution of sources was a problem. We forgot to acknowledge many authors, or informing them about whether or not the article will be published, or what exactly is it that we wanted from their work. The NERD mailbox was so flooded by the enthusiasts that we missed on a lot of mails. We never expected the kind of response, overwhelming is a lesser word to describe it, we received. And while our heartiest regards are due to everyone for that, so are our apologies. All we wish to say, as before, is that nothing was done on purpose. The biggest mistake that we committed was that a highly experienced Review Board of Faculty members and Editorial Board of Senior Graduate Students remained grossly underutilized. NERD could certainly have done better by incorporating their views in a much larger way. However a very tight schedule of publication and less meticulous planning (we were still struggling with establishing the magazine and articles, though numerous, poured in at the eleventh hour) are the reasons we attribute this mistake to.

We are committed to rectifying these mistakes. Layouts will be more professional, editing a bit tighter, attribution of each and every source will be tried, every author will be acknowledged on receipt and acceptance and updated on the publication status. The Review and Editorial board will be involved in the operation in a closer manner through proper planning and timely creation of content. Ideas for implementing these solutions and other improvements are welcome.

We thank everyone for their overwhelming support for NERD as readers, as authors and as providers of feedback which is indispensable for this magazine. We will also like to thank all the faculty members, especially Professor Manoj Harbola, the chief investigator of the NERD Project who kept us on track. We thank all the members of the NERD Review Board whose encouraged us and guided us. Our heartfelt thanks are due to Professor Muralidhar, our mentor, who has pretty much shaped this magazine by guiding us through countless esoteric discussions held in his office or lab or in corridors or on phone, through emails and what not—whenever and wherever we needed them. Thank You Sir!

A relevant question that a lot of people still ask, even after one year, is that what is it that NERD is trying to do? We are celebrating students' work in science and engineering. We are celebrating the fresh view point with which students look at established theories and paradigms. We are celebrating the fact that it is the students who will lead the next wave of revolution in science and technology.

The first year of NERD was about establishing the magazine and its survival. It has been proven now that such an effort is feasible. NERD needs to graduate from this phase. The next phase is more critical and it is the phase where we will have to brave the question of sustainability that has been around ever since the idea came to fore. And it is we, the students who can answer this question.

The next year, which starts now will be the year of the NERD Reader. The new NERD, as Al Neuharth, the founder of USA Today once said for his newspaper, will be more enlightening and enjoyable; informative and impelling; challenging and competitive; refreshing and rewarding. NERD will be edited not for the editors but for the readers and authors and for preserving the spirit and ethics of science and technology. For that we need all the help we can get. Hence the call to arms (see Page 40). **Welcome to the revolution!**

Moon, Asteroids and Little Green Men

AN INTERVIEW WITH DR. DAVID MORRISON OF NASA

Punnet Singh, Pranav Gupta and Mohit Kumar Jolly

Dr. David Morrison is a senior scientist at NASA Ames Research Center. He is the founder of the multidisciplinary field of Astrobiology, and has authored more than 155 technical papers and a dozen books. He has received two outstanding NASA leadership medals and was awarded the Presidential Meritorious Rank for his work as Director of Space at NASA AMES. He is best known for his leadership in defining the hazard of asteroid impacts and seeking ways to mitigate this risk. Asteroid 2410 Morrison is named in his honor. He can be reached as David.Morrison@nasa.gov. NERD team got the opportunity to have an interview with him when he was on campus as the Chief Guest in inauguration ceremony of Techkriti'09. Here are some of the excerpts:

NERD: Sir, you are a senior scientist on Astrobiology at NASA AMES Research Centre. Please explain to our readers what is Astrobiology?

Dr. Morrison: Astrobiology is the study of life in universe, and it centers on 3 questions – the origin of life, are we alone and the future of life.

NERD: Astrobiology is not such a frequently heard term. What cutting edge research is going on in this field?

Dr. Morrison: It's new - we essentially invented this multidisciplinary field of study in 1996 at NASA. A great deal of research is going on presently.

We started studying Astrobiology because it became clear that space science had a possibility of answering these questions. We had just discovered Jupiter's moon Europa had an ocean of water. We had found the first planets around other stars outside the solar system. There was all the interest in the evidence that the Mars meteorite contained fossil microbes. A lot of things were happening that made it seem as though this was a good topic to study. In the United States, we have been pursuing Astrobiology now for almost 15 years.

NERD: Has this exciting field of study also found

place in student curriculum in US or it has yet to percolate down?

Dr. Morrison: In the United States, introductory courses on astrobiology have been very popular. It's a topic that students enjoy. This is at the beginning college level. Of course a few want to go on professionally and there are about six universities in US that offer graduate programs in Astrobiology. It's not very big but there is real interest in it.

NERD: There have been various theories (as one due to Miller Urey experiment) to explain the origin of life. As an astrobiologist, which theory or hypothesis would you support?

Dr. Morrison: We don't understand the origin of life. We know that all life on earth came from a common ancestor and we can trace the evolutionary process from that common ancestor to the present but we don't know how life began.

Miller Urey experiment is a good example that showed that one can naturally produce some of the chemicals

- the organic building blocks, but it did not tell us how to put the building blocks together to create life. You need to create a system that can extract energy, that can reproduce itself and that's enclosed within the cell wall. Which comes first? We don't know.

NERD: You have been a leader in asteroid impact hazards and its mitigation, so what do you think has been your the most significant contribution in this field ?

Dr. Morrison: I think my most significant contribution was to recognize that today there is a significant threat from asteroid impact. This is not something that just happened billions of year back in time. Secondly, to conclude that the way you deal with it is to carry out a telescopic survey and find the asteroids before they hit us. I will tell you the example I give. Suppose you were going to



David Morrison

walk across one of these very busy streets you have here. Would you care about the statistics of how many pedestrians get killed? Or would you look to see if a car is coming? You would look and that is what I am saying with the asteroids. It is not just calculating statistics, you actually want to look and find the next asteroid before it hits us.

NERD: Is there any technical advancement to deal with these types of asteroids? Say if we get some information that some asteroid will hit the earth, what measures can we take?

Dr. Morrison: First we have never found one yet. With the Spaceguard Survey, we are expecting to get decades of warning. It is not a last minute thing. You find them long before they hit us and then there are two possibilities.

If it is not too big you may just evacuate the area where it will hit. If you are willing to spend the money, then I think we have the space technology to deflect it, to change the orbit of the asteroid. And especially if it were big, you would want to do that. It's the only natural hazard that we have the technology to stop. You could never stop an earthquake. You could never stop a volcano from erupting. You could never stop a typhoon. But you could, in theory at least, stop an asteroid from hitting us by shifting its orbit a little bit.

NERD: NASA has recently established its research team for the NASA Lunar Science Institute and you have been appointed as its director. What main objectives does this institute have for its long term vision and short term vision?

Dr. Morrison: The Institute wants to encourage scientific interest in studying the Moon. And this means to support research by scientists and also train students, train a new generation of scientific researchers. And we are working on that now in the US and we seek international partnership also because we can then share information and find ways to collaborate.

Of course, India would be very good country to have as our partners in the Lunar Science Institute. I am very impressed with the tremendous success of Chandrayaan I.

NERD: Man last landed on moon around 37 years ago and then recently we have been observing a surge in progress.

Dr. Morrison: Yes. Right now there are 3 very

successful satellites orbiting moon and they are all from Asia. India, China and Japan. The US and Europe will also be launching missions, so there is a great deal of scientific interest in the moon. Whether or not humans would go back on the moon? I hope that humans will go but we have interesting science to do anyway.

NERD: What reason do you think for this renewed interest, as there was a lapse of 3 decades?

Dr. Morrison: That's difficult to say. In the US, NASA always thought that after the space station is completed we would be going back into deep space, so that is a partial explanation. But I don't know all the reasons. I am just glad that there is interest in the moon.

NERD: Ex-President George W. Bush gave a vision for Space Exploration to discover Moon with manned missions by 2020. What is the progress?

"There is nothing more interesting than to try and discover the secrets of the universe."

Dr. Morrison: The progress is good. We could do it. But we don't know what the funding will be. And it all depends on funding.

There are technical problems but the main problem is sustaining the budget to do it. I hope we will succeed. But [it's] out of my hands.

NERD: Do you expect to see Russia, India or China before you get there?

Dr. Morrison: No, not at all. It's possible of course. If we stop what we are doing then I would expect other countries to step in. But then again it's not my decision to make.

NERD: What are your thoughts about the militarization of space? Like China destroyed a satellite using a ground missile. Do you think space should be more for academic and research interest rather than for political purposes?

Dr. Morrison: I can't answer that question. All I can say is that NASA is dealing with science not militarization. I am sure I can't recommend what your country should do.

NERD: 2009 has been declared as the International Year of Astronomy. Do you see a correlation between the expected results of the LHC experiment and research in Astronomy?

Dr. Morrison: I am very glad to have this year celebrating the beginning of telescopic astronomy by Galileo. Astronomy has always been exciting. It's also the bicentennial of Darwin's birth which is also very important. I think we are going to

draw more profound conclusions. This is just an important anniversary and it is a good opportunity especially to talk to the public about exciting things that are happening in science.

NERD: What one question would you like to see answered about space? Dark Energy? Life?

Dr. Morrison: Life. I would like to know if there is or ever was life on Mars. I think that's practical. It is possible I would live long enough to get the answer. You will almost surely live long enough to see the answer.

NERD: Final message you would like to give to the readers.

Dr. Morrison: I think the best message is that Science is exciting. *There's nothing more interesting than to try and discover the secrets of the universe.* And I hope that IIT students share that opinion.

Puneet Singh (punsingh@iitk.ac.in) is an undergraduate student in the Department of Aerospace Engineering. Puneet is very interested in aeromodeling. Apart from designing miniature aeroplanes he also makes cartoons and is an avid reader of scientific and non scientific texts alike. He is nicknamed in the NERD team as 'the NERD SERD'.

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Zonked!

QUESTIONS TO ZAP YOUR MIND

Utkarsh Upadhye

1. Suppose you have infinite supply of coins of values 'a' and 'b' (co-prime integers greater than 1). Prove that any sufficiently large value (say 'n') can be changed using these coins, that is, 'n' can be written as a non negative integer linear combination of 'a' and 'b'. Find the number of natural numbers that CANNOT be written in such a combination.
2. 'N' ants are set running on the circumference of a circle of radius 'r' starting from randomly chosen distinct points and in random directions (clockwise or anticlockwise). Each have constant speed 'v' and if any two ants collide with each other they change their directions. Prove that the initial configuration, which includes both position and direction, will be repeated after time $2\pi r d/v$ for some divisor 'd' of 'N'.
3. You have a chess board that continues infinitely in all directions and every square below a horizontal line has a soldier on it. Above the horizontal line all squares are empty and we say that this region is a desert. You can move a soldier only if it can jump over a soldier horizontally or vertically (but not diagonally) into an empty square 2 squares away. And when you move a soldier in this way you have to remove the soldier that it jumped over. Now prove that no soldier can be sent five squares out into the desert in finitely many moves.
HINT: Try to construct an invariant.
COMMENT: This puzzle is known as Conway's Soldiers. See Wikipedia.
4. There are '2n' football teams registered for a tournament. Each weekend they are to divide into 'n' pairs and play. At the end of '2(n-1)' weeks, we want every possible pair of teams to have played exactly once. Draw up a possible schedule for the tournament.

Send in your answers at nerd@iitk.ac.in latest by August 15, 2009. Awards worth Rs. 1000 to be won!!

For solutions of Zonked! In issue 3, please log on to <http://www.nerdmag.org/>

Microbes to the rescue

PHOTOBIOREACTORS FOR DOMESTIC WASTEWATER TREATMENT

Abhinav Gupta

Conventional methods of waste water treatment involving secondary and tertiary stages are not only expensive but also have high land, infrastructure and energy requirements. Thus the study focuses on finding a new method for domestic waste water treatment with the designing of Photo Bioreactors on a commercial scale for the purpose. Though Photo Bioreactors have been used in the past for commercial uses like biomass, algal and hydrogen production but couldn't be commercially used for domestic waste water treatment. Recently with introduction of blue LED's providing light in the requisite wavelength in addition to the high energy to light conversion, the situation has changed and the study focuses on exploring the possibilities of the commercial scale development by not only using this new technology for efficient and even distribution of light but also keeping in mind other factors effecting the microalgal and bacteria interaction like pH, Dissolved Oxygen (DO) etc whose values have both positive and negative interaction effects. Other factors on which study will be conducted are the culturing of microalgae, bacteria and the configuration of the reactor required to achieve optimal light distribution and hence greater organic and inorganic waste removal.

Introduction

Conventional treatment of water involves primary, secondary and tertiary stages which make it a very long process with high retention time and also not very high nutrient removal efficiency can be obtained. Due to the number of constraints involved in the treatment of large amounts of water for drinking purposes usually the tertiary treatment stage in which the nutrients like nitrogen and phosphorous are removed is left out which can be quite dangerous to our health. Hence due to the high land, energy, infrastructural requirements and cost involved in the setup of such a plant alternatives are being explored for efficient purification of water on a large scale for drinking purposes. One of the popular alternatives is the photo bioreactor

whose efficient industrial model is still under study.

A bioreactor is a device or system that supports a biologically active environment. Bioreactor maybe a vessel in which a chemical process involving organisms or biochemically active substances derived from such organisms is carried. This process can either be aerobic or anaerobic. Growing organisms may be suspended or immobilized.

Photo Bioreactors are systems in which phototrophic microorganisms, such as algae and bacteria are cultivated and in the process they help in removal of nitrate, organic carbon compounds and possibly other contaminants from wastewater, while accompanying production of renewable biomass.

Present Applications

Currently photo bioreactors are used for following applications :

1. Commercial Algae and Biomass production

Lower quality water has been used for growing algae, e.g. from the effluent of biological waste water treatment facilities. Algae effectively removes nitrogen and phosphate from these streams for their own use in photosynthesis and the CO₂ taken up by the algae is directly recycled in the form of biomass and derived products.

2. Hydrogen production for energy generation

Conventional H₂ production methods are usually expensive, energy-intensive and result in pollutants and green-house gases. Thus biological production of H₂ is considered as the most environment-friendly route of producing H₂. Hydrogen is produced biologically from photolysis of water and through light-dependent pathways using organic materials as the substrate in presence of photosynthetic microbes including green algae like hydrogenase and cyanobacteria for their ability to produce H₂ gas in the photo bioreactor.

3. Hazardous pollutant removal from industrial waste water

Algae effectively removes nitrogen, phosphate and toxic metals and other such compounds from the hazardous industrial waste water streams, which leads to a reduction of water treatment costs. Some of the species of algae used to remove various toxic compounds are:-

- *Chlorella fusca*, *vacuolata* and *Anabaena variabilis* to remove 2,4-dinitrophenol (DNP).
- *Scenedesmus obliquus*, *Selenastrum capricornutum* and *C. Sorokiniana* to remove Acetonitrile.
- *Chlorella sorokiniana* and *Ralstonia basile sis* strains to remove Sodium Salicylate. After separation of the algae (and final conditioning) the purified water can be reused for industrial purposes.

Scientific Relevance

Symbiotic relationship between bacteria and micro algae in a bacterial-algal photo-bioreactor is one of the major causes of the increased importance of the study of Photo bioreactors for the treatment of waste water. The algae depends on the bacterial oxidation of the organic matter for its supply of carbon dioxide for photosynthesis while the bacteria gets its required oxygen which is exhaled by the algae during micro-algal photosynthesis. Algae exhibit a growth potential of an order of magnitude greater than higher plants because of their extraordinarily efficient light and nutrient utilization.

More than 50% of the total energy requirement for treatment by conventional methods is used by mechanical aeration of oxygen but here no external supply of oxygen is required also mechanical aeration results in pollutants escaping the water in the form of aerosols which does not take place in this type of water treatment. A separate tertiary treatment unit for nutrient removal is required in conventional treatment but using Photo bioreactors both secondary and tertiary processes can be combined. Less land and infrastructure requirement should make photo bioreactors a great commercial proposition. Recent developments in LED technologies have to some extent solved the earlier problem of non-uniform and /or insufficient illumination

which is required for the growth of micro-algae. Moreover this method besides treating domestic waste water enables high growth of algae and algae oil is seen as viable alternative to petroleum so this process will help in exploring its high production techniques.

Interaction between Bacteria and Micro-Algae

Relationship between bacteria and algae species

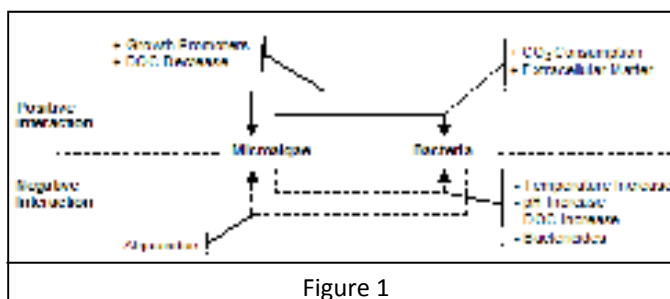


Figure 1

is not only limited to mere CO₂/O₂ interaction as was discussed in the previous section, it is much more complicated and needs to be understood to make optimum use of this technique for commercial purposes.

