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Foreword

Abhinav Prateek

The world has witnessed drastic advancements in science and technology over the past century. These advancements have made our lives comfortable, but we have never tried to subdue the negative impacts of these advancements on nature. We have utilized a major chunk of earth's resources and are in danger of exhausting them in another fifty years. Be it the Neolithic age where we started farming by clearing vast areas of land or the Iron Age where we developed metallic equipment to the current age, we have concentrated on using the resources apathetically without caring about replenishment.

Technology has advanced without our understanding of its consequences. For example, when nuclear technology was in the development stage, no one had even wondered that it could lead to the Chernobyl or the Fukushima disaster, incidents which affected the lives of generations and rendered the areas around them uninhabitable. With the use of chlorofluorocarbons as refrigerants, the concentration of ozone layer has been disturbed to such an extent as to create a gaping hole in it. Similarly, with the advent of automobiles and factories, it was never foreseen that it would lead to a problem of such nature as global warming. And this list only continues. What is important is that we learn from our past and build upon it. While we have indeed made some progress on these lines, we still often overlook the negatives accompanying a new invention.

As students of science and engineering, it is our responsibility to merge our understanding of science with an understanding of society. We need to understand how society will be affected by any new technological development. With the release of the fury of nature, mankind has become more cautious in its approach to technology. Alternate sources of energy, environmental engineering, and recycling are all by-products of this new approach. Environmental Engineering has come up in a big way. A major problem in today's world is the recycling of electronic waste. People have started looking for venues to store carbon dioxide. Frequent plantation drives and many other endeavours have been taken up in accordance.

The concurrence of our dogmas with the changing philosophies of the society is a necessity. We need to gaze the importance of impact of different research and innovation on nature from a very broad perspective. If we foresee that something might become dangerous in future then should the technology undergo change or should its use be strongly discouraged? Take for instance cloning technology. There has been a huge outcry against its use both from ethical and technical perspectives. Its implications haven't been completely understood. Yet, the process is still in use. There are other such technologies where we need to refrain ourselves from using them until an exhaustive research has been accomplished. We cannot proceed ahead with some innovation just to win accolades and put the society at risk.

Contents

Can We Compete With Nature?

"You don't appreciate the complexity of nature until you try to reverse-engineer and recreate it."

Naman Kumar

Fantastically complex technological systems now crisscross Earth, harnessing nanotechnology, biotechnology, information technology, applied cognitive science and, of course, robotics.

Robots really are, in some sense, an attempt to model human abilities; whether they are physical or mental abilities. We think about robots as substitutes for what we can do. Robots are also interesting in what they tell us about ourselves. You don't really understand how complicated a human hand is until you try to build one. You realize how extraordinary things that usually taken for granted really are – for example, natural human abilities – when you go out and try to recreate them. Robots represent our attempts to understand what it means to be human.

We are actually closer to being able to mimic what nature has done (mechanically), because we fundamentally understand it at a much deeper level than we do the concept of intelligence. We understand how most of our body works. Probably the most mysterious object in the known universe is the human brain. Seemingly intelligent artificial systems, such as computers, work very well because their behaviour and environment can be formalized with symbolic representations of what they're dealing with. However, the real world where robots must function is inherently resistant to high levels of symbolic representation due to its overwhelming complexity.

The key is sensory awareness. Humans have evolved to fit into their environment, despite the huge amount of sensory input, by filtering out information they do not need. If we look at the amount of data coming in through all our senses, it is huge: approximately 100 million bits of information report to the brain every second through our visual system and another 10 million bits come in through the auditory system, and another one million bits come in through the tactile system. We are, at any given time, absorbing hundreds of millions of bits of data per second through our senses. Our brain can manage this information overload because our conscious stream is only aware of a very tiny fraction of that sensory input, maybe a few hundred bits per second. Most of our intelligence is really a filtering process. Which of those bits are most relevant at any instant? Our sensory awareness is really much higher than we perceive.

I always look at animals and ask why they are the way they are. Looking at them from the perspective of an engineer and speculating is fascinating process. Recently, a project was proposed and all the robot had to do was to imitate a frog jump. The idea seemed primitive and simple, since I had already worked on robots that can pick up things, follow lines, and even play football. But when I actually started working on it, I could never have imagined the complexities involved. Just making a robot that can be aware of its surroundings was difficult enough. Maybe that is where the root of inhibition lies in our development: The robots we have developed so far are optimized for certain surrounding which are made to favour it. As soon as the robot finds itself in an open surrounding, the sensory data is different that its systems are not able to make heads or tails of it.

Moreover, all this is just the mechanical part, where we have reached a certain level of expertise. We are yet far away to compare robots with humans, or even nature, for that matter.

Leave aside humans or mammals; let us talk about a group of ants or birds. Try to observe a group of birds. In a big flock, their motion appears to be all random, yet two birds never collide with each other. Ever wondered why? Are these birds capable of mapping every bird in the flock and calculate a trajectory for itself to avoid collisions? And then, what else might they have to compute to map the other birds: their speed, direction and what not? One finds it hard to believe that they are capable of performing this feat. Nevertheless, the truth is, they are able to do it, and not through any algorithm or mapping, but through a very simple set of rules they follow blindly. What is that rule? All they do is maintain a specific minimum distance from the nearest bird. Now, try to implement this to a group of 12 small robots kept randomly; they will arrange themselves in a certain defined fashion. There: we have taught discipline to a group of robots.

However, nature is again far more developed than we are. Ever wondered how an ant colony works? Being a kid once, I used to try to follow an ant trail. I used to think that these ants, when crossed each other, would direct each other. Obviously, that is not the case. There is a whole science behind it known as Ant Colony Optimization.