The bacterial activity is reported to be adversely affected by micro-algal activities in terms of increasing pH, Dissolved Oxygen Concentration, temperature and the release of inhibitory metabolites. As we can see in the Figure 1 they have both positive as well as negative interactions with each other which affect their performance in waste removal and growth.

There exists catalytic effect of the release of micro-algal extra cellular compounds on bacterial activities. Micro-algae metabolism is reported to be increased by bacteria as bacteria release growth promoting compounds for algae. Also the removal of CO₂ from the medium by some bacteria decreases the micro algae growth. Hence the identification of proper mixed culture of micro-algae and bacteria is important for efficient removal and mutual co-existence in the photo bioreactor.

Light Source Selection for Efficient Illumination

Though oxidation ponds in tertiary treatment invariably utilize algae + bacteria for water treatment in the presence of sunlight for the removal of nutrients from domestic waste water but sunlight has limitations like :

- Fluctuating nature
- Time & space dependent
- Full wavelength spectrum
- Inefficient illumination

Because of these limitations of the source of illumination the kinetics of the process is quite slow and its retention time is about 50-60 days

which is quite long a period for domestic water treatment and is not economically viable on the commercial scale.

So this brings us to the possibility of the use of artificial light for efficient illumination.

Main challenge in designing a photo bioreactor is providing uniform illumination throughout the reactor volume with sufficient light intensity. The light intensity however should not exceed the photo inhibition level of micro algae. The commonly used sources of artificial illumination are:

Incandescent Sources: These include bulbs and have a very small electric to luminous energy conversion efficiency of the order of 15-20 % as most part of the energy is lost in the form of heat to the environment.

Fluorescence Sources: They have intermediate energy efficiency of 60 – 65 %, CFL is a common example of fluorescence light source.

LED: They have quite high energy conversion efficiency of 90 - 95 %. Photo bioreactors for domestic wastewater treatment.

A light-emitting diode (LED) is a semiconductor diode that emits light when an electrical current is applied in the forward direction of the device. The effect is a form of electroluminescence where incoherent and narrow-spectrum light is emitted from the p-n junction. Experimentally it has been found that photo synthetic activity of the algae reaches a peak at about 450 nm wavelength of light and the blue LED developed in the early 90's also shows similar behavior and thus is being developed for its use as light source in photo bioreactor to stimulate photosynthetic growth. Thus out of the available sources LED's which are relatively new are the best option as not only the energy efficiency is high but also the heat produced during illumination is low. As a result along with the overall efficiency of the reactor

which has improved due to better and efficient illumination, the cost of lighting has also gone down substantially.

To examine the influences of light on growth and product formation of micro algae it is necessary to have flexible illumination throughout the

whole reactor. The lighting should provide:

- Enough light for growth of the algae in the range demanded for it to perform photosynthesis.
- Adjustable light intensity.
- Variable wavelength composition (light quality).
- The possibility of generating light fluctuations in a wide frequency range
- Small gradient of light intensity throughout the reactor.

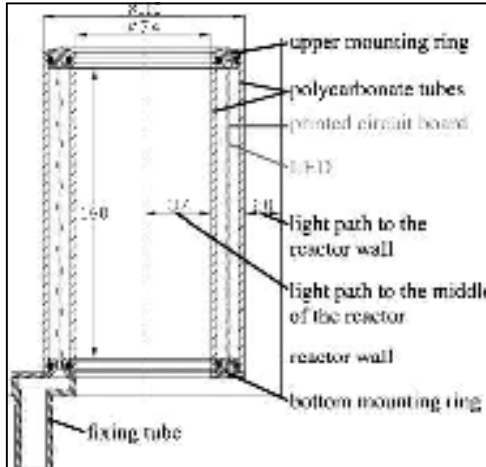


Figure 2: Illustration of LED as light source in a photo bioreactor. The LEDs are positioned in both sides of the printed circuit board and can be regulated separately to obtain a homogenous light distribution in the whole reactor volume.

Illustration of LED as light source in a photo bioreactor. The LEDs are positioned in both sides of the printed circuit board and can be regulated separately to obtain a

homogenous light distribution in the whole reactor volume.

Design Challenges

In the design of an efficient and economic photo bioreactor for domestic wastewater treatment on a commercial scale a number of parameters effected by the behavior of the algae and bacteria need to be considered as the variation of these parameters at times supports or inhibits the action of the algae and bacteria, so we need a model which optimizes these parameters for increased efficiency of treatment of the wastewater. These parameters and their variations are explained as:

Optimal Light Distribution

Provisions for efficient light supply throughout

the reactor volume remains most challenging task in photo bioreactors. The main constraint is attenuation of light energy in passing through the culture column due to mutual shading, scattering, refraction, reflection with the walls of

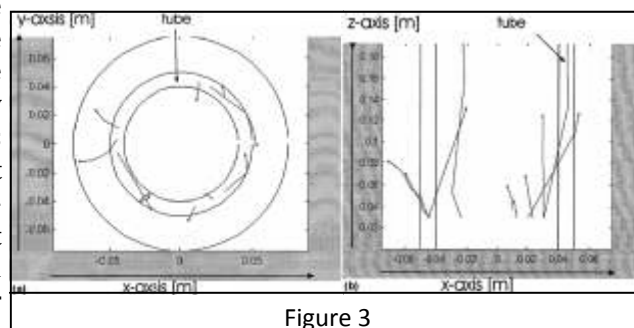


Figure 3

the reactor as in the Figure 3.

Cells nearer to the light source receive higher irradiance than cells elsewhere and these cells shade those further away which results in variation in productivity with position and time within the reactor. Mean value of irradiance may be defined as the volume average of the local irradiance values inside a culture. Mean irradiance depends on external irradiance, the reactor geometry, the concentration and morphology of the cells and the absorption characteristics of the pigment. For a given light source, reactor geometry and type of cells, an optimal cell density is defined which is mandatory to maintain in a culture in order to exploit light most efficiently.

Mixing

Mixing represents the most practical attempt to distribute radiation evenly to all cells in the culture, as well as accelerate growth by reducing the diffusion barriers around the cells. Inadequate mixing resulting in high O_2 tensions causes cell precipitation and wall growth which is the main reason of design failure. Mixing also exerts shear stress on the cells of micro algae which may result in the problems related to cell fragility.

Surface/Volume ratio

Illuminated surface to volume ratio is a crucial design parameter which determines the volumetric micro algae growth rate and therefore the volumetric O_2 production and pollutant removal rates of the reactor. Optimum surface/volume ratio is dependent on factors such as the biomass concentration established in the system & the impinging light intensity.

pH

Micro algal CO_2 uptake can cause pH value to increase up to 10-11 due to decrease in the acidic content of the water being treated. This increase in pH is beneficial for the disinfection of pathogens but it can also reduce the pollutant removal efficiency as complete bacterial inhibition is commonly observed at pH above 10. pH also influences N & P removal via NH_3 volatilization and orthophosphate precipitation at a high pH of 9-11.

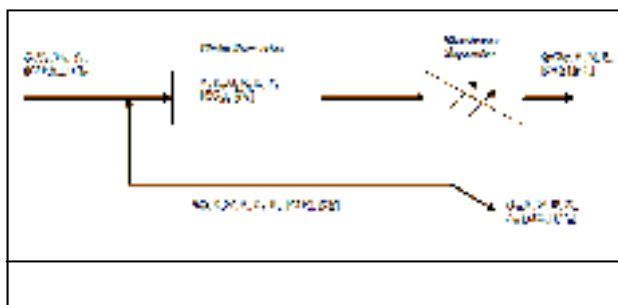
Dissolved Oxygen Concentration (DOC)

High DOC levels can generate photo-oxidative damage on micro algal cells & therefore decrease treatment efficiency. O_2 super saturation of 400% has been reported in closed photo bioreactors. Photo bioreactors for domestic wastewater treatment During pollutant removal by heterotrophic bacteria, DOC levels are less but increase rapidly after complete pollutant removal. Hence, high O_2 concentrations are a good indicator of complete pollutant depletion in continuous processes.

Various Configurations for Photo Bioreactor

Closed photo bioreactors offer higher photosynthetic efficiencies and lesser risk of pollutant volatilization & contamination. They can be built vertically in order to minimize space requirement & water losses by evaporation. The only constraint on their use being that they are more expensive to construct & difficult to operate & scale up. Closed photo bioreactors are designed as tubular or flat plate arranged in a horizontal, inclined, vertical or spiral manner.

Schematic representation of (A) a vertical spiral



(B) an inclined tubular column and (C) a vertical flat-plate photo bioreactor. Tubular photo bioreactors are the easiest to scale up by increasing the length & number of tubes and by the connection of several units via manifolds. They also exhibit higher light utilization efficiencies than flat plate photo bioreactors because of the larger reactor surface area per unit of occupied land. Oxygenation rates of up to $4.3 \text{ kg } O_2 \text{ m}^{-3} \text{ d}^{-1}$ have been achieved in tubular reactors which is comparable to the oxygenation capacity of mechanical surface aerators: $3 \text{ kg } O_2 \text{ m}^{-3} \text{ d}^{-1}$.

Modeling Strategies

The prototype of a typical micro-algae photobioreactor consists of the following subsystems:

1. Photo-Bioreactor, site of culturing the micro-algae
2. Illuminating unit, provides light energy to the algae
3. Micro-Algae collecting unit
4. Parameter measuring and controlling unit. The Figure 4 describes a simplified unit process diagram showing the important components of a

photo bioreactor:

Influent: Domestic waste water enters the reactor with a flow rate of Q and organic matter, nitrogenous matter, phosphoric matter, dissolved oxygen, carbon dioxide concentrations as $S_0, N_0, P_0, [O_2]_0$ and $[CO_2]_0$ respectively.

Photo-Bioreactor: It has V capacity and different components of WW achieve their saturation values of $S, N, P, [O_2]$ and $[CO_2]$ in presence of algae and bacteria of concentrations A and X respectively.

Membrane separation unit: Used for solid liquid separation in the effluent from the Photobioreactors and supplies an effluent with a flow rate of $Q-QW$. The supplied water thus will not only be free from algae and bacterial material but also have the pollutants within permissible limits.

Biomass Separation: Whatever remains of the membrane separation stage is basically biomass; some part of the biomass will be recycled back into the photo bioreactor while rest is disposed off. The disposed algal-bacterial biomass has the commercial value as feed for animals and fish. Biomass also has high energy content which makes it a suitable feedstock for energy generation in biogas plants.

Recycle Unit: It recycles the indisposed biomass with flow rate RQ back into the reactor. This mixture has algae and bacterial concentrations A_0 and X_0 respectively such that at any time their concentration remains constant inside the reactor while the excess is disposed as biomass.

Chemical Kinetics

The basic governing equation for the system is *Accumulation rate = Inflow - Outflow + Transformation rate*. Apart from this there are equations involving different components of the waste. Hence we have sets of equations for Substrate Balance, Bacterial Biomass Balance, Algae Biomass Balance, Nitrogen balance, Phosphorous Balance, Oxygen balance and Carbon Di-Oxide Balance. Each of these is a pair of equations with one equation for the whole system and the other for the reactor. The exact equations have been dropped in order to maintain the simplicity of the article. However interested people may contact the author for further insight.

Conclusion

Conventional treatment processes for domestic waste water have their limitations in terms of huge energy demand, pollutant escape & nutrient removal which make them a sub optimal choice. Use of micro algae with their symbiotic bacteria

makes for an efficient alternative with only constraint being light. Recent developments in LED technology make the photo bioreactor a technology worth looking into. The photo bioreactor with LED as sole light source seems to be the process of future & is interesting and challenging enough with present technological advancement.

Ponder Yonder

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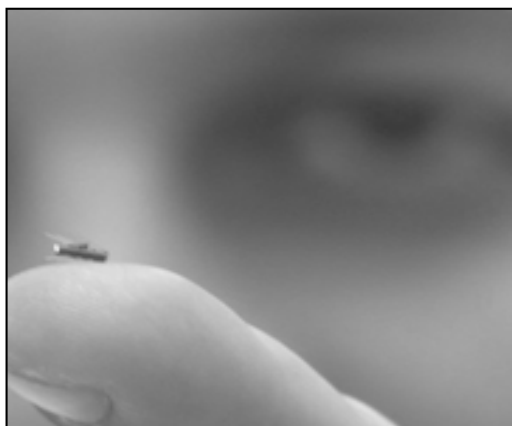
Small is the new big

MEMS IN MEDICINE: IMPLANTABLE DRUG DELIVERY SYSTEMS

Gopalakrishnan R and Pallavi Kesarwani

Prologue

All of us come across people who, willingly or due to some inability, do not stick to their prescribed medicine routine and have to later bear the consequences. This may vary from nominal headaches to consequences as severe as increased sugar or blood pressure levels. Also, there are certain drugs such as hormones which are more effective when released in a manner that is similar to their production naturally by the body. Complex dosing patterns are also required in certain cases wherein drugs should be released as a response to certain stimuli. All these functions can be performed quite effectively with the help of implantable devices based on the MEMS technology.



A typical in-body drug delivery system
(Courtesy Philips Systems)

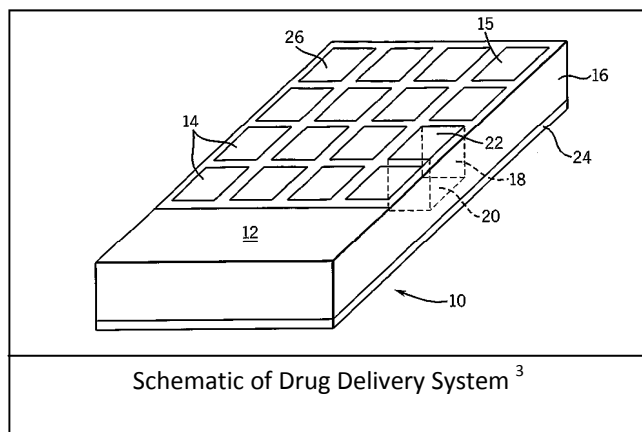
"devices or systems, constructed using techniques inspired from micro-scale fabrication, that are used for processing, delivery, manipulation, analysis, or construction of biological and chemical entities"². MEMS based drug delivery systems give a distinct size advantage over the non-MEMS counterparts and also other advantages such as controlled release of drug, through or by degradation of the drug compartment.

What are MEMS?

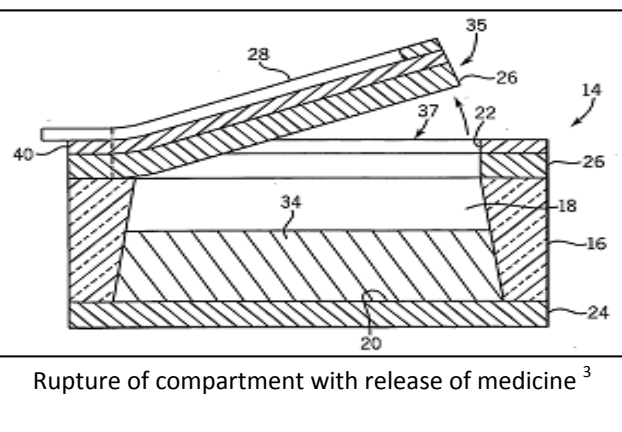
Microelectromechanical systems (MEMS)¹ are devices that have a characteristic length less than 1 mm but more than 1 μm . Microelectronic ICs can be thought of as the "brains" of a system and MEMS augments this decision-making capability with "eyes" (sensor) and "arms" (actuator) to allow microsystems to respond to the environment. Biological microelectromechanical systems (BioMEMS) involve the marriage of biology with MEMS technology. They can be defined as

Drug Delivery Systems

Various MEMS-based drug delivery systems have been patented by Curie et al (US Patent 5, 366, 454) and Santini Jr et al. We are looking at a particular system³ (10) implantable into a human or animal body for medicine discharge in a periodic or continuous manner. It includes a medicine delivery unit (14) and a control unit (12). The delivery opening (22) of the compartment (18) is sealed by a suitable rupture membrane (26). The compartment is also provided with a charging opening (20) permitting receipt of the medicine (34). The medicine is charged by any of the methods such as inkjet printing, capillary action, spin coating or centrifugation without any limitation. Each compartment may contain different



Schematic of Drug Delivery System³



Rupture of compartment with release of medicine³

medicines from the other, may be released at a different rate compared to the other or may have different dosages of the medicines. For in body or in vivo applications, the entire system (10) is enclosed in a suitable biocompatible material such as polyethylene glycol. Use of MEMS technology fabrication technique permits the incorporation of thousands of compartments in one single system.

The control unit (12) includes a controller, a memory, a sensor (15), a power supply, and a demultiplexer. The control unit may have internal or external memory, such as RAM and/or ROM. An insulating or dielectric layer (40) such as silicon oxide (SiO_2) is deposited over the entire surface of the system (10). The purpose of this dielectric material is to protect the electrodes from corrosion, degradation or dissolution in all areas where electrode removal is not necessary for the drug discharge. The cap (24) is disposed over the compartment to seal the charging opening under vacuum. The membrane is hermetically sealed over the delivery openings to form a vacuum in the compartment. Under vacuum, the membrane is strained to just less than its yield point. The release element (28) stretches the membranes beyond its yield point and as a result, the membrane ruptures. Various release elements may be used to rupture the membrane (26) including electrostatic, magnetic, piezoelectric, shape memory alloys, temperature, chemical, and other mechanisms that cause stress or strain on the membrane (26). As the membrane is in a pre-stressed condition, a very little value of stress is required to cause this rupture.

The sensor detects the environment and actuates the system to release the medicines. For example, there are cases where people suffer from hormone deficiencies in their body. In such a case, MEMS-based drug delivery systems help bridge a wide gap between conventional medicines and the localized release required in this case. The system can be programmed to travel to a specific region where the deficiency exists and once this environment is sensed, the actuator performs the function of rupturing the membrane and releasing the drug in such a fashion as if it were produced naturally by the body. Moreover, this technology enables complex dosing patterns to be achieved and medicines can be released in a very effective way.

MEMS technology has revolutionized the field of

medical science and in particular the area of drug delivery. It offers various advantages over the existing systems due to its miniature size and its capability for controlled and targeted drug delivery. However, there is still a long way to go towards its commercialization in drug delivery.

Research opportunities

This fantastic integration of MEMS technology with medical science provides an opportunity for researchers from various fields of science and technology. The choice and fabrication of materials and their effective integration via the control unit are certain issues that have the potential for further improvement. Some of the challenges requiring immediate attention are:

1. Economical fabrication methods
2. Increased biocompatibility
3. Improving the stability in the biological environment
4. Improved drug loading and targeting
5. Improved sensitivity and specificity

The biocompatibility of the system is extremely important in this case as the function of the white blood corpuscles is to fight against external bodies. If it were not compatible, the WBCs would incapacitate these systems and the drugs will not be released and the entire design would be a failure. The design which has been presented here is the patented work of Steven T Cho et al³. There are various other paradigms which exist and are unique in their own way. The idea of this article is to present to the readers the concept behind such a drug delivery system and to emphasize the vast potential for research in this field.

Ponder Yonder

¹ www.allaboutmems.com

² BIOMEMS by Nabiollah Abolfathi

³ US Patent WO/2004/010971 by Steven T Cho et al (2004)

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Decisions: More than just a Game

UNDERSTANDING AND APPLYING THE GAME THEORY

Ankita Panwar and Ish Dhand

Imagine a situation where-in more than one agents are to make informed decisions. The benefits that each one derives from the outcome of this decision making process depend on the action taken by all the agents. This 'Multi-Person Decision theory' is what is better known as Game theory.

How it all began?

Game theory sees its origins in the early nineteen thirties when the brilliant Von Neumann published a series of papers. Von Neumann's work which culminated in the 1944 book 'Theory of Games and Economic Behaviour' by von Neumann and Oskar Morgenstern was extended and made applicable to a wider array of situations by John Nash who developed a criterion for mutual consistency of players' strategies, known as Nash equilibrium.

Making Decisions... 'Normally'

Let's call this multi-person decision situation as a game and the agents involved, players. Now let's put ourselves back into the game. In a way, our actions would, in principle, depend upon:

1. The actions available to us & our preferences on the outcomes.
2. Our beliefs about which actions are available to each player and our beliefs about their preferences to the outcomes
3. Our beliefs about each

player's beliefs about each player's available actions and preferences ... and so on, ad Infinitum.

The best way to learn game theory is by playing games, so, let's get started with a very popular and intensely surprising game, viz., the Prisoner's Dilemma. We shall also see how we can represent a game in the so-called Normal Form.

The Prisoner's Dilemma: Two rational thieves are arrested on the basis of only circumstantial evidence. The shrewd police inspector comes up with a clever plan to entice each of them into confessing their crime. He asks them both, separately if 'they' have committed the crime. If prisoner I confesses but prisoner II betrays then the first prisoner serves as testimony against the other and gets no punishment, while the prisoner II gets full term of 10 yrs and vice versa. If both confess, then they get 5 years of imprisonment each. If both deny the police has evidence against none, so maximum punishment that they can get is 1 yr each.

Prisoner's Dilemma		
I \ II	Confess	Betray
Confess	-5,-5	0,-10
Betray	-10,0	-1,-1

All this can be represented as a simple matrix as shown above containing the 'pay-off'

corresponding to each decision's outcome. This representation is called the Normal Form of the game.

Let us see what's going on in prisoner I's mind:

1. If prisoner II confesses then I should better confess too and get five years in prison instead of ten.
2. If prisoner II betrays then again confessing would mean getting out scot free rather than spending one year in prison.

Something similar must be going on in prisoner II's mind too, hence based on the assumption that both are rational, each would prefer confession over betrayal. Both end up spending five years in prison even when they could have gotten away with just one each.

The Chicken game: Imagine two brash teenagers driving towards each other on a collision course. One must swerve or both will die. If only one swerves, he shall be called 'chicken'. Convince yourself that the following normal form representation approximates the situation well:

Chicken Game		
I \ II	Swerve	Straight
Swerve	0,0	-1,1
Straight	1,-1	-10,-10

Unlike the previous case where we don't know for sure which outcome is preferred in all the

cases. In the case that player II swerves, going straight would 'benefit' player I but had player II gone straight in the first place, the same strategy would be catastrophic. Since the latter loss outweighs the gain from the former, it seems rational to swerve. Now, player I assumes that his opponent shall make this rational decision and swerve. In response to that, he keeps going straight. Sadly, so does player II who had assumed the same for player I. Collision results.

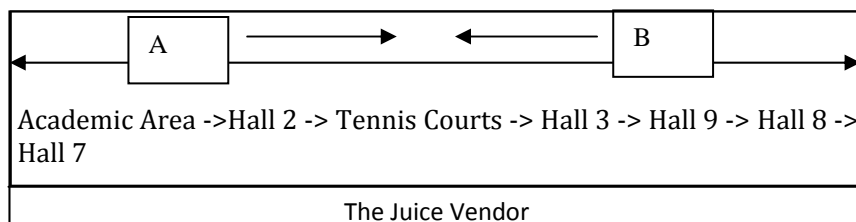
Nash Equilibria: Coming back to the prisoner's dilemma, consider the case wherein both confess. It would have been unfavourable for player I to change his decision (-10 v/s -5). Similarly for player II. Such a situation where changing the strategy does not increase the pay-off of either of the players is called Nash Equilibrium.

Prisoner's Dilemma		
I \ II	Confess	Betray
Confess	-5, -5 →	0, -10
Betray	-10, 0 ↓	-1, -1

Can you spot the equilibrium (or equilibria) in the chicken game?

Homing in to IITK - Juice Vendors

Let us consider 2 Juice vendors A and B who can situation their vending carts anywhere along the road as shown in figure.



It is natural to assume that those students situated to the left of A would buy juice from A and those to the right of B, from B. Those between them, will go to A or B with equal probability. To improve his profits, A would move one step towards B and so would B towards A. This process would be repeated until both are situated around the centre of the route. So, finally they decide to set-up their Vending carts around the centre, i.e. In front of Hall-3. Though this is less comfortable for the customers, this situation is what actually results, as this is the position of Nash equilibrium.

Tragedy of Commons: Game theory can be used to explain the overuse of shared resources, by just extending Prisoner's Dilemma to more than one player.

Let us consider the crude example of a village with N farmers and limited cultivable area. Each farmer has an option of rearing a sheep. Let us assign the value 1 to the utility of a sheep, and -5 to the 'value' of grass eaten by it representing the harm to the environment. The damage done to the grasslands is borne by all the villagers equally.

If the number of villagers is more than 5, then, the loss incurred per villager per sheep is less than one and hence, each

time a farmer buys a sheep, he improves his utility. Hence, an average farmer being rational would buy sheep. What we must notice here is that each sheep contributes a -5 to the environment and hence, everyone ending up owning a sheep leads to heavy environmental damage. In a real life situation to avoid this catastrophe, a population tax (of value -5 per sheep, representing the harm done to the environment) must be imposed.

The above example of tragedy of the commons can be used to explain large number of real life situations. Consider, the scenario of industries polluting the environment. Here, the industries can be considered as sheep and the environment can be considered as grassland and similar analysis of tragedy of commons holds true. In another scenario of illegal construction of houses causing infrastructure problems, the houses denote the sheep and the infrastructure denotes the grassland in the tragedy of the commons.

Thus, game theory can be used to design laws and mechanisms to get socially desirable outcomes.

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THE MACHINE PAATHSHALA

IN CONVERSATION WITH DR. LESLIE VALIANT ON MACHINE

Manjish Pal and Ankit Sharma

Dr. Leslie Gabriel Valiant is a computer scientist and computational theorist. Valiant is world-renowned for his work in theoretical computer science. Among his many contributions to complexity theory, he introduced the notion of #P-completeness to explain why enumeration and reliability problems are intractable. He also introduced the "probably approximately correct" (PAC) model of machine learning that has helped the field of computational learning theory grow, and the concept of holographic algorithms. He also works in computational neuroscience focusing on understanding memory and learning. He received the Nevanlinna Prize in 1986, the Knuth Prize in 1997, and the EATCS Award in 2008. He is a Fellow of the Royal Society (London), a Fellow of the American Association for Artificial Intelligence, and a member of the National Academy of Sciences (USA). He can be contacted at valiant@seas.harvard.edu

NERD: How did you get interested in doing research in Theoretical Computer science?

Valiant: When I was an undergraduate I was interested in physics. I was looking for some research area that would excite me. I talked to various graduate students and faculty members about physics but couldn't find anything that would excite me enough. So I thought I would explore computer science, which was very new at that time. I read a few journal papers in computer science and was intrigued. That's why I went in that direction.

NERD: So what kind of problems did you start off with initially?

Valiant: At that time I was looking at some questions related to whether in principle a problem was computable or not. There wasn't a question of efficiency but whether there is an algorithm at all. I was working on basic problems in automata theory and computability. I was looking at questions like: given two deterministic context free languages are they the same? It is a very simple to state problem but was hard to resolve. I didn't manage to resolve it, but other people did afterwards.

NERD: Tell us something about your definition of PAC (Probably Approximately Correct) learning. When you introduced it, how was it different from the prevalent notion of learning?

Valiant: At the time the word "learning" was used

in the artificial intelligence community in various senses. There wasn't agreement on any one meaning. It was defined informally. Different learning algorithms achieved quite different goals. What the PAC learning framework achieved is that it incorporated both the computational aspect of efficiency and computational feasibility, and the statistical aspect that when we learn something we need not and cannot do it with perfection. Earlier definitions had not combined the computational with the statistical.

NERD: So while defining PAC learning did you know that it is going to be robust or when people worked on and they couldn't find a much better definition and that's how they found that it is robust?

Valiant: It was a combination of both. I always thought that it was robust. But it needed a while for people to be convinced, after they had looked at different variations and found it hard to come up with anything more powerful.

NERD: What is your belief on the P vs NP problem?

Valiant: Well, I like to say that its an open problem (laughs). Many people say that it is obvious that P is not equal to NP, and it is just that no one is able to prove it. But I don't think this is so obvious. The arguments that have been given for why P should be different from NP I don't find very convincing. Just because people have looked for algorithms for NP-complete problems for a long time and haven't succeeded does not mean that no such algorithm exists. May be we are missing one really good idea.

NERD: So it is possible that one may come up with a short proof of P not equal NP?

Valiant: Yes, or may be P equals NP. The fact that people have not succeeded so far may suggest that there is no easy proof either way. But it doesn't give evidence for whether it will go positive or negative.

NERD: Do you feel that the current methods for solving the problem are not very convincing?



Dr. Leslie Valiant

Valiant: No. I am saying that the arguments which people give for believing that P is different from NP aren't very convincing. May be the most convincing one is that people have been trying to prove P different from NP for only the past forty years since the problem has been explicitly formulated, but people had been looking for fast algorithms for various things for centuries. This is a historical argument for thinking that a positive result is less likely than a negative result, but I don't find it very convincing.

NERD: So how much of undergraduate research have you seen for example at Harvard ?

Valiant: It actually depends on the field. In experimental fields with labs, there is quite a lot of involvement because undergraduates can be clearly very helpful. In general, students at Harvard can do a senior thesis in their final year. In theoretical and mathematical fields it is harder to do original research in such a short time.

NERD: Do you have some undergraduate conference/journal or something similar at Harvard?

Valiant: Yes I think so. Some undergraduates do pieces of research which get converted into conference papers. But it is not that common. Sometimes work done in course projects or summer projects become conference or journal papers.

NERD: Coming back to the technical side what do you think is the relationship between biology and computation ?

Valiant: The relationship is very complicated and I know only about certain aspects of it. May be the most mainstream connection is in bioinformatics, where the computer scientist analyses experimental data from biology. But I myself do not work in bioinformatics, but rather areas where computational models help to explain what is going on in biology. One area in which I am interested is neuroscience. Sixty years ago, when people first used computers, they immediately started speculating that our brain is a computer of some sort. I think that this is a very obvious connection. Its quite difficult to do and so far the achievements of this field are probably limited, but it is a field which will work out in the end, and I have spent a lot of time on it myself. What I talked about yesterday, evolution is a different aspect of biology, where we also expect

to have some mechanistic process underlying it. I think computer science is the right framework to discuss certain aspects of evolution. Evolution is very fundamental to biology, and Darwinian evolution is already formulated in somewhat computational terms.

NERD: Coming back to the point that artificial intelligence has not been so successful. How do you address that question and how will your approach help artificial intelligence?

Valiant: I was proposing that artificial intelligence be based on machine learning, because it offers robustness. Otherwise, for example, one can try to base artificial intelligence on predicate logic, which people have been trying to do for decades. In that approach people write down common sense rules and give some reasoning method which is to be used to derive conclusions from them. But often the conclusions obtained by such systems are just absurd because the rules do not apply in the circumstances at hand. But in the learning context a learning system would always check itself against the environment. For example if chaining two rules

"...a significant part of the "education" through which we master common sense knowledge we probably obtained through evolution."

together results in some absurd conclusion then that can be discovered and learned from experience. So the only way of getting robustness seems to be continuous learning and checking. That is why I think AI should be based on learning.

The reason why people haven't done this before is because they haven't tried hard enough. More is known now on computational learning than a decade ago, so that helps. There are good learning algorithms known, but what I emphasized in the talk is that if you want to push common sense knowledge into machines you not only need to use the best learning algorithms in some sensible way, but also need to feed the algorithm with the right kind of data. You cannot feed it with nonsense or contradictory data. This is analogous to human education, which goes on for about twenty years, and involves very carefully prepared teaching materials. May be the only way to make computers understand common sense knowledge is by the same process. You need both good learning algorithms and also knowledge presented that is carefully prepared. Besides being correct the knowledge also has to be sequenced in the right way. Humans today may be given some information and tomorrow given some more information which builds on today's. Randomly throwing in information is of much less

help. May be the only way of making computers intelligent is by carefully preparing teaching materials just as a teacher does, and present it to the computer in a helpful sequence.

NERD: But common sense is something which one would know even without the education of 16-20 years. When you say “common sense” it apparently seems you are talking about some obvious facts which don't require that kind of an education. Do you disagree? What do you say about it?

Valiant: You make a good point, which gets to the other part of my work about where humans might be getting common sense knowledge from. The carefully sequenced aspect of learning common sense knowledge by humans may be through evolution. We are born with some understanding of how the world works. Some further common sense knowledge we learn as small children, but even there the information presented is in some sense carefully coordinated with what we are able to absorb. But the main point is that a significant part of the “education” through which we master common sense knowledge we probably obtained through evolution.

NERD: Tell us something about your recent work on Holographic algorithms ?

Valiant: The main idea is that in complexity theory one notion is that of an algorithm, but an equally fundamental other notion is that of a reduction. Basically, a holographic reduction is a more general kind of reduction than previous kinds of reduction. It makes sense for quantitative problems, where for example you are counting something. It is a richer class of reductions where you can relate more problems to each other because you have a more powerful notion of reduction. When you want to find a fast algorithm, you can try to find a holographic reduction to a problem already known to have a fast algorithm.

NERD: What is the idea of cancellation in a Holographic reduction?

Valiant: The idea comes from quantum physics. Simulating an infinite or exponential number of dimensions is in general not realistic on a computer. Holographic reductions are formulated so as to be polynomial time computable on a classical computer. The commonality with quantum physics is that things need not be either “yes” or “no” but a combination of both. In the theory of NP-completeness a typical reduction uses the notion of “gadgets” to map solution

fragments of one problem to those of the other one-to-one. In a holographic reduction individual fragments are not mapped to each other one-to-one, but some other quantity is preserved after cancellations, such as the number of solutions.

NERD: Can this idea be used to improve the time complexity of certain problems known to be solvable in polynomial time?

Valiant: In principle yes, but I don't know of a natural example. A central aspect of a holographic algorithm is a change of basis. In that sense a holographic reduction costs zero because it is like when you look at the problem in one basis you get Hamiltonian circuits, and if you just change the basis the problem looks like a different problem. So the reduction itself is in some sense free. I don't know how promising it is to look at what you just said, but it is a possibility.

NERD: So where do you see the computer science field heading? What are the five questions which you feel the computer science field should answer in next 15-20 years?