Consider a single ant. As it leaves its colony, it leaves out a trail of pheromones. These pheromones are volatile in nature. As soon the ant finds a food source, it returns to its colony, leaving behind a trail of pheromones on its path. Now imagine a dozen ants scavenging off in an area looking for food. Naturally, in case of one food source, they would all converge onto it following different paths. Here, the volatile nature of pheromones comes into play. The strength of pheromones would be least on the path that takes maximum time, and highest on the shortest path. Slowly, more and more ants will also follow the shorter paths leaving behind a trail of their own which adds up to the strength of the previous trail. Eventually, the shortest path will be the only one remaining.

Now, for us to replicate this in robots, of course, we need a considerable number of robots, and pheromones could be a memory function guided by a master system that improves on itself and finds the shortest way out.

Take a cheetah for an instance: it is well known as the fastest animal on earth. The Pentagon recently developed a four-legged dog-like robot. Just take a wild guess at what its maximum speed would be. It is approximately 1 m/s. So have we beaten nature when its fastest creation can run 40 times faster than that?

A recent theory suggested that, for legged animals, number of joints directly correspond to the speed of the animal. That is why cockroaches and spiders are so quick. A cheetah on the other hand has a very flexible backbone and thus while running, every joints' power adds up to its thrust.

The spherical Jollbot, designed by Rhodri Armour, a Ph. D. candidate in mechanical engineering at the University of Bath in England, does not resemble a grasshopper, but it owes its ability to jump to these tiny creatures. Insects do not have the muscle action to hop like kangaroos, so they store energy like a compressed spring and release it suddenly to leap. Likewise, when the flexible Jollbot is flattened and then released, it bounds upward roughly 20 in (50 cm) into the air.

Jollbot is an example of a biomimetic machine—one that borrows ideas from nature as inspiration for its appearance, behaviour and physical mechanisms. Biomimicry, or biomimetic design, is nothing new (think: Leonardo da Vinci's gliders based on bird wings). But engineers and roboticists are now "proactively looking toward nature for solutions to specific engineering issues," says Jollbot's designer, Rhodri Armour

Over the past decade, biomimicry design has thrived. Biologists have better tool, such as advanced microscopy for viewing things on the scale of thousandths of nanometer, that allow them to learn more about animals and their physical mechanisms.

In 2003 the Defence Advanced Research Projects Agency (DARPA), the Pentagon's advanced research arm, spent several million dollars to commission the building of a robot that could climb walls for surveillance purposes. The result was Spinybot, which could ascend rough surfaces like trees and cement walls with the aid of micro claws tipped with tiny spines, a mechanism borrowed from insects such as cockroaches. Stickybot, which debuted in 2006 and walks up smooth surfaces such as windows, uses an adhesive inspired by geckos. On their feet, the lizards have millions of setae—hairs with split ends—that use intermolecular forces to accomplish "directional adhesion": If their setae encounter a surface moving in one direction, they adhere; when going the opposite direction, they peel off. It is like Scotch tape that you do not have to press down to stick it.

Engineers noted that their climbing robots fell of walls if they did not have a tail. They thought geckos never use their tail, but it turns out they do. The rear appendage helps the reptiles stabilize themselves and keep their heads from moving back, causing them to fall head over tail to the ground.

From bird flocks to fish schools, animals move together and respond to their environment in remarkable ways; their natural collective motion patterns appear well choreographed and their collective survival strategies seem ingenious. Animal group behaviours inspire design for mobile multi-agent robotic systems, where demanding cooperative sensing tasks, such as exploration and sampling in an uncertain and dynamic environment, find their analogue in natural aggregation behaviours, such as foraging and feeding. However, bio-inspiration of this kind is not transparent, since the natural "design" mechanisms are not well understood. The joint challenge is to explain the enabling mechanisms in animal groups and to define provable mechanisms for robotic groups. This suggests an integrated approach: formal bio-inspired models and analysis tools derived to synthesize collective robotic motion and exploration can be used to evaluate design hypotheses for animal groups; subsequent revelations from the biology will in turn inspire new approaches for robotic systems.

Biomechanical Control of Locomotion in SNAKES

Farid Ahsan

Most animals, whether unicellular or more complex, can move to satisfy their needs. The control of locomotion can be understood at many different levels. The general principles are explainable in terms of central programs and reflex interaction, but a deeper understanding requires that a variety of information be considered. This should include pure biomechanics and nerve membrane properties, the interaction of different types of identified neurons, organisational principles within the nervous system, and adaptive behaviour.

The human step consists of an active phase, in which the limb provides support and a small propulsive force, and a reset period (swing phase), during which the limb is initially flexed and moved forward (flexion phase) and subsequently extended and brought into contact with the ground (first extension phase). As the speed of locomotion increases, the duration of the support phase decreases markedly; also the swing phase shortens, but only to a very limited degree. The amplitude of the limb movement during each step may change—in humans it may even double with increasing speed. The electromyographical (difference in electric potential developed in muscles due to their movements) output patterns of different species are similar with regard to both limb and trunk muscles. The movements result from interplay between active and passive mechanical factors.

The tetrapod inter-limb coordination can be divided into alternating (walk, pace, and trot) and non-alternating (gallop, half bound, and leaping) gaits. Animals preferentially use different gaits at different velocities, but a certain type of gait is not directly linked to a certain speed. For example, a horse may pace or trot at the same speed and even gallop at normal walking speed. Humans use two distinctly different alternating gaits: walking and running. Not only does control of the foot (ankle) differ between these gaits, but also movement of the entire limb is different.

Fishes use undulatory waves that travel down the body to achieve propulsive force. Newts and reptiles also use lateral body waves during propulsion, but they may be of the standing-wave type. Many mammals use extensive dorsoventral movements of the spine during high-speed gallop. Humans use torsional movements along the longitudinal axis (for eg. the sprint of a leopard is accompanied by a crouch, to streamline its body). Nevertheless the pattern of electromyographical activity in the walking cat and human is similar.

Biological snakes supposedly lost their limbs to move effectively in cluttered and highly convoluted environments such as underground chasms and in and between cracks and crevices. However, when snakes returned to the surface with open flat terrains, they developed new modes of locomotion without the need to re-grow legs. Snakes exhibit four main modes of locomotion:

Lateral Undulation

Fish move forward by shaping their bodies in an “S-shaped” curve that travels tail wards. Almost all limbless vertebrates, including snakes, mimic their ancestors by using this kind of locomotion for traversing the ground, however they have to induce higher torques and forces in order to deal with the loss of buoyancy in water. Snakes propel themselves on the ground by summing the longitudinal resultants of asymmetric friction forces exerted by the hindquarters of snakes. Biologists do not agree on the energetic cost of snakes using lateral undulation. Some scientists claim that lateral undulation requires half the metabolic cost compared to tetra-pod of equivalent mass, while others claim that energetic cost is comparable between undulating snakes and locomoting tetra-pods of the same size and mass.

Concertina

The movement occurring in snakes and other legless organisms that consists of gripping or anchoring with portions of the body while pulling/

pushing other sections in the direction of movement. Each point on the snake's body goes through alternating cycles of static contact and movement, with regions propagating posteriorly (i.e. any point on the snake will change from movement to stasis or vice-versa shortly after the change occurs in the point anterior to it). This movement is quite strenuous and slow compared to other methods of locomotion. Energetic studies show that it takes more calories per meter to use concertina locomotion than either side winding or lateral undulation. The prime exponents are 'tree snakes', like Imantodes and Indian Bargati that make use of this technique to move from branch to branch.

Rectilinear Progression

The slowest mode of snake locomotion is rectilinear, which is also the only one where the snake does not need to bend its body laterally, though it may do so when turning. In this mode, the belly scales are lifted and pulled forward before being placed down and the body pulled over them. Waves of movement and stasis pass posteriorly, resulting in a series of ripples in the skin. The ribs of the snake do not move in this mode of locomotion and this method is most often used by large Pythons and Vipers when stalking prey across open ground as snake's movements are subtle and harder to detect by their prey in this manner.

Side Winding

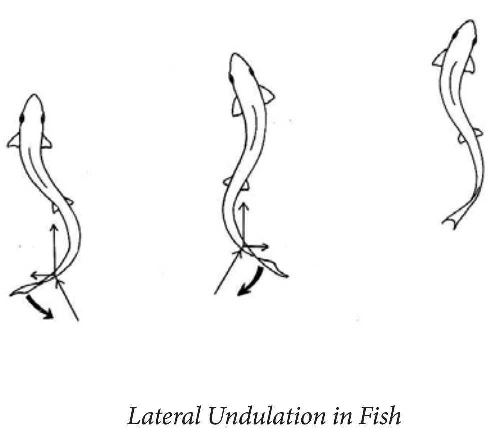
This mode of locomotion is a special case of concertina using static friction, but was previously believed to be a form of lateral undulation. At any given instant, at least two portions of the snake are in static contact with the ground. The rest of the snake body is lifted and moves forward. The snake uses small irregularities in the surface against which it pushes sideways. Side winding conserves momentum and is claimed to be the most efficient mode of locomotion. All the mid-sized snakes are capable of side winding and many will do a crude version of it if pressed, but only the truly desert species like Crotalus cerastes, Candoia aspera and some more rather short bodies snakes are truly proficient at it.

Mentioned above is a description of classical snake locomotion modes in their usual habitats. In this project, we have taken a biomimetic approach in which we looked at biology for inspiration, but not as a blueprint, for designing locomotion algorithms. The goal here is to identify the fundamental principles that describe the snakes' motion and how they switch from one locomotion mode to another. Observing the snakes' behaviours motivated engineering advancement in developing our locomotion algorithm.

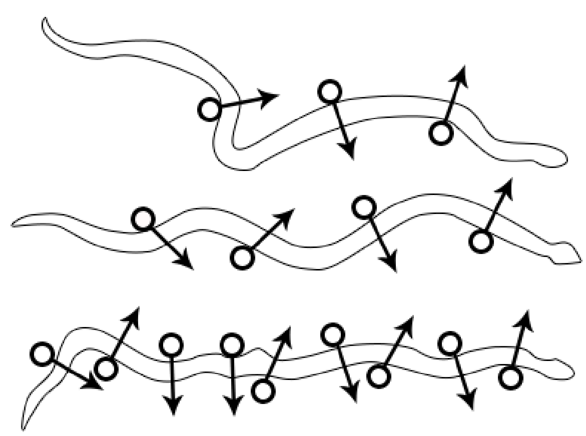
Modular Design of Snake-Like Robots

Many factors such as size, power, and weight constrain the design of modular snake robots. Meeting these constraints requires implementing a complex mechanical and electrical architecture. Here, we present our solution, which involves the construction of six aluminium modules and adding such components as sensors to monitor current and temperature, a communications bus, and a programmable micro controller. Any robust solution must also protect components from hazardous environments such as sand and brush. To resolve this problem we insert the robots into skins that cover their surface. Functions such as climbing the inside and outside of a pipe add a new dimension of interaction. Thus we attach a compliant, high-friction material to every module, which assists in tasks that require gripping. This combination of the mechanical and electrical architectures results in a robust and versatile robot.