Valiant: I think computer scientists have been very good at asking very good questions. The questions which are around now are worth pursuing further. Complexity theoretic questions like P vs NP are important and in some sense many other important questions where, for example, you are asking about cryptography, learning, evolution etc., are analogs of it for other complexity classes. This complexity theoretic aspect of computer science is the one which I think is the most fundamental. The fact that it leads into such a broad set of issues, like the power of quantum, power of randomization, power of learning, and the power of evolution, is further confirmation of that.

Manjish Pal (manjishster@gmail.com), a 2009 graduate of the Department of Computer Science and Engineering at IIT Kanpur, is interested in theoretical computer science. He is particularly interested in combinatorial/computational geometry, approximation algorithms, metric embeddings, mathematical programming techniques and machine learning. Currently a Research Assistant at IIT Kanpur, he head to Princeton for his doctoral research in Fall 2009.

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Saving the rains

GE3 TALKS ABOUT UPCOMING RAIN WATER HARVESTING WORKSHOP AT IIT KANPUR

Rain water harvesting is a key issue that needs to be addressed in a major way. IIT Kanpur is now involved in a major way in Environment issues, however the CESE department is confined to PG activities only and it is imperative that the UG involvement is increased.

Rainwater harvesting technologies are simple to install and operate. Local people can be easily trained to implement such technologies, and construction materials are also readily available. Rainwater harvesting is convenient in the sense that it provides water at the point of consumption, and family members have full control of their own systems, which greatly reduces operation and maintenance problems. Running costs, also, are almost negligible. Water collected from roof catchments usually is of acceptable quality for domestic purposes. As it is collected using existing structures not specially constructed for the purpose, rainwater harvesting has few negative environmental impacts compared to other water supply project technologies. Although regional or other local factors can modify the local climatic conditions, rainwater can be a continuous source of water supply for both the rural and poor. Depending upon household capacity and needs, both the water collection and storage capacity may be increased as needed within the available catchment area.

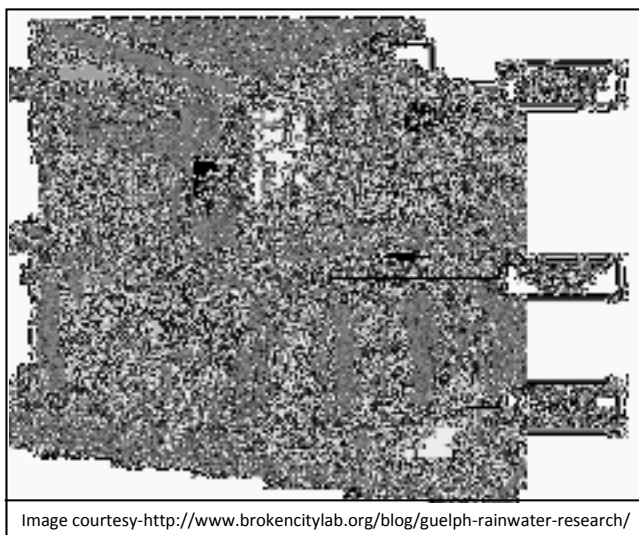


Image courtesy-<http://www.brokencitylab.org/blog/guelph-rainwater-research/>

Realizing the importance of saving rainwater the Group for Environment and Energy Engineering at IIT Kanpur is organizing a one day workshop on rainwater harvesting. The workshop will also concentrate on energy efficiency and green homes.

Measures related to Energy Efficiency and Rainwater Harvesting are certain to become mandatory in future housing facilities and it will be very productive if students and campus residents can learn something about these technologies.

The workshop will be delivered by Mr. A Shivakumar, a research scientists at IISc Bangalore and an expert in the field. He is a member of Karnataka State Council for Science and Technology. He has created a demonstration project on green homes by making his home energy efficient and environment friendly by taking various measures. Refer to *Home Green Home, NERD Volume 1 Number 3, page 40* for more details. For more information log on to <http://www.kscst.iisc.ernet.in/rwh.html>

The workshop is open to the entire community. We hope that as a follow up of these lectures and with Mr. A. Shivakumar's guidance we can come up with RWH prototypes which can be installed across the campus and can become functional from these monsoons thus ensuring solid deliverables as a result of this activity.

Group for Environment and Energy Engineering or GE3 is an independent student group working at IIT Kanpur in the field of alternative sources of energy (solar photovoltaic, fuel cells et cetera), energy efficiency and environmental engineering. Currently four different projects are under progress. For more details log on to the GE3 website <http://www.ge3.org/>. To join the urgent discussion on the future of energy and environment join the GE3 forums at <http://www.ge3.org/forums>

This write up was prepared by Anand Vardhan Mishra (avmishra@iitk.ac.in), an undergraduate student in the department of Mechanical Engineering at IIT Kanpur and an active member of GE3.

Weeding Arsenic with weeds

REMOVAL OF ARSENIC FROM AQUOUS ENVIROMENT BY WATER LETTUCE

Suparno Mukhopadhyay

Arsenic, a toxic metalloid emanating from various industrial sources such as ash pond leaching, paints, pesticides, tanneries, etc., is a hazardous water & soil pollutant. Its introduction into the environment leads to its bioaccumulation & biomagnification, which ultimately affect the human beings. The conventional technologies used for its removal from water viz. coagulation, lime-softening, ion-exchange and adsorption are cost ineffective, requires skilled maintenance and often generates secondary pollution. These limitations can be overcome by using the "green technology" of *phytoremediation*, an engineered use of plants to remove, contain, or render harmless environmental contaminants. The process involves the introduction of plants into an ecosystem and allowing them to assimilate the contaminants in their roots and leaves. To date the main area of studies in the domain of phytoremediation are presented by the research of types of such hyperaccumulating plants. These studies have shown the hyperaccumulation potential for metals like As, Pb, Hg, Cd, etc.. In certain cases, the rate of metal uptake has been reported to go upto even 90-95% depending on the plant species concerned, its biomass, metal concentration, and environmental factors like pH, temperature, etc. The plants can also be easily harvested and after treatment can be anaerobically digested to produce

biogas.

Considering the abundance of arsenic sources and its extremely harmful nature, an investigation was conducted in Environmental Engineering Laboratory, Civil Engineering Department, Jadavpur University, Kolkata to examine the arsenic uptake potential of water lettuce (*Pistia stratiotes* L.) under laboratory conditions.

Materials and Methods

The experiment (detailed in Figure 1) was carried out in multicells aquarium placed at the Laboratory. For each initial concentration set, the same

procedure was repeated 3 times with fresh laboratory cultured *Pistia stratiotes* L. and same biomass dry weight. The equilibrium concentration (which is reached when the plants can no longer decrease the arsenic concentration in the water) and time data were fitted to adsorption isotherm model of Langmuir.

Model Formulation

Based on the experimental results a mathematical model was formulated to give the instantaneous concentration of residual arsenic in the aqueous phase. Such a model may be a

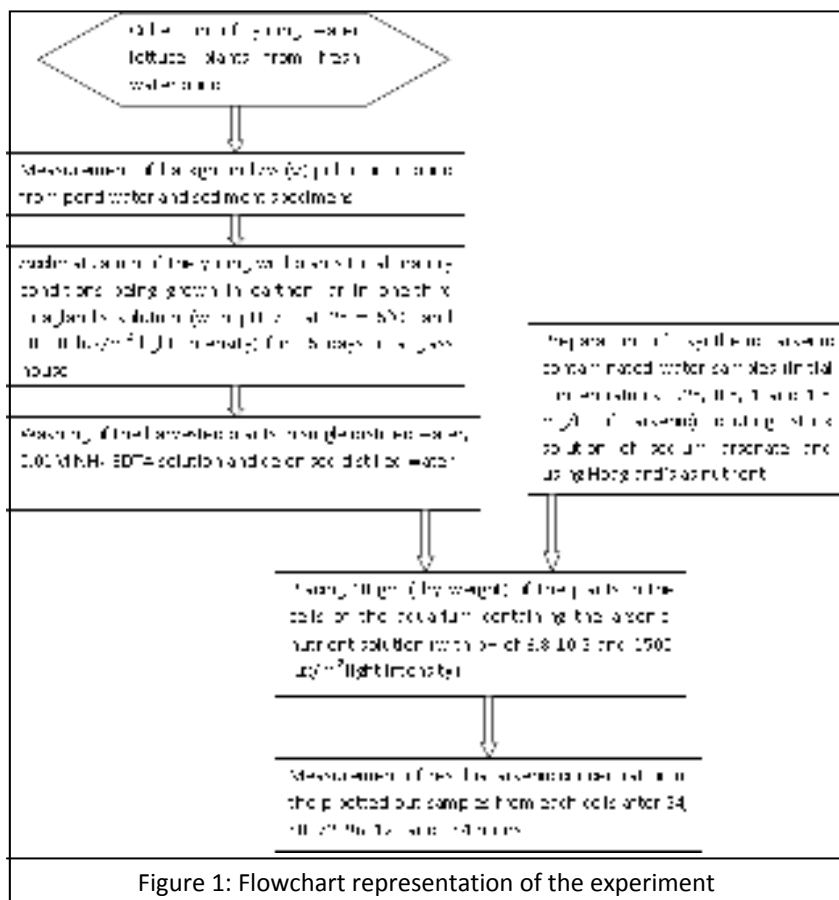


Figure 1: Flowchart representation of the experiment

useful tool for the design of treatment ponds for arsenic removal.

The model assumes a steady state system where the arsenic is removed only by the biomass in question. The rate of arsenic removal is assumed to be proportional to the product of the instantaneous biomass weight (g) and the rate of arsenic uptake by biomass per unit biomass (mg of arsenic/g of biomass/hour) and inversely proportional to the total volume

$$\frac{dc}{dt} = \left[-\frac{m_0 p}{V} + \frac{p}{\delta} (C - C_0) \right] \frac{C - C_e}{b + (C - C_e)}$$

V (in L) of the aqueous phase. The final model equation whose solution gives the instantaneous residual arsenic concentration (c in mg/L) in the aqueous phase at any time t (in hours from the start of arsenic uptake by the biomass) is as shown in above equation.

The parameters p and b may be chosen by comparing with Langmuir's isotherm, where by, p is the sorption capacity per unit time (mg of As / g of biomass / hr, X_m) and b is Langmuir's constant (mg/L, K_L). C_0 is the initial concentration of arsenic in aqueous phase (mg/L), C_e , the equilibrium residual arsenic concentration in aqueous phase (mg/L) and m_0 is the initial biomass weight (g). The parameter d is defined as the amount of arsenic accumulated per unit weight of biomass (mg of arsenic/g of biomass).

Results

The experimental data obtained for residual arsenic concentra-

tion after 24, 48, 72, 96, 120 and 144 hours for the initial concentration of 0.25, 0.5, 1.0 and 1.5 mg/L were plotted (Fig. 2) illustrating the removal kinetics graphically. The results indicate that the removal is dependent on both the contact time and the initial arsenic concentration. A biphasic removal pattern with rapid initial uptake upto 48 hours and gradual attainment of equilibrium after 120 hours is revealed. It is also evident that the As (V) removal (%) decreases with increase in initial concentration. This may be due to the increase in the toxic

equilibrium arsenic concentration, the sorption equilibrium being attained by 144 hours. Fitting these equilibrium residual arsenic concentration data to Langmuir's adsorption equation, $(X/M) = [(X_M C_e) / (K_L + C_e)]$, we obtained the values of adsorption capacity ($X_M = 1.43$ mg/g) and Langmuir's constant ($K_L = 0.006$). Langmuir's adsorption isotherm was chosen based on existing literature establishing the process as an adsorption phenomenon and owing to the fact that the adsorption involving a single contaminant, here arsenic, is closely represented by Langmuir's isotherm.

The solution of the model equation was obtained through the Runge-Kutta iterative process. The parameter δ was varied for each initial arsenic concentration (C_0) to obtain the value of δ for which the discrepancy between the experimental results and model predictions appeared to be minimal. The minimization of error attained are 0.0424 mg/L ($\delta = 1.0$, $C_0 = 0.25$ mg/L), 0.0421 mg/L ($\delta = 4.0$, $C_0 = 0.50$ mg/L), 0.0716 mg/L ($\delta = 9.0$, $C_0 = 1.0$ mg/L), 0.1199 mg/L ($\delta = 14.5$, $C_0 = 1.5$ mg/L), which are the RMS error values. The theoretical residual arsenic concentration at 24, 48, 72, 96, 120 and 144 hours were graphically represented by scatter plots (Fig. 2) alongside the experimental removal kinetics curves.

The different δ values generating the minimum errors between experimental and theoretical results were plotted against the initial arsenic concentration values giving a model $\delta - C_0$

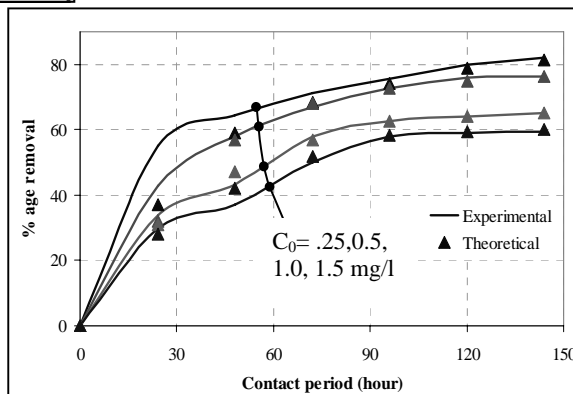


Figure 2: Removal kinetics

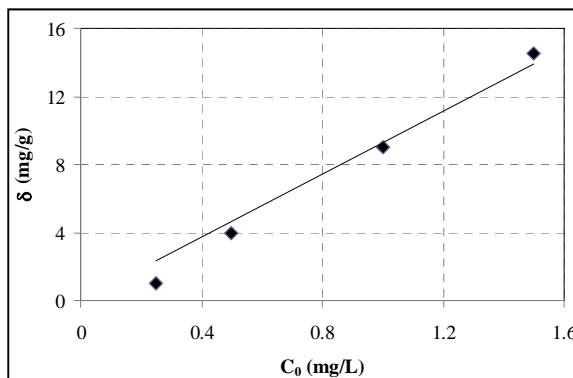


Figure 3: The $\delta - C_0$ curve

effects of arsenic on plant metabolism with increase in initial arsenic concentration leading to senescence.

From the removal kinetics (Figure 2), it can be inferred that the residual arsenic concentration at 144 hours represents the

curve (Fig. 3). This linear fitting of the $\delta - C_0$ data seems to be quite satisfactory ($R^2 = 0.9756$) generating the $\delta - C_0$ relationship $\delta = 9.2632 C_0$.

Conclusions

The present study demonstrated the use of water lettuce for removal of arsenic from water. The high percentage removal obtained (e.g. 82 % removal for 0.25 mg/L C_0 at 144 hours) justifies the suggestion of its potential use to remediate arsenic contaminated water and wastewater. The mathematical model formulated has its main utility in the identification of a $\delta - C_0$ relationship. The use of the relationships provided may be made to get the δ value for any C_0 value within certain limits. Experimental determination of δ may also be made and used in the model equation to get the instantaneous residual arsenic concentration. The model may, thus, serve as a useful prerequisite for the design of wastewater

treatment facilities concerned with arsenic removal. The input of C_0 and C_e data and the required concentration C below which the arsenic level should be brought down generates various $V-m_0-t$ combinations whose optimization may form the basis of design of arsenic removal plants.

Future scope of work

The study was performed for a limited data population. Also, the parameter δ , which is measurable through the study of the ash generated by the incineration of the biomass, was not measured, as the experiment had been performed before the formulation of the model. Studies on larger data population and actual measurement of δ may lead to more refinements of the results and improvement in the model equations. Again, the study of the limitations of $\delta - C_0$ curve, which may be induced due to the increase in arsenic toxicity on plants with increase in C_0 ,

provides scope for future research. The effects of arsenic induced toxicity on plant metabolism demand attention and need to address in future studies. In addition, divergence from the assumptions of the model may lead to further development of the present study. The model may be also extended to other metal-plant combinations. The study should be generalized for a more realistic situation where consideration of multiple heavy metal pollutants in the aqueous phase in conjunction with multiple plant species for their removal is considered.

This work was carried out in the winter of 2006-07 at Jadavpur University, Kolkata, by Suparno Mukhopadhyay (presently 2nd year M.Tech student, Civil Engineering Department, IIT Kanpur), along with his then classmate, Nilanjan Manna and teacher, Prof. Somnath Mukherjee (Professor, Jadavpur University, Kolkata). It was presented in the International Conference on Cleaner Technologies and Environmental Management (ICCTEM'07) held at Pondicherry in January, 2007.

LIGHTS! DETECTION! AAAND ... RANGE!

A PRIMER TO LIDAR TECHNOLOGY FOR IMMERSIVE VISUALIZATION AND PREDICTING SOUNDS IN 3D

Suddhasheel Ghosh, Susham Biswas, Bharat Lohani

Introduction

Mapping the topography of the terrain has been a long practice. Elevation adds a significant amount of value to the mapping procedure. This parameter is often required for planning conventional methods of land surveying for mapping the terrain using equipments like the theodolite and levels. Modern techniques use satellite images and aerial photography. As time marches ahead, the hunger for higher accuracies has grown in the mankind. This necessity has fired the invention of devices like the total station and techniques like LiDAR (Light Detection And Ranging). The state-of-art laser ranging technology now enables us to

survey the cities as big as Kanpur and deliver accurate 3D data-products within a short period of time. The emerging challenges are the representation of 3D data products, processing and utilization for potential hotspot applications. We explore the use of 3D terrain data applied to visual and acoustic domains.