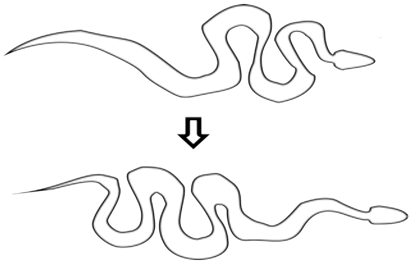
Snake robots are a class of hyper-redundant mechanisms that locomote through internal shape changes. Snake robots' unique shape and ability to



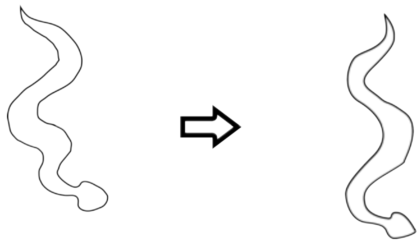
Lateral Undulation in Fish



Lateral Undulation in Snakes



Concertina Motion



Side Winding Motion

Rectilinear Motion

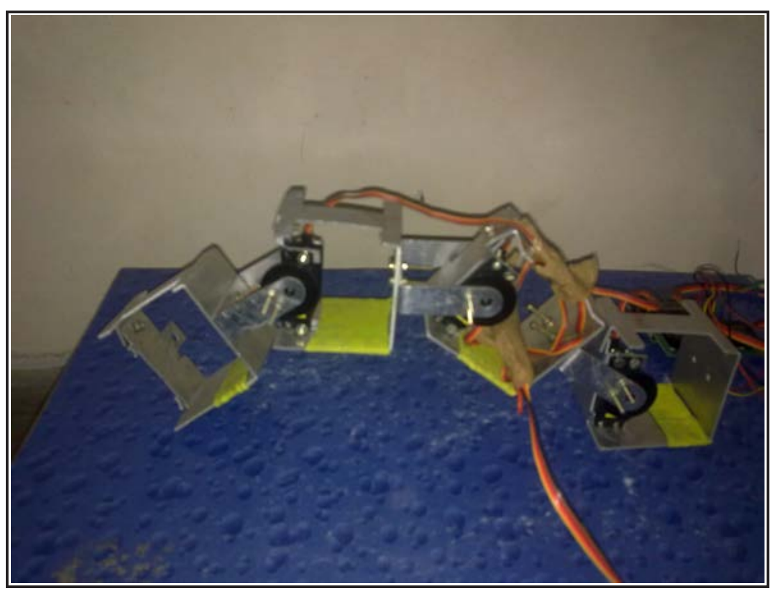
navigate highly variable environments, make them suitable for urban search and rescue missions. There are also various military uses. However, only strong, well-designed, and reliable robots will be useful for these tasks. We have designed a modular architecture that allows for both a wide range of gaits and resilience to failures. This architecture incorporates a well-refined mechanical design coupled with advanced electronics and software.

We had two motives for beginning biomechanical research on the movement of snakes. The first motive was that, up until that time, the fundamental problem of "How is it that a snake can go forward without legs?" largely remained unanswered, and this required an engineering analysis. The second motive grew from the expectation that a "snake-like robot", which would be modelled on a snake, would have a particularly broad functionality while maintaining a simple shape. The future possibilities of serpent robots can be anticipated from the fact, that the body of a snake, which has the simple form of a rope, functions as "legs" when moving, as "arms" when traversing branches, and as "fingers" when grasping something. So, it acts as an actuator, a locomotor and a manipulator at the same time.

On the evening of December 26, 1972, for the first time in the world Dr. Shigo Hirose of Fukushima Labs, Japan succeeded in producing artificial serpentine movement at a speed of approximately 40 cm/s using the principles of a serpentine movement that is the same as actual snakes. The entire length of the device was 2 m, and it had 20 joints. Each joint consists of servomechanisms that can bend to the left and right. To make contact with the ground, casters were installed along the direction of the body, and characteristics were added that make it easy to slide in the direction of the torso and difficult to slide in the normal direction. The propulsion motion was conducted by inputting command values, which impart sinusoidal bending motions to the head joint servomechanism, and that bending signal was shifted at a fixed speed to the following joint servomechanisms. When this is done, the body as a whole begins to move by sending a wave to the rear, but in order for the torso to slide over the floor surface with the casters, all of the torso joints produced a serpentine movement like the flow of water that trace the same loci. This principal of propulsion corresponds to the swimming motion of eel. They were also successful with experiments in slalom motion between poles set up in an open space.

The snake-bot that we at IIT Kanpur have made mimics horizontal undulatory progression gait of a snake, with implementation for vertical centipede-like motion using modular servomechanisms and based on a central control, and was completely fabricated using reverse engineering keeping Hirose's model as the benchmark.

Source: Sensor Based Planning Laboratory, Carnegie Mellon University



Snake Robot Engineered at IIT Kanpur

Commutators and the Rubik's Cube

Going Beyond Algorithms

Nikhil Pangarkar

The Rubik's cube has been a mystery for countless people around the world. Invented in 1974 by Erno Rubik, a sculptor and a professor of architecture, it is considered as one of the most popular toys around the world. Although it is widely reported that the cube was designed as a teaching tool to help his students understand three dimensional objects, his actual purpose was to solve the structural problem of moving the individual cubes independently without causing the entire mechanism to fall apart. He did not realize that what he had created, a cube with scrambled colours, would become a worldwide phenomenon.

The Rubik's cube is a fine blend of two contrasting features: simplicity & complexity. The different types of movements that can be performed on the cube are very less owing to its structural simplicity. However, these small set of movements can give rise to many possible configurations of the cube. To be precise, the number of movements that can be performed is only six, whereas the possible configurations are 43,252,003,274,489,856,000 - that too without disassembling the cube.

In spite of its inherent complexity, the world record for the fastest complete solve of a Rubik's cube is just 5.66 seconds. "Speedcubing" is fast gaining popularity around the world as a mind-sport and as a hobby. Speedcubers, as they call themselves, usually use a solution called the Fridrich method that involves memorization. In recent years, many different kinds of puzzles have emerged which are more complex nevertheless, they all have the same underlying concept as the Rubik's cube.

This article introduces an intuitive approach towards solving the Rubik's cube without memorization.

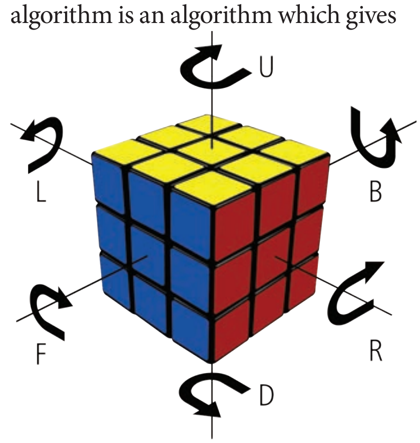
To make matters simpler, this article shall use a notation for the cube that is a standard and is widely accepted. The cube is composed of three layers – the top layer, the middle layer and the bottom layer. The basic method of solving the cube, that is, bringing all the same-coloured faces onto the same plane, is to approach the problem in a layer-by-layer fashion. Solving the first two layers is intuitive and easy, whereas solving the third layer requires the application of certain algorithms. These algorithms are sequences of cube rotations. As mentioned earlier, there are six possible rotations. These rotations are {F, B, R, L, U, D}. Each symbol represents a clockwise rotation of 90° of Front, Back, Right, Left, Up/Top and Down face respectively.

R2 means rotating R face twice and R' means rotating R face anti-clockwise. For example, you can try and see that applying the sequence R2URUR'U'R'U'R'UR' onto a cube cycles three edge pieces of the top layer.

A common question is whether there exists an intuitive method to derive these algorithms.

The answer is commutators: a mathematical concept from the field of permutations and combinations. This concept, though tricky to understand, is an intuitive approach towards solving the cube rather than memorising a set of algorithms. It also helps to gain an in-depth understanding of the mathematics behind the Rubik's cube. Commutators can also be used to solve other puzzles which have properties similar to those of the Rubik's cube.

Before introducing commutators, let us bring to the fore another property of the Rubik's cube: the inverse of an algorithm is an algorithm which gives



back the original cube, and is the same sequence of moves in a reverse order, with each move being converted to its own inverse. For example, the inverse of R U D' is D U' R'. If

$$P = RUD'$$

The inverse of P is expressed as

$$P^{-1} = DU'R'$$

Notice that executing PP^{-1} on a solved cube will result in a solved cube: P^{-1} will undo the moves of P.

If P and Q are algorithms, the commutator of P and Q is $PQP^{-1}Q^{-1}$. Therefore, you first execute P, then execute Q, then 'undo' P and then finally 'undo' Q. This means that you can make an unlimited number of commutators. Of course, most of these commutators are not quite useful in solving a puzzle. To find useful commutators, let us first look at permutations.

Take a solved Rubik's cube and apply the following algorithm

$$P = (RBLF).(U).(F'L'B'R').(U')$$

Which results in a three-cycle. A three-cycle is an algorithm that cycles three pieces of the cube. If the positions of the pieces are labelled with numbers, P can be expressed as:

$$P = (1\ 2\ 3)$$

Which means that the piece in position 1 goes to position 2, the piece in position 2 goes to position 3 and the piece in position 3 goes to position 1. Notice that (1 2 3) means the same as (2 3 1) or (3 1 2).

Now, suppose

$$Q = (3\ 4\ 5)$$

Which results in another three-cycle. Now, what would PQ result in?

$$PQ = (1\ 2\ 3).(3\ 4\ 5) = (1\ 2\ 4\ 5\ 3)$$

The result is a five-cycle.

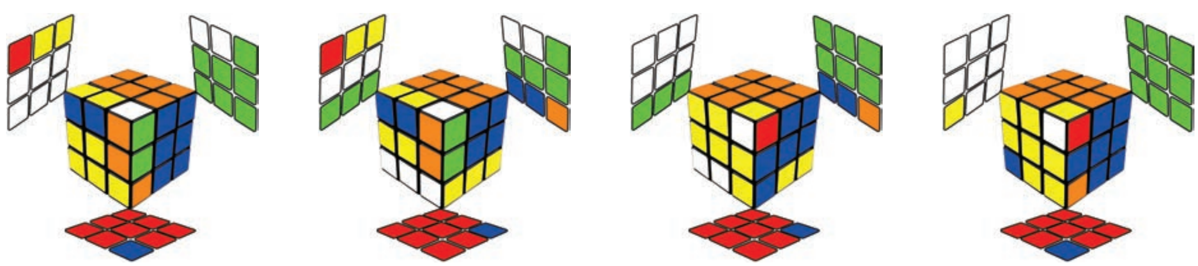
A few more examples of calculations with permutations:

$$(1\ 2).(2\ 3) = (1\ 3\ 2) = (3\ 2\ 1)$$

$$(1\ 2\ 3).(3\ 2\ 5).(6\ 1\ 3) = (1\ 5\ 6)$$

$$(1\ 2\ 3\ 4\ 5).(5\ 4\ 3\ 2\ 1) = (1\ 2\ 3\ 4\ 5).(1\ 2\ 3\ 4\ 5)^{-1} = (1) = id$$

Where *id* stands for the identity permutation that does not change the state of the cube.



P = RUR'   Q = D P^{-1} = RU'R' Q^{-1} = D'

Let us look closer at one of the examples from above:

$$(1\ 2\ 3).(3\ 2\ 5).(6\ 1\ 3)$$

Applying the first cycle on the cube:

1 ->2 (piece at position 1 goes to position 2, etc.), 2 -> 3 and 3 -> 1.