Three dimensional geo-visualization

Virtual Reality is a concept which has been studied since the early sixties of the previous century. One of the first machines developed included not only the immersive visualization of a city, but also sounds and aromas which give the

feel of being there in the environment. Visualization of 3D geographic data is considered an effective way to view data and answer topographical questions [Brenner, 1999]. Geo-visualization is an extension of the concept of virtual reality which has been largely used for development of highly interactive and immersive games. Geo-scientific visualization is now considered to encompass the development of theory, tools and methods for the visualization of spatial data. It helps in the understanding of how the tools and methods are used for hypothesis formulation, pattern identification, knowledge construction and facilitation of decision making [Buckley et al., 2000]. A case study was conducted by the Center of Geoinformation, GmbH [CeGi, 2003] regarding the demands and chances of 3D geo-visualization, and it was observed that areas where virtual reality could be applied are quite a number (see Figure 1).

The procedure of three dimensional mapping

Given a point $P(x, y, z)$ we can find the coordinates of another point Q , if we know the angles of the vector PQ with respect to the x , y and z -axes or the bearing angle (angle measured clockwise from the north), the vertical angle and the length of the vector. A total station uses the same principle to measure the coordinates of various points of the terrain to very high degree of accuracy. It fires a laser ray to the target and catches it back thus measuring the time of travel of the laser beam. The distance between the total station instrument (P) and the target point (Q) is thus easily measured by using the speed of light.

LiDAR technology

If we have a system which can fire multiple laser beams or pulses from a fixed point to multiple targets and also measures the required angles we would be able to find out the coordinates of the target points pretty fast. The Terrestrial Laser Scanner (TLS) and Airborne Altimetric LiDAR are such instruments. The TLS is a device which fires multiple laser pulses at fast and user defined speeds to measure the coordinates on the surface of the target object given its own coordinates. The latter is also known as the Airborne Laser Terrain Mapper (ALTM) which is mounted on an airplane

equipped with a Global Positioning System (GPS), which can measure the coordinates of the airplane wherever it goes, and an inertial navigation system which uses computer and motion sensors to track the position, orientation and velocity of the plane. These peripherals work together to correctly determine the coordinates of the target points on the ground. Since the ALTM can fire laser pulses at a very fast rate, the entire terrain can be mapped in a small period of time. Modern sensors are capable of firing up to 200K pulses in a second and digitize the full return waveform or provide multiple returns along with the intensity.

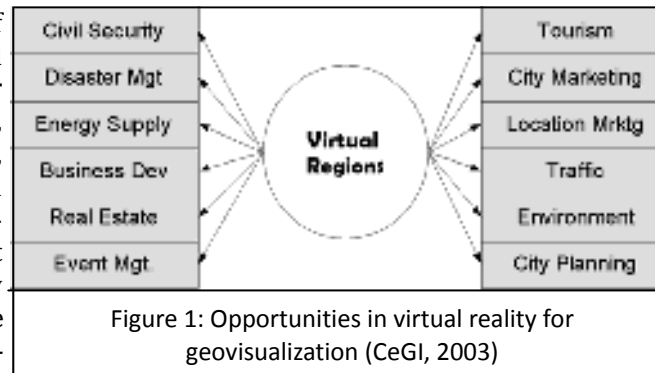
The LiDAR data obtained from the ALTM is in the form of a collection of data points. These points are stored

either in a text file in the x - y - z format or in the LAS format. Thus the entire data of the terrain is available as a point cloud to the user. Although the airplane is equipped with highly precise equipment, LiDAR data is not free from errors. Owing to human errors in mounting the ALTM, Inertial Navigation System or the GPS related errors, the resultant data has a known degree of error.

3D Visualization of LiDAR data

It is possible to generate three dimensional views using spatial data like aerial photographs and satellite data if they have a sufficient amount of overlap [Kraus, 2007]. The three dimensional views are however limited as they can be viewed only from the top and not from the flanks. A general user of a three dimensional visualization system would appreciate a view which is closer to real life i.e. looking at things on the computer screen as he sees it in daily life. A visualization system for LiDAR data would enable us to see the terrain from multiple perspectives. Further, if the view is immersive, it would enable the user to walk through the data.

However, we understand that since the entire terrain is measured by a point cloud, it becomes difficult to reconstitute the same to the screen in real time. Thus processing algorithms are required in order to smoothen, and filter out LiDAR points. The smoothening process should be such that surfaces with less details should contain less



number of points and more details would be covered with more points. This would mean extraction of 3D features from the LiDAR data. However, this is not a trivial task. Many algorithms have been developed using a classification based approach. In these approaches, points have been labelled as buildings, trees, ground and then the features have been extracted from them. It is to be noted that these classification approaches are not foolproof and therefore manual corrections need to be done in order to increase the accuracy of mapping.

In our approach, we try to bypass the process of classification, and extract features from the data using elementary geometrical entities like the triangles and the tetrahedrons.

We thus partition the data into two different parts: points belonging to planar objects and points belonging to non-planar objects. For this we take the help of a triangulation algorithm named QHULL developed by Barber et al. [1996] to generate tetrahedrons on the basis of the data points and then filter out the tetrahedrons based on their shape, area of the facets and their neighbourhood. As the tetrahedrons are removed, the eliminated vertices help us to smoothen the point data. We then break down the tetrahedrons into triangles and use a small module developed in C to export the data to an OpenInventor scene wherein we wrap the 3D model with a texture or aerial photograph of the same area. The OpenInventor is an engine that allows us to see 3 dimensional models in an immersive mode.

In order to visualize these models (Figures 2, 3, 4 and 5) generated by the utilities, anaglyph glasses would be required.

Predicting Sounds in 3D

The sound that we hear at a place at a particular moment is a function of (i) nature of sounds origi-

nated from various sound source (such as human voice, traffic, machines etc.); (ii) spatial location of a listener (or receiver) in 3D in relation to sound source(s); and (iii) the communication routes sounds follow before reaching to listener. It is important to determine the extent of sound energy reaching at different

corners in 3D space (outdoor or indoor) for various applications such as urban planning, noise controlling, sound scaping, indoor acoustic designing (of theaters and buildings). Available sound modeling techniques for predicting sounds at a location are inadequate owing to the poor 3D space information they incorporate, inefficient techniques applied to feed these information and to some extent weaknesses existing inside these models. Laser scanned 3D point cloud data creates an opportunity to overcome above difficulties and accurately predict sound at 3D and even would lead to exciting world of 3D realization of sounds.

Sound modeling basically involves accurate characterization of source(s), finding paths through which sounds can propagate to different locations and finally combining all energies relevant to a listener location to determine or predict sound characteristic

specific to that location. In the real world scenario, there can be sound sources of multiple types which can be located at various spatial locations with respect to the position of a listener. Hence one needs to identify all possible source and path through which energy transmission is possible between a pair of source and listener. When all the acoustic and spatial parameters are available one can use available predictive sound models to determine sound energies reaching to a location.

LiDAR point data and classified aerial photographs are used for determination of various spatial parameters for sound modelling. Thus all the energy transmission paths between

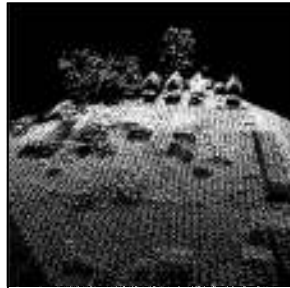


Figure 2: Raw point data shown in anaglyph



Figure 3: Texture Wrapped on Triangles (top view)

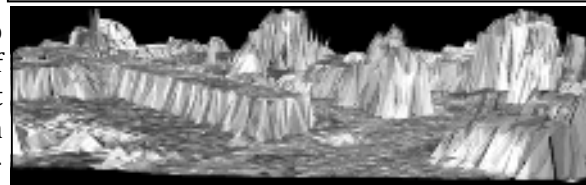


Figure 4: Texture wrapped on triangles (side view)



Figure 5: Texture Wrapped data where geometrical figures have been filtered

the source and the listener following reflection, refraction, diffraction, direct and absorbed transmission (through trees etc) are accurately accounted for and used along with the source characteristics to accurately compute the sound energy specific to a point. The methodology is illustrated in Figure 6.

Final remarks

Availability of 3D structure of terrain makes it possible to provide better initial conditions for running of physical models that require terrain information. This necessitates bringing changes in the way models are formulated to accommodate LiDAR data. In addition, LiDAR data provide several other useful information, which are not

obtainable with conventional topographic techniques. In the Geoinformatics Laboratory, LiDAR data is being used for derived information for prediction of *Tsunami flooding* and its impact on coastal zone. We are awaiting a LiDAR flight in our study site in the East coast of India.

We are working on a project to study propagation of error in LiDAR data capture process. For this IIT Kanpur is our study site where we are currently generating ground truths. A LiDAR flight has already been conducted over IIT Kanpur and the surrounding areas. Following clearances from the Ministry of Defence, the data would soon be with IIT Kanpur. The data of IIT Kanpur will also serve as input to our several other researches.

Ponder Yonder

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Both the authors are from the Department of Civil Engineering, IIT Kanpur and have collaborated for developing an immersive 3D audio-visual realization engine

Acknowledgement: Dr. Bharat Lohani (for constant inspiration for innovative research)

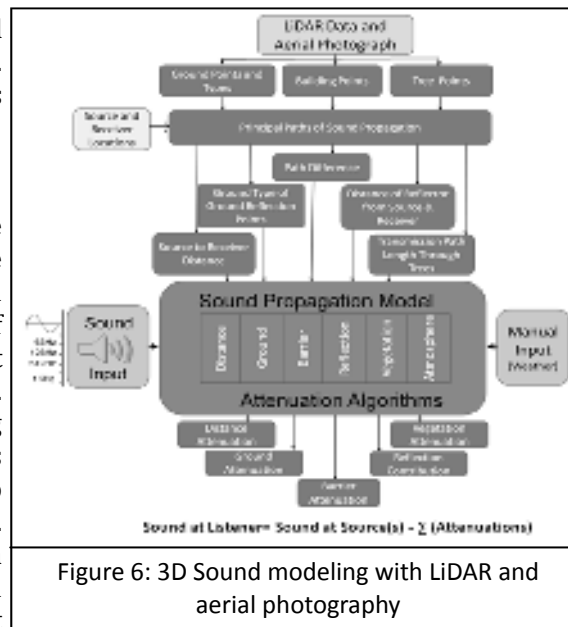


Figure 6: 3D Sound modeling with LiDAR and aerial photography

DOG-EARED

GALILEO'S PENDULUM

Pranjal Nayak

NERD Rating: 4/5

Author: Roger G. Newton

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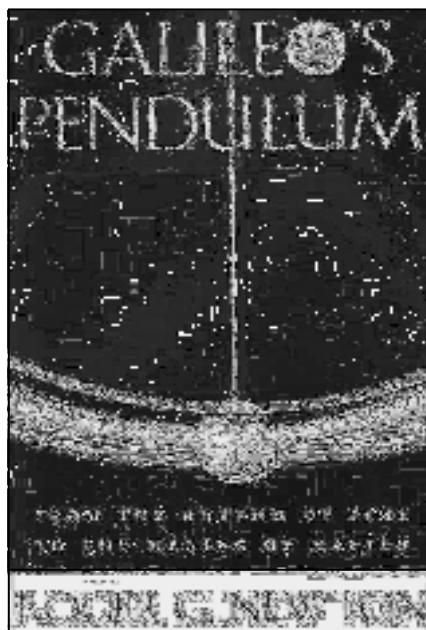
Genre: Science

SAC Book Club Availability: Not- available.

Review

'What's the *time* by your *watch*?' is one question that we encounter quite a number of time in a day. And yet how many times do we wonder what legacy these two words carry with themselves! It is this legacy carried by the two words- *time* and *watch* which this book discusses in detail. A well written book, it hardly contains anything technical. It is a work well done by the author to discuss this legacy that has been carried through ages by various astronomers, physicists, chronographers, astrologers and numerous other scientists, in a language that can be well understood by a general reader.

The book starts with a good question- Does it make sense to talk of time if one had no means to measure it? Is time an in-built sense in the living beings or it is just a response to the external cues? As an answer the author discusses the image of time that



is inherent to all living creatures, i.e., the various ways in which nature keeps time for itself. The author discusses biological clocks or *zeitgebers* in various living creatures and the experimental results that show the ability to keep time even in the absence of external stimulus. In this discussion it is interesting to note the way in which the biological clocks of the creatures are synchronised with the external cues. Experiments show that even plants know how to keep time! From here the author takes over the topic of 'what keeps the clocks ticking inside the living creatures and how?' How the chemistry powers these clocks in small creatures is interestingly described by the author.

From here the author moves to the 'need of time-keeping'. There might have been various needs

of the people which only increased with the development of the civilization, which resulted in various ingenious methods to record time, which have developed drastically over the time. Starting with the crude methods like noting the periodicity of the flooding of the rivers and their relations with the crop seasons, other methods like tides and then moon and day cycles were employed for various functions. The book beautifully discusses how the various periodic events (like earth's rotation for days, lunar cycles for months and earth's revolution for the year) were interrelated with each other to develop various calendars. The authors does a good job in developing the interest at this point regarding how these quite unrelated cycles were well fit and then intercalated to further improve upon the calendars. What is more beautiful is the fact that how the varied observations over the years (or rather centuries) brought out the best out of the observers to complete this beautiful work of science! These developments are spiced with various interesting stories associated with these developments that the author discusses along with.

From here on the author moves to the topic: the clocks. When the long division of the day was no more enough, the lack of shorter periodic motions to keep time urged man to develop ways on his own. Sun-dials and celestial

clocks served the purpose till the increased accuracy led to the invention of water-clocks and the mechanical clocks with falling masses. As the author moves ahead he discusses a few designs of these clocks and the improvements that were brought with time in them to increase their accuracy as well as beauty. This is a good way in which the author increases the interest in the book! At this point comes Galileo and his pendulum. The Galileo's discovery of the periodicity of the pendulum brought a great advancement in the notion of time- from just the division of the day (which was still equivalent to notion of time) it gained the abstract notion of 'true time'/ 'mean time' that is independent of the earth rotating or the pendulum swinging. This laid the foundation on which the whole of the Physics was to be based. This is roughly the notion that we still carry with us (apart from the relativity). It was understood that all the periodic motions were a measure of this time and its flow was independent of them.

Again the author describes development of the clocks hence. How the naval needs led to the improvements in the watches and brought out some of the best works of history from Swiss chronographers, in general and Harrison, in particular, is discussed in the next few pages. Moreover other predecessors of the pendulum are discussed over the next chapter which include clocks and watches based on springs, tuning forks, quartz oscillators and atomic clocks among others. The author does a good work when it comes to introducing the working of these pieces to a layman.

Moreover the author also

discusses the contributions of Newton (Isaac, of course) in the development of physics behind the pendulum and oscillations as such. He moves ahead to discuss the physics of oscillations, its applications in Electromagnetism and work of Faraday, Maxwell and others. Further the effect of relativity on the notion of time is also discussed. Moving ahead the author discusses how the oscillations led to the development of the Quantum physics. Elaborating on these points the author shifts completely to Quantum physics and Field theory and a few recent developments in the field. Although at this point the author could have done a better job, but nevertheless it brings out the beauty of the fact that how from the development of notion of time led to such great advancements in science. In author's words- 'From the rhythm of time to the making of matter'.

The way the author builds on the development up to a certain point to highlight the point how the next generation of the clocks evolved in one great plus of this book! This brings out what differs a good observer from the others. Another thing that I liked in the book was the way author kept introducing each new character he introduced with a brief history about him. This kept the rhythm of reading lively.

Finally, if you were looking for some light interesting book to read and yet learn something new this book is the one for you.

About the author

Professor Roger G. Newton is Distinguished Professor Emeritus in Indiana University, USA. Professor Newton's

research areas are field theory, scattering theories, nuclear and high energy physics, elementary particles, quantum mechanics, and mathematical physics.

Professor Newton received a Ph.D. degree from Harvard in 1953 and was a member of the Institute for Advanced Study at Princeton for the next two years. From 1955, he has been with the Department of Physics, chairman from 1973-1980, and Director, IU Institute for Advanced Study, 1982-86. In 1989 he was the recipient of a Departmental Teaching Award presented by physics graduate students.

Newton has served on various committees in many professional organizations and as associate Editor of the *American Journal of Physics*, and *Inverse Problems*. He was the Editor of the *Journal of Mathematical Physics* from 1992-2005.

Recent Publications

His most recent publications are *Thinking About Physics, What Makes Nature Tick?* (Harvard University Press, 1993); *The Truth of Science* (Harvard University Press, 1997); *Quantum Physics: A Text for Graduate Students*, (Springer Verlag, 2002); *Galileo's Pendulum: From the Rhythm of Time to the Making of Matter* (Harvard University Press, 2004); and *From Clockwork to Crapshoot: A History of Physics* (Harvard University Press, 2007).