Now apply the second cycle i.e. (3 2 5) on this but apply them on the right hand side of each equation (why?). Therefore, the new 3 goes to 2, the new 2 goes to 5, and the 5 goes to 3:

1 -> 2 -> 5, 2 -> 3 ->2, 3 -> 1, 5 -> 3

After applying the two cycles, the net effect is: 1 goes to position 5 (via 2), 2 goes to 2 (via 3) and thus remains unchanged, 3 goes to 1 and 5 goes to 3. Finally apply the last cycle (6 1 3):

1 -> 2 -> 5, 2 -> 3 ->2, 3 -> 1 -> 3, 5 -> 3 -> 6, 6 -> 1

Hence, the net effect is 1->5, 5->6 and finally 6-> 1 thus completing the 3 cycle. Positions 2 and 3 change to some other intermediate positions, but eventually move back to their original positions.

Take two algorithms P and Q whose results are

$$P = (1\ 2\ 3)$$

And

$$Q = (4\ 5\ 6)$$

In this case, the cycles of P and Q are disjoint, and therefore, PQ will have the same effect as QP. Also, if PQ = QP, it can be shown that the commutator of P and Q is the identity (id):

$$PQP^{-1}Q^{-1} = QPP^{-1}Q^{-1} \text{ (since } PQ = QP)$$

$$QPP^{-1}Q^{-1} = QQ^{-1} = id$$

If the commutator of P and Q is the identity, P and Q are said to commute, which is equivalent to saying that PQ = QP.

On a puzzle, this means that executing PQP-1Q-1 on the solved puzzle will result in the solved puzzle again. You can probably see that this also works for P = (1 2 3 4 5 6 7 8 9) and Q = (10 11 12 13 14 15 16 17 18); again, because these cycles are completely disjoint.

What happens if P and Q have only one number in common? For example,

$$P = (1\ 2\ 3\ 4\ 5\ 6\ 7\ 8\ 9)$$

$$Q = (9\ 10\ 11\ 12\ 13\ 14\ 15\ 16\ 17)$$

In this case:

$$PQP^{-1}Q^{-1} =$$

$$(1\ 2\ 3\ 4\ 5\ 6\ 7\ 8\ 9).$$

$$(9\ 10\ 11\ 12\ 13\ 14\ 15\ 16\ 17).$$

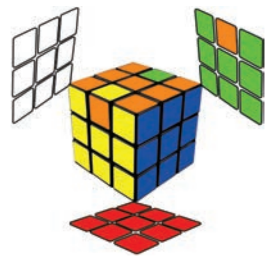
$$(9\ 8\ 7\ 6\ 5\ 4\ 3\ 2\ 1).$$

$$(17\ 16\ 15\ 14\ 13\ 12\ 11\ 10\ 9)$$

It is easy to check that nothing happens to most numbers. $PQP^{-1}Q^{-1}$ "almost commute", and almost result in the identity, but not quite: a small number of pieces, exactly 3 of them, will not fall back in place. In this case

$$PQP^{-1}Q^{-1} = (9\ 17\ 8)$$

In general, if the cycles of P and Q


M’ Move

have only one number in common, the commutator of P and Q will be a three-cycle.

Cycling Three Pieces on the Cube

A Rubik’s cube will help in understanding this section, preferably a solved one. The move RUR’ inserts a corner piece from the U layer into the D layer. If the result of one of these moves is expressed in the cycle notation, the DRF (corner piece common to the down, right and front face of the cube) piece will be one of the pieces. Also, notice that the DRF piece is the only piece in the D layer that is changed by RUR’. This means that if

P = RUR’

And

Q = D

Then the cycles of P and Q will have only one piece in common: the DRF piece. This means that if we build a commutator with P and Q, the result must be a three-cycle of corners.

Thus,

$PQP^{-1}Q^{-1}$ = RUR’DRU’R’D’

It is also possible to take

P = RU2R’ or P = RU’R’

And

Q = D2 or Q =D’

To create different three-cycles. Another example is:

P = FDF’, Q = U

To summarize: if the positions that two algorithms P and Q permute have only one position in common, then the commutator of P and Q is a three-cycle.

Setup Moves

This section demonstrates how to use basic eight-move three-cycles to solve any random three-cycle of corners of the cube. Some three-cycles cannot be solved in eight moves, in which case a few ‘setup moves’ are necessary. If an algorithm is known to solve a particular problem, the same algorithm can be used in combination with some extra moves to solve another version of that same problem. For example, the algorithm to flip two edges can be used to flip two other edges:

M’U M’U M’U M’U2 M’U M’U M’U

M’ -> (R’F’).(M’U M’U M’U M’U2 M’U M’U M’U M’).(FR)

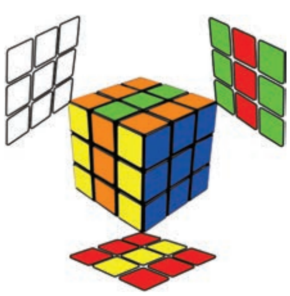
Using these basic three-cycles in combination with some setup moves, one can solve nearly any three-cycle of corners in 10 moves or less, the maximum being 12 moves. In order to do this, it is useful to recognize the applicable situations from other angles, as well as practice solving the algorithm from different angles.

The above method can be summarized as:

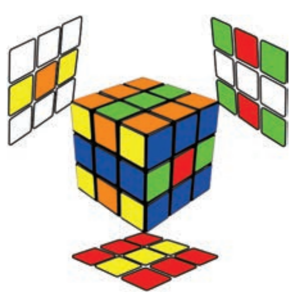
(set-up move).(commutator).(reverse of the set-up move)

This simple equation can be used to create a three-cycle of any three pieces given the knowledge of some commutators.

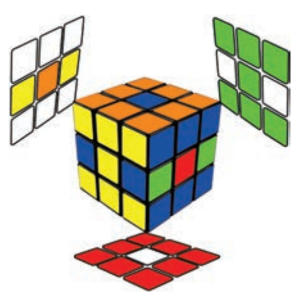
To sign off, what follows is an example to illustrate the beauty of commutators: MEM’E’ (M denotes the middle layer and E denotes the equatorial layer).