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It's not just waste water

BIOENERGY GENERATION THROUGH ANAEROBIC TREATMENT OF WASTE WATER

Manoj K. Tiwari and A. R. Quaff

Introduction

The water and wastewater industry is one of the most energy intensive sectors in India and world-wide. In water supply sector, about 90% of energy use is due to pumping, whereas in wastewater management sector, treatment processes accounts for majority of the energy uses. Since the last two decades, an effective and economical solution for the treatment of wastewater has been a major thrust area for the developing world.

The conventional (aerobic) wastewater treatment options ensure good efficiency but require high energy for aeration and sludge management. Anaerobic (in the absence of oxygen) treatment technologies are reported to be relatively less efficient but still provide an attractive alternative as they produce less sludge, require less energy for operation and can produce bioenergy. In processes of anaerobic digestion of organic waste, bacteria breaks down organic matter into biogas, consisting of methane (CH_4), carbon dioxide (CO_2), and trace amount of other gases. Further the biogas can be used to generate heat and electricity. In this article, we discuss the prospect of energy generation through anaerobic wastewater treatment in India.

Principle of Anaerobic Wastewater Treatment

The anaerobic reactors are attractive treatment options because of their potential to recover

energy from the wastes and utilize as the dried sludge as fertilizers [1]. The anaerobic conversion is a multi-step process involving many independent, sequential and parallel reactions and requires the participation of several groups of bacteria carrying out rather specific reactions [2]. Complex organics like proteins and carbohydrates are first hydrolyzed by exo-enzymes forming soluble amino acids and sugars (monomers). Acting on these monomers, the fermenters produce fatty acids (formate, acetate, propionate, butyrate, etc.), alcohols, ketones, hydrogen and carbon dioxide. These

are then converted by acetogenic bacteria forming acetate, hydrogen and carbon dioxide. Methanogenic bacteria belonging to *Archea* use these products of acetogens as substrates and convert them to the final products of methane (Figure 1). The methanogens depend on the acetogens and fermenters for the food while the former groups

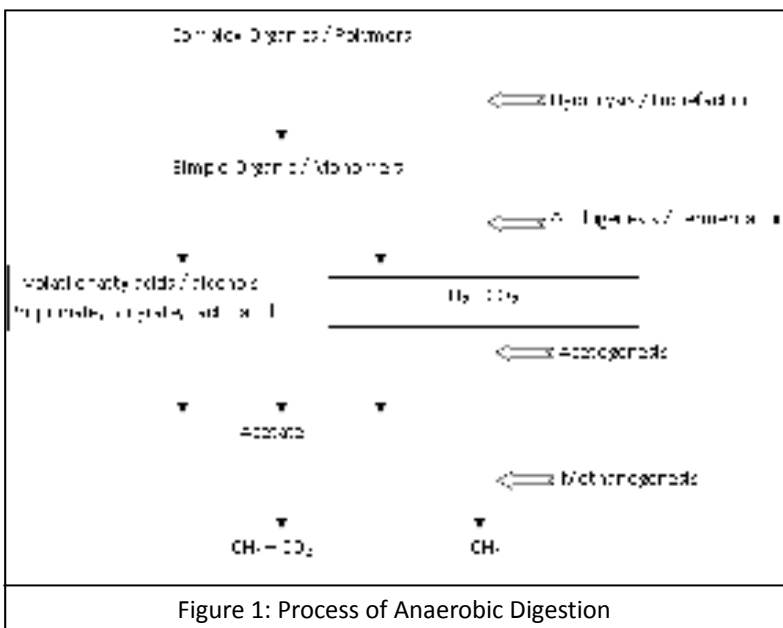


Figure 1: Process of Anaerobic Digestion

depend on the methanogens for depletion of fatty acids and hydrogen from the milieu. This interdependence between the groups is called *syntrophic* association. The requirements for a successful anaerobic reactor are therefore, oxygen free environment, presence of sufficient organic compounds, and other important environmental factors, such as pH, temperature and nutrients suitable for supporting the growth of syntrophic groups of diverse microbial population.

The process has been used in many reactor

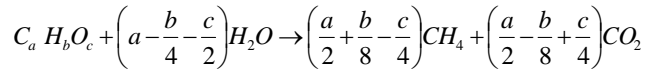
configurations for different applications such as sludge digestion, industrial and agricultural wastewater treatment, and sewage treatment. The common anaerobic reactors include Covered Lagoon, Plug-Flow Digester, Completely Stirred Tank Reactor (CSTR), Anaerobic Sequencing Batch Reactor (ASBR), and Up-flow Anaerobic Sludge Blanket (UASB). Lately, much activity in this area has concentrated on one particular unit process UASB. Figure 2 shows the schematic of a typical UASB reactor. The UASB process achieves treatment through the actions of active anaerobic biomass, which is held in suspension in the reactor by hydraulic design [3]. Upward motion of the released gas bubbles causes hydraulic turbulence that provides mixing in the reactor without any mechanical parts. At the top of the reactor, water phase is separated from sludge solids and gas in a three-phase separator, known as the gas-liquid-solids separator (GLSS). The three-phase-separator is commonly a gas cap with a settler situated above it. Below the opening of the gas cap, baffles are provided to deflect gas to the gas-cap opening [4].

Utilization of reactor produced biogas

Reactor produced biogas can be used in a number of ways. However initial processing is required before its end uses. The refining steps and uses are illustrated in Figure 3. Typically biogas from reactor is first passed through condenser followed by filter for removing any particulate carried by the gas. Filtered biogas is compressed, cooled and dehydrated.

At this stage, the dehydrated biogas can be used as direct fuel for boiler or burners. However, due to lower

heating value of biogas, natural-gas-fired-burners require small modifications when biogas is used. The advantage is that even lower quality gas can be utilized in burners and boilers. The heat gen-



eration efficiency of biogas is nearly 50%. Alternatively, electricity could be generated on-site using a reciprocating engine, steam turbine, gas turbine, or micro-turbine. Using a steam turbine requires generating the steam first. Micro-turbine can be used to generate electricity at a capacity as small as 30 kW. However, micro-turbine technology is not commercialized yet due to issues of biogas clean up cost and limited engine running time. The typical energy yield of 1 m³ methane is 11.04 kWh [4].

Alternatively, biogas can be purified to the level of natural gas by removing CO₂ and other impurities in biogas by passing through scrubbers. The cleaned methane gas can be injected into a natural gas pipeline. In comparison to other alternatives, the capital cost of upgrading pipeline quality gas from biogas is higher because of required treatment and also need of significant compression to conform to the interconnect point pipelines pressure. However, the technology is highly efficient and all the biogas produced can be utilized. Also, after removing CO₂ and water vapor from biogas, it could be compressed under high pressure, reformed, and catalytically converted to methanol. But, this is an expensive process due to its low efficiency as the entire process results in around 67% loss of available energy [4, 5].

Biogas Collection from anaerobic digester

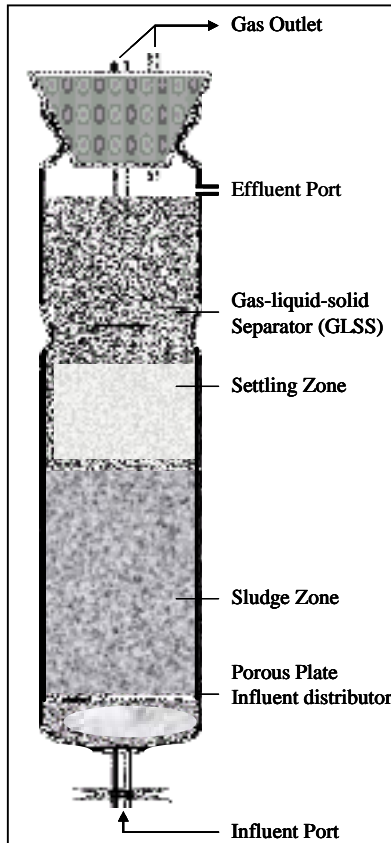


Figure 2: Schematic of a typical UASB reactor

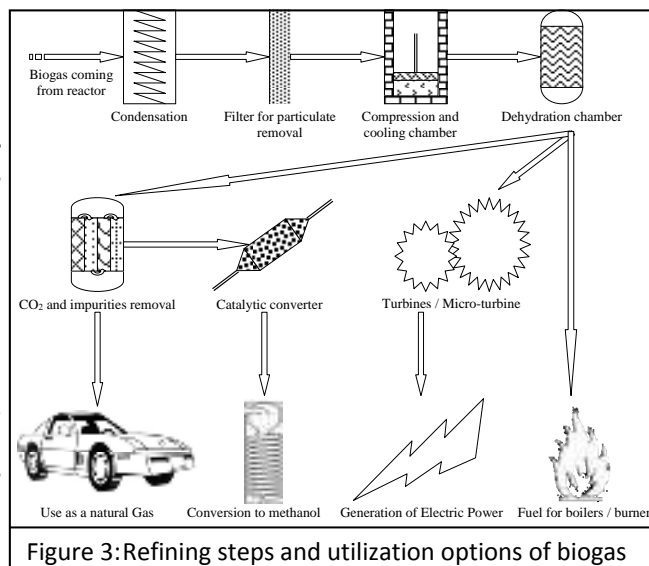


Figure 3: Refining steps and utilization options of biogas

The biogas production in an anaerobic digester primarily depends on wastewater composition (type of substrate). Theoretical gas production for different substrates can be calculated through following equation derived by Buswell and Mueller [6]: The equation gives theoretical methane fraction in biogas produced from carbohydrates, fats and proteins as 50%, 72% and 60%, respectively. In general, the methane fraction in total biogas ranges from 40-75% for most substrates.

The typical biogas yield from anaerobic wastewater treatment systems ranges from 200-600 L/Kg COD treated [1]. The biogas collection efficiency

depends on the collection protocol and ranges from 60 – 98 %. In our laboratory a 3.25 L lab-scale UASB Reactor operating with sucrose based low strength synthetic feed (COD~750-850 mg/L) produced 380 L of methane/Kg of COD removed [7]. However, when the same reactors were operated with real domestic sewage from IIT Kanpur campus (COD = 238.8±79.3 mg/L), the yield was about 50% of the above value (Table 1). This difference could be attributed to complexity of the substrates in real wastewater as well as lower strength of wastewater causing lower collection efficiency [8].

Wastewater treatment scenario in India: Energy Prospective

The water pollution is perhaps India's worst environmental problem. Three fourth (v/v) of total wastewater generated comes from the domestic sector which accounts for nearly half of total pollution load. In India, there are huge variations in per capita water consumption and thus, sewage generation among rural, small town and big cities populations. The treatment status of wastewater generated in all cities across India has been grossly inadequate. The figures of a recent study by Central Pollution Control Board [9] revealed that municipal wastewater treatment capacity developed so far in India accounts only for 27% of wastewater generation in Class I (Population > 1,00,000) and Class II (Population between 50,000 - 1,00,000) urban centers. Apart from this, only 60% of industrial effluent receives

treatment in spite of strict government norms.

Currently, majority (~ 70%) of the treatment plants in India uses conventional activated sludge process for organic matter removal. The process is highly energy intensive as it requires continuous aeration. On the other hand, power required in operation of anaerobic reactor is only due to pumping. It has been demonstrated in several pilot and full-scale applications all over the world

that with efficient design and operation, biogas produced can generate power which can meet partial or entire power requirements, thus making the treatment process sustain-

able [4]. In India, UASBs working on distillery waste (typical COD ~ 80-120 g/L) achieve 65-70 % COD removal efficiency and produces ~ 0.5 m³ biogas / Kg COD removed [10]. However, due to difficulties in collection and use of biogas, many plants across the world and most of the anaerobic installations in India either do not collect the biogas or burn it at the exit point. Some small scale units use biogas, mostly as direct fuel to burners. To the best of authors' knowledge, there is no comprehensive data/survey report available on the total power production potential from wastewater treatment in India.

Discussion

In activated sludge process, 1 kWh or 3.6 MJ of aeration energy is required for complete oxidation of 1 Kg BOD [10]. Additionally, 0.6 Kg of sludge will be produced as new waste. On the other hand, anaerobic treatment produces nearly 0.35 m³ of methane with an energy value of 4 kWh. Also, waste sludge produced is typically one tenth of the amount produced under aerobic conditions. Due to these benefits, many industries in India, especially distilleries, are converting their conventional treatment system to UASBs.

In a larger perspective, as per CPCB reports [11], 423 Class I cities and 499 Class II towns (~ 20 crore population) generate 26,254 MLD wastewater having a total BOD load of 5,244 t/day. In addition, nearly 57,000 polluting industries

Reactor	Feed Type	Organic Loading Rate (Kg COD/m ³ /day)	Total COD Removal Efficiency	Gas Collected (L/Kg COD Treated)		
				Total Biogas	CH ₄	CO ₂
3.25 L Lab-Scale UASB	Sucrose based synthetic wastewater	1.477±0.118	95 %	657.85	393.75 (59.7 %)	274.11 (41.3 %)
	IIT Kanpur domestic sewage	1.24±0.41	77.1 %	238.85	199.66 (83.2 %)	25.75 (10.8 %)

NA = not available. COD Removal calculated by subtracting CH₄ from total gas, assuming other gases negligible.

Table 1: Steady state COD removal and gas collection in Lab-Scale UASB reactor

generate 15,438 MLD wastewater having a total BOD load of 10,852 t/day. The estimated energy consumption and possible production in treating these effluents are shown in Table 2. Conservative calculations were made assuming only 60 % of total energy produced could be collected and/or utilized. Conservative estimates

be generated from anaerobic treatment (20835.84 MWh).

Combining cases for both, domestic and industrial wastewater, the anaerobic-aerobic treatment can not only be energy self-sustainable but can yield nearly 24,000 MWh of net energy.

Wastewater Characteristic				Total Possible Requirement		Wastewater Treated				2 nd Stage Aerobic Treatment	
Type	Area	BOD Level	BOD COD Ratio	Eff	Energy requirement @ 18 kWh/tg BOD	Eff	Energy requirement @ 24 kWh/tg COD	Energy production @ 18 kWh/tg BOD	Energy Collection (60% eff.)	Addl. BOD load to 1 st treatment	Energy requirement @ 18 kWh/tg BOD
	(MLD)	(mg/L)		(%)	(MWh)	(%)	(MWh)	(MWh)	(MWh)	(MWh)	(MWh)
Domestic	26,254	5,244	0.68	90	4719.6	60	525.08	18508.24	11104.94	1573.2	1573.2
Industrial	15,438	10,852	0.50	90	9766.8	40	308.75	34726.4	20835.84	5426	5426
Total					14486.4		833.83	22024.64	13188.78		21159.2
Net energy requirement for 90 % treatment efficiency					14486.4 MWh						5608.00 MWh
Net energy production for 60 % efficiency (60% collection)											20835.84 MWh
Net energy saving											16227.84 MWh

In anaerobic reactor, the energy required for pumping only if reactor is not gravity fed, however most of the anaerobic installations in India are gravity fed.

Table 2: Estimation of energy consumption and production through domestic and industrial wastewater treatment

for the COD removal efficiencies of anaerobic plants were also made with only 60 % and 40 % for domestic and industrial wastewater, respectively. To meet with the aerobically treated effluent quality, the anaerobic effluent can be further processed aerobically (2nd stage aerobic treatment). Thus, the total energy requirements for the same quality effluent will include power needed for pumping in the anaerobic reactor (if needed) and power required for aeration of the anaerobic reactor effluent. In general, UASB reactors are designed as gravity fed eliminating power requirement for pumping. At present in India, most of the anaerobic, in particular UASB installations are gravity fed. But, considering the worst case scenario, the pumping requirements have been considered in estimations made in Table 2.

For 90 % BOD removal of 26,254 MLD domestic sewage, anaerobic followed by aerobic processing require 2098.28 MWh of power. During anaerobic treatment 11104.94 MWh of power will be produced resulting in a net yield of 9006.66 MWh of power. Only aerobic treatment of same efficiency would require 4719.6 MWh of power for aeration and would not produce any energy. The scenario with industrial wastewater is even more attractive. The anaerobic followed by aerobic treatment for 15,438 MLD industrial wastewater require 5734.76 MWh of power which is significantly less than the power likely to

Since, average per capita energy consumption in India is ~ 400 kWh per annum [12], the power generated from wastewater can satisfy daily energy needs of approximately 2.2 crore population.

Conclusions

Treatment of sewage and industrial wastewater is unavoidable due to environmental concerns. Most of the currently installed wastewater treatment systems require significant amount of power for the process, which can be avoided by replacing conventional aerobic treatment units with a combination of anaerobic followed by aerobic systems. Anaerobic treatment of wastewater has significant potential as alternative energy source, which if rightly exploited, can not only make the wastewater treatment process sustainable in terms of energy, but can produce significant amount of usable energy.

Ponder Yonder

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The fragile homeostasis of the blue planet

NERD SERIES ON SUSTAINABILITY

Professor S. Sarkar

After "Big Bang" when the Sun ejected Earth from its own mass, the Earth has gone through many changes that have affected its environment. The Earth maintained its emotional relationship with the Sun just for its sheer existence. From the past 4.5 billion years the Earth has continued its adjustment causing, among other changes, climatic variations. Consequently, in the continued evolutionary process, many of these changes led to the development of newer species of plants and animals, while other species faded away when the environment that they were accustomed to no longer existed. Today, the Earth is still evolving and man, the last creation of the Earth, hastens this process by contributing unearthly changes to create a hellish environment by which the human race may extinct like the earlier inhabitant, dinosaurs. What will assure us that future generations will have a nurturing environment in which to live, or will history

repeat itself?