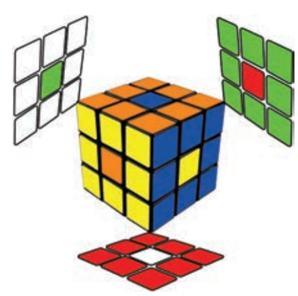
M



E



M’



E’

India's First In-House Planetarium

Vijin Venu

Being inside a planetarium and closer to the heavens is a memorable experience, like watching the clearest of skies. However, dust and terrestrial lights from cities have made clear skies rarer than a blue moon. A group of freshman and sophomore astronomy enthusiasts from the Indian Institute of Technology have come together to provide a unique solution to this problem: a low-cost in-house planetarium

designed and built entirely by students. With nothing but willpower and the mentorship of their seniors, these students have achieved a remarkable feat; one that is in the process of going down in the record books for being India's only such endeavour.

What is a Planetarium?

A planetarium is a room which has a large spherical dome to facilitate spherical projection which can showcase the animated night sky and the wonders of the cosmos. Archimedes is said to have built the first such system which was a primitive planetarium that could describe the motion of the sun and other planets visible from the earth. The planetarium was said, according to Cicero, to be an extraordinary set up that, at each rotation, showed the Moon rise after the Sun above the immobile Earth, the eclipses of Moon and Sun at proper time intervals, as well as the motions of the other five known planets: Mercury, Venus, Mars, Jupiter and Saturn. Unfortunately, no detailed description exists of the mechanisms that animated Archimedes' planetarium.

The first modern planetarium was designed by Dr. Walther Bauersfeld and constructed by Carl Zeiss company for the Deutsches Museum, Munich. The planetarium, also called the Zeiss 1, is considered as the first geodesic dome derived from an icosahedron, designed 20 years before Buckminster Fuller reinvented and popularized this design. It consists of a single sphere studded with projection lenses supported above a large, angled cage.

Modern Planetariums are mostly automated and require spherical projectors and a variety of audio-visual equipment. The SOS or Science on a Sphere projection system is one such example. It has a spherical screen which neither moves, nor has any electric parts. The projection system consists of four perfectly synchronized video projectors kept at ninety degrees to each other to cover the whole screen.

Unlike these systems, an in-house planetarium is a small scale planetarium, built inside a hall which can accommodate at most 20 people. It uses a mirror projector system consisting of a single mirror and a projector for

Skeleton Structure of the Planetarium

projecting over a curved surface, such as the one inside a spherical dome, and can project a variety of images on the screen.

Why a Planetarium?

Perhaps the best reason to construct a planetarium was to teach the celestial navigation. In a location such as Kanpur, this cannot be achieved through direct observation since only prominent objects are visible in the night sky due to excessive atmospheric pollution and terrestrial light from all around. To make matters worse, skies tend to be cloudy throughout the year. A planetarium can also provide a space to bring together a bunch of enthusiasts who can enjoy a guided journey of exploration through the vast cosmos in which we all belong. The scientific world is collecting information about our universe faster than ever. However, the general public is remains ignorant about even the basic facts of astronomy and astrophysics. A planetarium would kindle the enthusiasm in people towards the celestial sciences.

The Design

The proposed structure for the planetarium was that of a geodesic design, one that is not popular in India. It is the best possible option for the construction of the dome and highly preferred over all other models for the spherical dome. A geodesic model can be understood as the model of a football that has triangles as its basic building blocks. This model can be easily understood from a football if one could join the edges of all the pentagons and hexagons to their corresponding centres.

Since the geodesic model is widely used in many countries for construction purposes, such as greenhouses, etc., construction kits are readily available in the international market. However, this drives up the cost prohibitively. Consequently, a conscious decision was made to forego any professional help and have all the construction tasks executed by students themselves. The downside of this decision, however, is the increased probability of error in the construction process due to unskilled labour.

The construction location was finalized to one of the large, empty rooms in the Student Activity Centre at IIT Kanpur. The diameter of the dome was restricted to 24 feet: the construction site would not allow anything larger than a dome of 24 feet diameter. Additionally, raw materials for larger bigger sizes were not available in the market, which restricted the design to a maximum of 28 feet diameter.

Construction of the Dome

In the construction of any large structure, an important consideration is the material used to construct the skeleton of the structure. With little idea of how to achieve the proper load distribution that would not cause the dome to collapse on itself, a hit and trial method was employed to select the materials for construction. Plywood rods were the first choice. On completion of a part of the dome, however, it was quickly realized that plywood rods could not create a stable structure, since their strength was insufficient to hold the weight of the entire structure and would cause a structural collapse, regardless of whether the rods were reinforced. The next choice were metals, such as aluminium, but were quickly ruled out due to cost and difficulty in constructing the dome. Finally, PVC pipes were the material of choice. They were ideal for a number of reasons: they were cheap, light and strong enough to hold a structure 24 feet in diameter intact.

The 3V geodesic model (a particular type of geodesic model) demands three different types of hubs to connect the pipes together. However, since these are not available in India, they were designed by the students themselves using the cheapest material available for it in the market: plywood. The hubs provide proper inclination for the connection angle with respect to the vertical, and thus, for the perfect dome, the error margin in the angle construction is very small. An indigenous process was developed to manufacture the hubs from plywood. The hubs were named as Green, Red and RGB. Each hub is a pyramid consisting of different types of bases. The Green hub has a regular hexagon as its base; the Red hub has a regular pentagon; while the RGB hub has an irregular hexagonal base. PVC pipes of lengths specific to the position in the dome were cut and joined to these hubs using screws to obtain triangles which acted as the building blocks for the dome.