In the beginning, Earth has a very hostile setting. In fact, it was such a hostile place that it is difficult to believe that the Earth that we know today could have arisen from such an environment. After millions of years have come and gone, and a rich environment has developed to protect the Earth from the harsh, damaging, inferred rays from the Sun filtered by thick ozone layer, after all the tectonic folding, after many pyrotechnics like volcanic eruptions and abyssal intrusions, the very first organisms of life appeared and with the passage of time the latest of all lives, the human emerged. The Vedic hymn of early human paid all the respect to this blue planet, "*Whatever I dig up of you, O Earth, may you of that have quick replenishment! O purifying One, may my thrust never reach Right into your vital points, your heart!*"

But our greed and ignorance about those *vital points* drove us to the development of 'Deccan Trap' like environment on the Earth. No lava flowed, no eruptions took place no massive asteroid impact felt to annihilate the dinosaurs in this 'Modern Trap' but huge amounts of poisonous gases such as sulfur oxides and nitric oxides, along with carbon dioxide, were continuously interjected into the atmosphere. Likewise, many substances such as metals, paints, pesticides and other chemical vapors are being constantly emitted by industries into the atmosphere.

Another factor that influences our environment is water. Aquifers produce billions of liters of water every day but our need is paramount. Likewise, fertilizers, pesticides, factory outlets, sediment from erosion, and large amounts of treated sewage are released into our water systems. Rubber particles from tires being worn down by the roads we drive upon each day and oil from leaky engines run off the roads into our water systems when it rains. Polluted water affect the ability to absorb light, which would impede photosynthesis resulting lower oxygen production for the atmosphere.

It has not been until recently that man has begun to realize the impact our species have on the Earth. Today, the two main causes of pollution are created by actions of mankind. The first is high population density, which inhibits the ecosystem's ability to rid itself of toxic substances. The second cause is man's materialism. As in all situations, there are trade offs; man has traded short term convinces for the very Earth that supports his life and the lives of future generations.

However, one of the major concerns associated with air pollution today is combustion or burning of substances which adds high concentrations of carbon dioxide to the atmosphere. Also enormous amount of tiny nano sized carbon particulates float in the atmosphere. These are responsible for the greenhouse effect that is progressively causing temperature changes which might have caused damage to the ozone layer and affected global temperatures and climates. Higher atmospheric temperatures could cause unusual circulation of air masses, causing violent storms such as tornadoes, hurricanes, and even El Ninos. Further, higher temperatures could melt the polar ice caps creating a substantial rise in the ocean levels, causing flooding. Tiny non destructible carbon particulates in aerosol prevented the

condensation and precipitation of water drop because of its heat radiative process leaving a foggy and supernatural weather in cold months paralyzing man's daily routine. And by breathing in such air one involuntarily invites millions of such dusty particles inside triggering all respiratory problems.

Another ill-fated result of burning fossil fuels, such as coal with a high concentration of sulfur, is the emission of sulfur dioxide into the air. When sulfur dioxide joins with water particles in the air, acid rain is produced. Acid rain can kill plants and change the pH of the soil; it can kill fish and inhibit some bacteria's ability to fix nitrogen; it can damage structural surfaces such as brick, stone, and metals and monuments like Taj Mahal, not to mention what it might be doing to our skins! Equally important, when temperatures rise or drop from a certain range, organisms began having difficulty with their metabolic processes. Global temperature is closely related to organisms' metabolic rates. If the temperature is too hot, then enzymes began to denature. Therefore surrounding temperature environments affect most organisms. If the temperature changes more than a few degrees above or below the accustomed temperature, the organism can not maintain its body temperature and will die. Additionally, the pH and mineral composition present in the soil affect the distribution of plants, and the animals that consume these plants. Acid rain, mineral mining, and fertilizers could affect the pH and the mineral composition of the soil; thus limiting the amount of food crops that could be grown, load production for consumer use.

The prehistoric species had no control of their environment; however, man does. Most of the environmental threats to man have been of our own making. Every second we are doing something that destroys factors that influence our environment. Human's inventive nature has allowed them to live in the Arctic, the tropics, the mountains, and the deserts. We have changed our environments by building cities and roadways. In fact, even Rawatpur to Kanpur and the campus of IIT have changed so much in the last 30 years that I am amazed to watch at what man has accomplished in such a short time. Conversely, although man has improved his standard of living, he has, due to poor conservation, destroyed deep green, lush topsoil that took many years to develop. Water reservoirs that were once homes for many species and sources of drinking water are

struggling to survive. Additionally, the air in many locations became unhealthful and filthy to breathe and this can even be felt if it rains a bit and one takes a morning or evening walk through the gorgeous GT road near Kanpur University. Or you face breathing problem as you pass through the industrial hub of Unnao or Ghaziabad. Likewise, the supply of fossil fuels that were made during the carboniferous period is being used at an alarming rate. The driver of a two wheeler in mad rush will try to accelerate beyond the capacity of its engine releasing huge amount of half burnt fuel to the atmosphere. Under utter power failures diesel powered generators lightened the shopping malls contributing enormous smoke in the atmosphere.

Nevertheless, possibly the most dangerous pollutant of all is mankind. Although we have devised many ways to prevent pollution such as sewage waste plants, automobile emissions control, conservation and many others, man could indeed be his own worst enemy.

Presently the Environmental Protection Agency (EPA) has established regulations in industrialized nations to protect the Earth. Unfortunately, the developing nations ignore the warnings of environmentalists. In spite of their efforts, ignorant and self-serving individuals continue to destroy the Rain Forest at an alarming rate. Habitat is being destroyed which most likely will lead to the extinction of species. Some of these organisms may possess the potential to cure serious illnesses such as various cancers, HIV, to name a few; yet, we may never have the opportunity to discover their medicinal qualities.

So, one may ask, what does all this have to do with us today? How does the extinction of the dinosaurs compare with what is happening to our world presently? First, the dinosaurs extinction was mainly due to natural processes that occurred not to just the dinosaurs, but to other species such as plants that the dinosaurs depended on for life. The human species, like many others, influences and is influenced by his environment.

Overpopulation is putting too much pressure on a planet that is already over burdened to produce food; clothing; clean water and air; shelter, and all of the other material possessions we all hold so dear to our hearts. All of these factors and too many others to mention are leading to a slow degradation of the human race. If mankind continues in the same vein, it is expected to last only couple of hundred more years! However, unlike the poor dinosaurs we do have a choice.

What will your choice be, life or extinction for future generations?

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The Mathemagician of Paris

A PROFILE ON SOPHIE GERMAIN

Parul Agarwal

What do Archimedes, Monsieur LeBlanc, Lagrange, Gauss, and Fermat have in common? The person who connects all these names is Sophie Germain, a French mathematician of the late 18th and early 19th centuries.

Sophie Germain is a revolutionary scientist who

belonged to a middle class family and went against the wishes of her family and the social prejudices of the time to become a highly recognized mathematician. She is best known for her work in number theory, but her work in the theory of elasticity and differential geometry are also very important to mathematics.

Early Life And Schooling

Sophie Germain was born in Paris on April 1, 1776 to Ambroise-Francois and Marie Germain as their middle daughter. Her father was a prosperous silk merchant and later became a director of the Bank of France. Sophie's home was a meeting place for those interested in liberal reforms and she was exposed to political and philosophical discussions during her early years.

Sophie's interest in mathematics began during the French Revolution when she was 13 years old and confined to her home due to the danger caused by revolts in Paris. She used to spend a great deal of time in her father's library, and one day she ran across a book in which the legend of Archimedes' death was recounted. Legend has it that "during the invasion of his city by the Romans Archimedes was so engrossed in the study of a geometric figure in the sand that he failed to respond to the questioning of a Roman soldier. As a result he was speared to death". This sparked Sophie's interest. If someone could be so engrossed in a problem as to ignore a soldier and then die for it, the subject must be interesting! Thus she began her study of mathematics.

Sophie began teaching herself mathematics using the books in her father's library. According to the common belief of the middle-class during that period, her parents felt that her interest was inappropriate as she was a female. They tried many ways that they could to discourage her. She began studying at night to escape them, but they went to such measures as taking away her clothes once she was in bed and depriving her of heat and light to make her stay in her bed at night instead of studying. Sophie's parents' efforts failed. She would wrap herself in quilts and use candles she had hidden in order to study at night. Finally her parents realized that Sophie's passion for mathematics was incurable, and they let her learn. Mathematics books became her intimate friends. Thus Sophie studied differential calculus without the aid of a tutor!

Career

In 1794, when Sophie was 18, the Ecole Polytechnique was founded in Paris. It was an academy founded to "train mathematicians and scientists for the country". Women were not allowed to enroll in the academy. Germain befriended students and obtained their lecture notes. Sophie

was mainly interested in the teachings of J. L. Lagrange. She submitted a memoir to him under the pseudonym of M. LeBlanc (a former student of Lagrange's). Lagrange saw talent in the work, sought out the author, and was bowled over to discover it had been written by a woman. Lagrange decided to help her and became her mentor. With a male to introduce her, Sophie could enter the circle of scientists and mathematicians that she never before could. Up until this point not only had her gender been a hindrance to her, but her social status had been too. It was socially acceptable for aristocratic women to be taught the sciences and mathematics so that they could talk about it casually with friends. Sophie was of the middle class so this opportunity had passed her by.

Sophie's most famous correspondence was with the German mathematician, Carl Friedrich Gauss in the year 1804. She was intrigued with his work in number theory and sent him some of the results of her work in number theory. She wrote a dozen letters to him, initially adopting again the pseudonym "M. LeBlanc" because she feared being ignored because she was a woman. During their correspondence, Gauss gave her number theory proofs high praise. It was not until 1807 that he found out who M. LeBlanc truly was. He was thrilled to find that his "pen pal" was a very gifted woman and praised her for her interest in Mathematics in spite of various social prejudices.



Sophie Germain:
A painting

About 12 years later, however, she wrote to the mathematician Legendre about what would be her most important work in number theory. "Germain proved that if x , y , and z are integers and if $x^5 + y^5 = z^5$ then either x , y , or z must be divisible by 5. Germain's theorem is a major step toward proving Fermat's last theorem for the case where n equals 5" Fermat's last theorem says that if x , y , z , and n are integers then $x^n + y^n = z^n$ cannot be solved for any n greater than 2. She also stated an identity, commonly known as Sophie Germain's Identity which states that for any two numbers x and y :- $x^4 + 4y^4 = (x^2 + 2y^2 + 2xy)(x^2 + 2y^2 - 2xy)$. Sophie also gave the concept of Sophie Germain prime. A prime number p is a Sophie Germain prime if $2p + 1$ is also prime. For example, 11 is a Sophie Germain prime because it is a prime and $2 \times 11 + 1 = 23$, also prime. A Sophie Germain prime $p > 3$ is of the form $6k-1$.

In 1808, the German physicist Ernst F. F. Chladni had visited Paris where he had conducted experiments on vibrating plates, exhibiting the so-called Chladni figures. The Institute de France set a prize competition with the following challenge: formulate a mathematical theory of elastic surfaces and indicate just how it agrees with empirical evidence.

A deadline of two years for all entries was set. Lagrange had said that the mathematical methods available were inadequate to solve the problem. Therefore, most mathematicians did not even try. However, Germain did not give up and spent the next decade attempting to derive a theory of elasticity, competing and collaborating with some of the most eminent mathematicians and physicists. In fact, she was the only entrant in the contest in 1811, but her work did not win the award. She had not derived her hypothesis from principles of physics, nor could she have done so at the time because she had not had training in analysis and the calculus of variations. Her work did spark new insights, however. Lagrange, who was one of the judges in the contest, corrected the errors in Germain's calculations and came up with an equation that he believed might describe Chladni's patterns.

The contest deadline was extended by two years, and again Germain submitted the only entry. She demonstrated that Lagrange's equation did yield Chladni's patterns in several cases, but could not give a satisfactory derivation of Lagrange's equation from physical principles. For this work she received an honourable mention. Germain's third attempt in the re-opened contest of 1815 was deemed worthy of the prize of a medal of one kilogram of gold, although deficiencies in its mathematical rigour remained. To public disappointment, she did not appear as anticipated at the award ceremony. Though this was the high point in her scientific career, it has been suggested that she thought the judges did not fully appreciate her work and that the scientific community did not show the respect that seemed due to her.

The prize from the Academy, however, was of immediate importance because it introduced her into the ranks of the prominent mathematicians of the time. She became the first woman who was not a wife of a member to attend the Academy of

Sciences' sessions with the help of Jean-Baptiste-Joseph Fourier. She was praised by the Institut de France and was invited to attend their sessions. This was "the highest honor that this famous body ever conferred on a woman".

Germain continued to work in mathematics and philosophy until her death. Before her death, she outlined a philosophical essay which was published posthumously as *Considérations générales sur l'état des sciences et des lettres* in the *Oeuvres philosophiques*. Her paper was highly praised by August Comte.

She was stricken with breast cancer in 1829 but, undeterred by that and the fighting of the 1830 revolution, she completed papers on number theory and on the curvature of surfaces (1831). Germain died in June 27, 1831, and her death certificate listed her not as mathematician or scientist, but *rentier* (property holder).

Honours and Awards

1. University of Gottingen grant her an Honourary Doctoral Degree in 1830
2. Won with her paper Memoir on the Vibrations of Elastic Plates in 1815 on Chladni's patterns

Sophie lacked many of the advantages that other women in math have had. She was not born into a mathematical family, nor one in aristocratic intellectual circles. She yearned for professional training, but was continually denied. Yet, she had determination and an undistracted passion for mathematics. She continually strove for excellence amidst prejudice. She offers an excellent model for us to follow.

Ponder Yonder

1. http://en.wikipedia.org/wiki/Sophie_Germain
2. <http://www.agnesscott.edu/Lriddle/WOMEN/germain.htm>

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The one with the hand gestures

COMPUTER VISION TECHNIQUES TO RECOGNIZE AND CLASSIFY HAND GESTURES

Shiva Nigam

Hand and arm movements, generally away from the body, commonly accompany, and appear to bear a direct relationship to, speech. Hands are extremely expressive, with approximately 29 degrees of freedom. Detection and interpretation of different human gestures has been a fascinating field in various areas such as psychological studies, military purposes, gesture recognition, robotic control, interpreting the language of small babies, etc.

To recognize and classify hand gestures, we need a vision system which captures and processes image to extract application-specific information in real time. There should also be a processing unit which performs application specific information processing (hereafter, referred as ASIP) so that whenever system detects a (movement or) gesture, this unit should process the image and extract information useful to particular application. This means that this vision system should integrate image sensing, ASIP and communications. This vision system can be any system such as a normal web cam or a smart camera, etc. The smart camera can be an embedded vision system or based on Field Programmable Logic Array (FPGA), etc. An embedded system refers to a system that is defined (made) to perform a particular task. Infact, everyone uses it in some or the other form like the washing machine we use! A smart camera is a stand-alone, self-contained embedded system that integrates image sensing, ASIP and communications in one single box.

Vision based gesture recognition, which uses cameras and computer vision techniques, is more flexible, portable and affordable. Vision based gesture recognition is not a trivial task, especially when built as an embedded system. Hand gestures may be single handed or double handed. Surely, two-handed gestures would be more difficult to analyze, and also their interpretation would be tougher. A topic running parallel to this is "To recognize and classify Finger Gestures".

Classification of hand gesture

Any kind of gestures have four aspects which are hand shape, position, orientation and movement. According to different application scenarios, hand gestures can be classified into several categories such as:

1. Conversational gestures
2. Controlling gestures
3. Manipulative gestures
4. Communicative gestures

These can be understood by their names only. On a different criterion, hand gestures can also be classified as:

(1) Conscious gestures

These are consciously produced gestures. There are two types of conscious gestures:

Emblematic Gesture: These gestures are culturally specified in the sense that one single gesture may differ in interpretation from culture to culture and are *consciously* produced.

Propositional Gesture: An example is the use of the hands to measure the size of a symbolic space while the speaker says "it was this big".

The conscious gestures do not make up the majority of gestures found in spontaneous conversation.

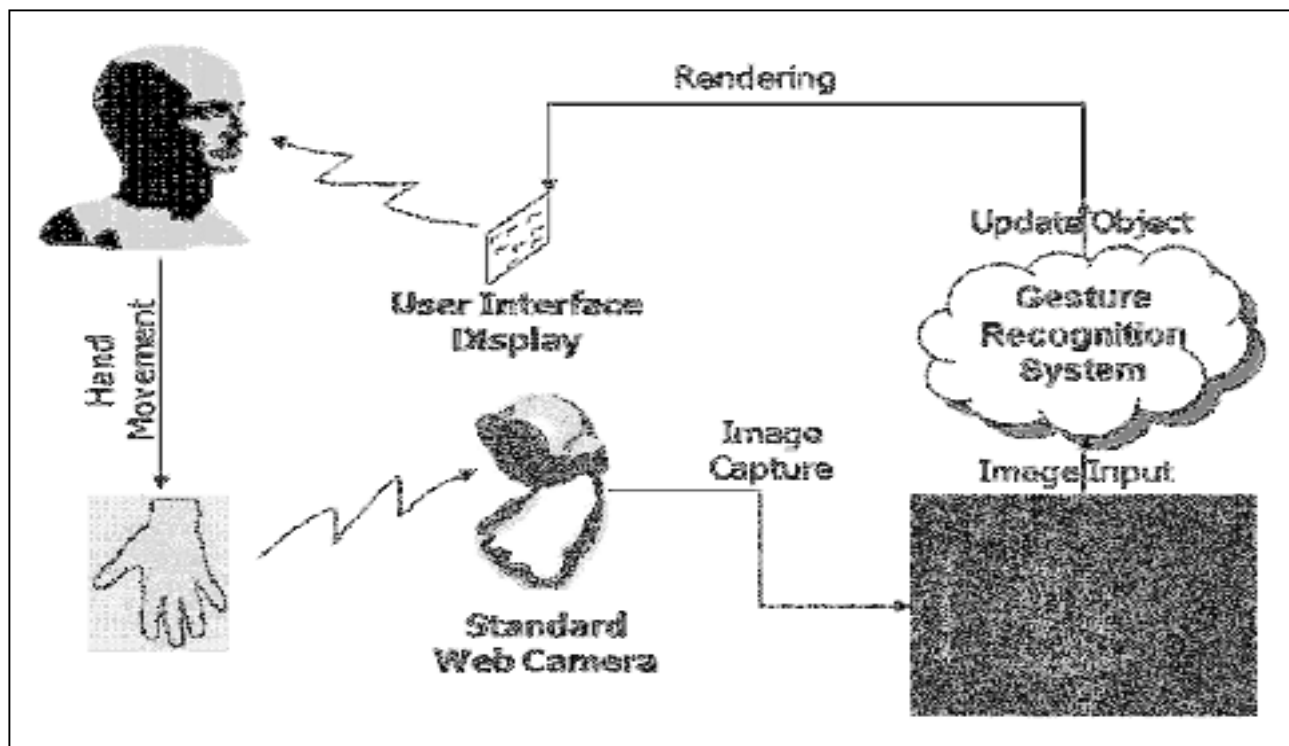
(2) Unconscious / Spontaneous gesture

The vast majority of gestures are those that although unconscious and unwitting are the gestural vehicles for our communicative intent, with other humans, and potentially with our computers as well. Spontaneous gesture accompanies speech in most communicative situations.

Iconic – representational or pictorial gestures that represent physical entities in the world depicting some feature of the object, action or event being described.

Metaphoric – gestures that represent an abstract concept or a common metaphor, rather than the object or event directly.

Interactive/beats– small, formless gestures, often associated with word emphasis; physically oriented to an Interlocutor (a person who takes



A schematic for the system which would recognize and process hand gesture is shown in the above figure.

part in a dialogue) that play a role in regulating the interaction and/or transitions in discourse.

Deictic – pointing gestures that refer to people, objects, or events in space or time.

Classification of gestures can be done by using template matching (from a database of predefined gesture representations) or by geometric features or by using neural networks or time-compressing templates or Hidden Markov Models. A simple nearest centroid algorithm serves as the classifier. 2-D analysis can provide us with hand bounding boxes and centroid of the hand. That is, in a layman's language, we can locate the hand after we determine its centroid.

Recognition of hand gesture

Recognizing gestures is a complex task which involves many aspects such as motion modeling, motion analysis, pattern recognition and machine learning, even psycholinguistic studies. Motion analysis is to be done for dynamic gestures because an information can also be conveyed by moving your hand in a specific manner, just as you do it when you are trying to call someone from a distance !!! There can be four aspects of a gesture which may be important to its meaning:

1. *Spatial information* – where it occurs, locations a gesture refers to;

2. *Pathic information* – the path which a gesture takes;

3. *Symbolic information* – the sign that a gesture makes;

4. *Affective information* – the emotional quality of a gesture

For static hand gesture and posture recognition, it can be possible to recognize hand gesture/posture by extracting some geometric features such as fingertips, finger directions and hand contours, but such features may not be always available and reliable due to self-occlusion and lighting conditions. We can use programs in MATLAB (a technical language) or simple languages to determine the coordinates for the determination of these. There are also many other non-geometric features such as color and textures, but they may not be reliable in recognition. If it is not possible to specify features explicitly, then whole image or transformed image can be taken as the input and features can be selected implicitly. Feature selection is important to the recognition algorithms. Also, the hand will have to be localized in the image sequences and segmented from the background. It may be possible to recognize some gestures by 2D locations of hands, but then this would give approximate results for a 3-D object, that is it will not be general. However, it may be possible that in some cases, gesture recognition

can be satisfactorily done using 2-D features alone. Also, image processing of the image sequences can also give us simple 2-D trajectory (motion path) for the dynamic hand gesture.

3-D analysis of a hand gesture, on the other hand, can provide us with the hand orientation and shape as well, which may be useful for some applications. But, as hand cannot be treated as a rigid object, it would be hard to determine the hand orientation in space accurately. 3-D position of hand should be achieved by an approach which would take into account not only hand movement, but also hand postures and palm orientations.

Based on the above requirements, a gesture recognition system should comprise of systems for:

(1) *Sensing human position, configuration, and movement using cameras* - its output will give us a time-varying sequence of parameters describing the position and velocity of the hand.

(2) *Preprocessing* - processing the image (images will be normalized, enhanced, or transformed in some manner).

(3) *Gesture Modeling and Representation* - this will include transforming the input into the appropriate representation (feature) and then

classifying it from a database of predefined gesture representations followed by selection of suitable characteristics that ensure an accurate representation of the gesture and then the determination of the smallest number of characteristics, so as the recognition task to be accomplished in shortest time possible.

(4) *Feature Extraction and Gesture Analysis* - it will include extraction of the features (statistical properties or estimated parameters) followed by computing the parameters from image features that are extracted from sequences. Thus, pose and trajectory description would be possible then. Suitable image features can then be easily selected.

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The Soil Spoil

SURGE PROPOSAL ON STUDYING LIQUEFICATION OF SOILS DURING EARTHQUAKES

Prayakarrao Sukanya

Earthquakes are one of the most disastrous natural calamities which pose a great hindrance as well as challenge to construct quake resistant structures. Due to this threatening natural disaster, thousands of years of human constructions could be demolished within a fraction of minute. Extensive research is being undergone to understand the reasons and mechanisms behind these devastating quakes. The earthquake hazards include the following:

1. Ground Shaking
2. Structural hazards
3. Liquefaction
4. Land slides
5. Retaining structure failures
6. Lifeline hazards
7. Tsunami and Seiche hazards

Among these hazards, Liquefaction damage triggered by earthquakes caught the sight of scientific community and several criteria were devised to ascertain the liquefaction potential of cohesion-less soil beds. Soil liquefaction describes the behavior of soil that when loaded, suddenly goes from a solid state to liquefied state or having the consistency of heavy liquid with effective stress reduced to zero.

The most intense damage is confined to areas where buildings and other structures are situated on top of loosely consolidated, water saturated soils. Loosely consolidated soils tend to amplify shaking and increase structural damage. Water saturated soils compound the problem due to their susceptibility to liquefaction and

corresponding loss of bearing strength.

Liquefaction is a physical process that takes place during some earthquakes that may lead to ground failure.

As a consequence of liquefaction, soft, young, water-saturated, well sorted, fine grain sands and silts behave as viscous fluids rather than solids. Liquefaction takes place when seismic shear waves pass through a saturated granular soil layer, distort its granular structure, and cause some of its pore spaces to collapse. The collapse of the granular structure increases pore space water pressure, and decreases the soil's shear strength.

If pore space water pressure increases to the point where the soil's shear strength can no longer support the weight of the overlying soil, buildings, roads, houses etc., then the soil will flow like a liquid and cause extensive surface damage.

The resistance of the cohesion-less soil to liquefaction depends on the density of soil, confining stresses, soil structure, the magnitude and duration of the cyclic loading, and the extent to which shear stress reversal occurs. I would like to carry out experimental work to find out optimum parameters and conditions that best serves the purpose by conducting Shaking Table Test and Cyclic Tri-axial Loading Test. During the proposed brief summer training, I am conducting studies on liquefaction of sands, flyash and other



Effects of Liquefaction

cohesion-less materials with different initial test conditions such as initial density, water content and degree of saturation and also to understand the

influence of admixtures like cement, lime, clay etc., to mitigate liquefaction.

The data would be analyzed for understanding the critical parameters that control the liquefaction. The delay in time for liquefaction upon the addition of cementitious admixtures can be studied by conducting Shaking table tests at varied frequency, amplitude and acceleration. The cyclic stress ratios could be determined from cyclic tri-axial tests and it could be used to predict the possible liquefaction in fields.

It is hoped that the results from this work will help in understanding how various factors lead to sand liquefaction during earthquakes. Depending on soil and surface studies, this will also help in predicting the possible liquefaction in fields and other areas in earthquake prone regions.

Prayakar Rao Sukanya (prayakarro.sukanya@gmail.com) is an undergraduate student in the Department of Civil Engineering at NIT Warangal. She is very interested in the field of Geotechnical Engineering. Sukanya is an academic at heart and wants to pursue graduate education in Civil engineering after completing her undergraduate education. The current article is a research proposal that she submitted for SURGE 2009 Program at IIT Kanpur.

WIRED

This is the feedback column of NERD. Various comments, general or article specific, that we receive at nerd@iitk.ac.in or on the website will be published here with occasional replies from the **NERD**. Do send your valuable feedback.

Here are the comments that NERD received for its third issue :

"I really liked this idea of a magazine totally for students by the students. I hope that this initia-

tive will go a long way, but for that we ourselves need to do some work and send stuff that is really new to outer world for publish." **Shoeb Hussain Khan, Aligarh Muslim University**

"I advise the NERD team to manage their budget with more prudence. I know that NERD receives considerable financing as it is a popular initiative, but it is evident from the quality of paper of the latest issue, that the funds are mismanaged."

Anonymous comment on the NERD Website

NERD Replies

The people who fund us wanted us to publish all copies on NERD on the same page quality as the third special issue (90 GSM Gloss). However we wanted to save money and hence we cut down on the paper quality in the first two issues. But since the third issue was special issue and a lot of its copies were to be sent outside, we were asked to publish it on better quality paper. We assure you that the funds are not mismanaged. Spending money on quality is not always mismanagement.

"In hall seven there are over 100 copies kept in mess since 1 month. This was also the fate of many earlier issues. Please reduce the print of nerd by at least 20 %. I appreciate NERD. It is a good venture." **Rahul Verma, Final Year Dual Degree Student, Department of Mechanical Engineering, IIT Kanpur**



NERD Replies

Thank You Rahul. We always take back extra copies after 15 days of release. The left over copies form the part of NERD Archives and help us in publicizing the magazine with Institute Guests and Scientists/Engineers at various other establishments. But yes, based on the number of copies returned from now on, we will cut down on the number of copies published.

"I read [the] Special Issue on Energy and Environment. As I am personally interested in Renewable Energy Field, so I like techniques for making energy efficient buildings. Section having Interview with C.V.R Murthy sir was well designed. It was joyful to read and it worked like mirror of our IIT Education system for me. Overall it was good effort." **Shyam Panjwani, Second Year Undergraduate, Department of Chemical Engineering, IIT Kanpur.**

"Really good effort! I will like to congratulate the NERD team for coming out with flying colors. Some of the articles were really appreciative. I also liked the ingenuity of framing the titles of some of the articles. Keep up the good work. However, presentation of the graphics is quite monotonous for each article, though I like the tone of the language used for explaining the facts." **Rajat Puri, Department of Bio sciences and Bio Engineering, IIT Kanpur.**

NERD Replies

Dear Rajat, Thank You for the encouraging remarks. We have been lagging in presentation of Graphics but with the second Volume of NERD all set to start in August 2009, we are really trying to improve the presentation. As for the NERD Comic strip and similar research related fun, we have actually planned a comic strip featuring the NERD Mascot. We are calling it the Möbius Strip for obvious reasons. Ideas for the same are welcome.

"Excellent initiative but has to be sustained. Scientific debates and ongoing controversies should be covered. This can lead to increase readership.

Quality is nice and needs to be maintained. NERD should not become another journal." **Professor R. Sankararamakrishnan, Department of Bio Sciences and Bio Engineering, IIT Kanpur.**

"I really liked the outlook of this [NERD] magazine. The types of articles were very nice. It is a great effort by the NERD team. Keep up the good work." **Professor Ajai Jain, Department of Computer Science and Engineering, IIT Kanpur.**

"NERD was nicely done and well written. Some articles were very good. There should be separate column depicting the achievements, awards and research works by students and Professors. You should be having some articles on activities that are going to be conducted at some special events like the golden jubilee ceremony of IIT Kanpur. You should involve issues questioning the decreasing participation of students in research related activities." **Professor Bikramjit Basu, Department of Materials and Metallurgical Engineering, IIT Kanpur.**

"I went through the recent issue of NERD and found it to be very well done. Another scientific journal which comes to mind is Resonance, which is published by Indian Academy of Sciences (<http://www.ias.ac.in/resonance/>). I would be glad to see more articles written by IITK faculty/Students (in the spirit of Resonance). Best of luck!" **Professor Anurag Gupta, Department of Mechanical Engineering, IIT Kanpur.**

and the list continues...so will NERD!

Your feedback is important for the improvement of this magazine. Help us by expressing your opinion.

Miscellany

INVITATIONS AND ATTRIBUTIONS

The NERD HERD

Invitations: Call for Articles!

NERD is the scientific and technical research and development magazine run by the students. We publish news on scientific breakthroughs happening in various technical education institutes, research labs et cetera across India and the world with an emphasis on the **work done by students**. So NERD is a magazine of the students, by the students, for everyone. The NERD magazine is first of its kind and we need everyone who is interested in science and technology to be on our team. **Join the NERD Herd!** Yes, you can be the one writing for the magazine. There are a variety of things you can do:

1. Write about the work that you have done or will be doing at your institute as hobby project (write about those robots, will you?), semester projects, internships, B.Tech projects, theses or work presented elsewhere as papers.
2. We even publish articles on failed projects, abandoned research so that people know what led to failure.
3. "I've done work but it's incomplete." No worries! We publish work in any stage of completion—even ideas if they are well supported scientifically.
4. "I am interested in a field but haven't done any work in it." So what! Since you are interested in the field, why not tell about it to others? Who knows, you might get ideas while doing that.
5. Write book reviews for popular science and technology books.
6. Interview professors and eminent scientists doing research.
7. Collect ideas for geeky cartoon strips and send them to us. You can also send illustrations and cartoons.
8. Perform table-top science experiments and pen them down. You could maintain a field diary of your work and publish it with us.
9. Inspire more people to do these activities.

Note that although articles related to science and technology are published, these articles are NOT papers but accurate versions written by students that are more easily understandable to non expert audience.

Visit <http://www.nerdmag.org/faq> for more answers.

For author guidelines visit <http://www.nerdmag.org/resources/authors>

NERD Magazine will release Volume 2 Number 1 in August 2009. Interested people can send in entries for publication on or before July 10, 2009 to nerd@iitk.ac.in. Contact us for query resolution or if you have already written something or contact us just for the sake of it. We will be happy to chat with you.

~¤~

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NERD Artwork was originally created by Prabha Mallya (<http://crabbits.deviantart.com/>)

NERD artwork on back cover by Puneet 'irritant SERD' Singh

Reminiscences: Dr. Rajeev Motwani



Dr. Rajeev Motwani, a prolific researcher in the field of computer science, passed away on June 5, 2009 at the age of 47.

He did his B.Tech from IIT Kanpur, in 1983 and completed his PhD from University of California at Berkeley in 1988. Since then he had been a faculty member at Stanford University. He made seminal contributions in a number of areas pertaining to computer science, complexity theory, randomized algorithms, approximation algorithms, geometric algorithms, data mining to name a few.

He is a co-author of two of arguably the most popular books in computer science namely - Introduction to Automata Theory, Languages and Computation and Randomized Algorithms. The second book revolutionized the field of computer science by introducing a paradigm that demonstrates how a computer program can do wonders when it is allowed to access the outcomes of some random coin tosses. He was also a coauthor of one of the crowning results of computer science called the PCP theorem which proves that any mathematical proof can be written in a way such that one can be almost sure of its correctness by checking at only few places of the proof. In near past he was involved in designing efficient algorithms to interpret and mine large amount of data. Apart from his contributions to computer science, he also was an "angel investor" for many start ups including Google and was a luminary in the Silicon Valley. In fact, the research project of Sergey Brin and Larry Page which would lead to Google was done under his supervision even though officially he wasn't their guide. He was one of the proponents of designing high quality search engines and started Data Mining Projects (MIDAS) at Stanford University. Google founder, Sergey Brin said in his blog post about Rajeev: "...his legacy and personality lives on in the students, projects, and companies he has touched. Today, whenever you use a piece of technology, there is a good chance a little bit of Rajeev Motwani is behind it".

He was awarded Gödel Prize in 2001 for his work on the PCP Theorem. He also received Distinguished Alumnus Award from IIT Kanpur for his seminal contributions to Computer Science.

He is survived by his wife and children.

Do your bit, Save water.

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