The dome is not exactly hemispherical; rather, it is 5/8th of a sphere. This is a restriction imposed by the design, additionally, the extra space allows for proper ventilation and raising the diametric plane of the dome above the audience. Starting from the base, triangles were constructed layer by layer all the while maintaining a proper angle with the vertical by properly joining pipes to the hubs. The completed spherical dome consists of 61 connection hubs and 160 connecting rods.

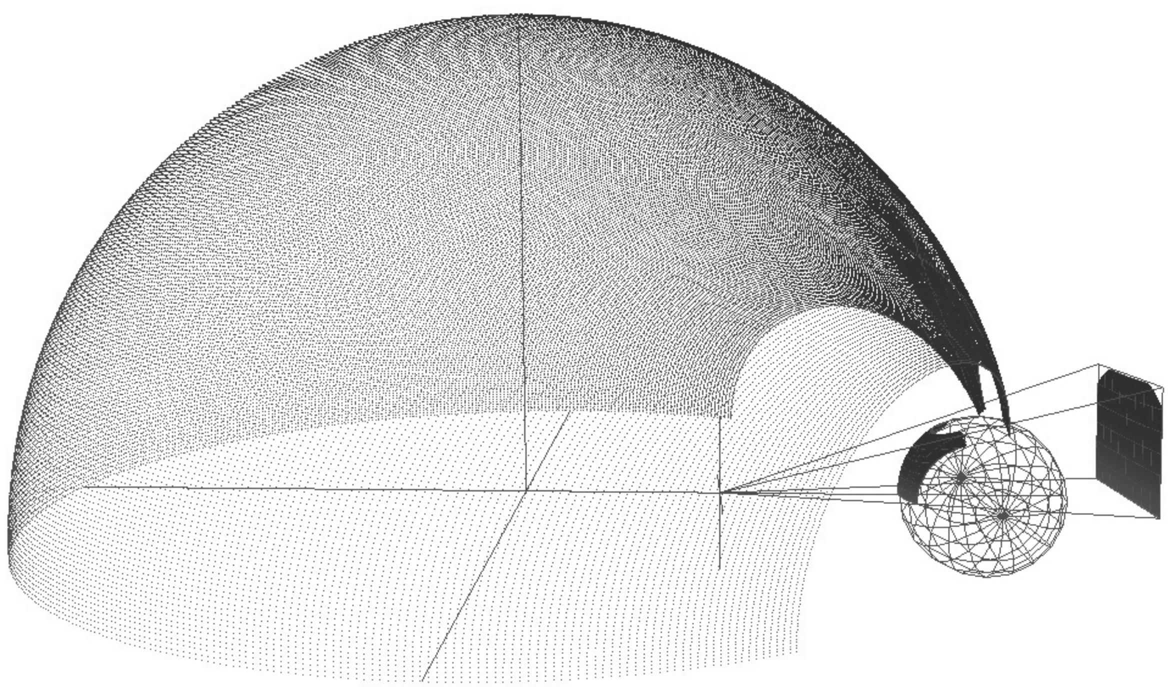
Covering the Geodesic Dome

Once the skeleton is completed, it needs to be covered with a surface for projection, ideally a cloth surface. The cloth should be opaque enough not to allow the projected light to go out of the dome. It should be non-shining and light. Most importantly, it should be wrinkle free for better projection. The colour of the cloth should be such that it clearly shows the contrast of a night sky or of other images. In order that the various pictures of nebulae, supernovae can be clearly seen, the cloth should not be of some dark material which reflects majorly its own light.

Contrary to many people's initial thoughts, an even white surface is not the best surface material. A white surface will cause multiple reflection of the light within the dome. A reflectivity of 50 % for the dome surface is considered to be ideal according to Paul Bourke's models for Planetarium. Modern planetariums use double sided Lycra for the projection screen. However, Lycra proved to be an expensive option and impractical option due to the weight of Lycra. Instead, different samples of the cloth available in the local market were tested against the proposed projection mechanism. Various colours were separately projected onto the cloth to measure the fidelity of the projection to the original image. A sky-blue coloured cloth proved to be the best for this purpose.

Considering the minor irregularities present in the dome, it was decided to make triangular sections of cloths with laces to fit the cells by tying it to the connecting rods, rather than rolling the cloth around the dome since it prevented any extra load on the dome. Also this method ensured uniformity, minimum usage of cloth, and thus minimum weight. The laces allowed for minimum wrinkles on the surface, since they could stretch to fit the contours of the skeleton.

The room needed to be completely free of any unwanted light source from outside that would interfere with the image projected within the planetarium. For this purpose the entire room was covered from inside with black paper. A light source from outside would, otherwise, illuminate and sketch an outline of the skeleton on the inside surface of the dome. Finally, an ordinary bulb was lighted inside



Spherical Mirror Projection System

to check for any irregularities in the dome surface. In an attempt to make the screen wrinkle free, the triangular cloth sections were manually stitched together, which would also help in making the dome completely lightproof. A laser pointer was used to check for irregularities in the seams: any distortion in the projection of the beam on the surface would indicate a potential distortion of the final image.

The Projection System

One of the simple methods of projecting over a spherical dome is the pinhole projector. A pinhole projector consists of a bright light source completely covered, except for tiny pinholes (hence the name) that let light through to project stars on the surface. Such a projector, however, is too primitive since it allows only for static images. It also requires a point light source, which works well only for smaller domes. If a filament bulb is used as the light source, each star in the projected image would be in the shape of the filament. Hence, the pinhole projector was deemed unsuitable.

A mirror projector system was preferred over the expensive spherical projection system. This system consists of a normal projector and a convex mirror. This idea is inspired from Paul Bourke's method of spherical projection: a projection over almost the entire surface of the dome is achieved by placing the mirror projection system at the rim of the spherical dome. This allows light from the projector to fall on the surface of the mirror and reflect onto the surface. To prevent obtaining a blurred image caused by multiple reflections within the mirror, it needs to be silvered on the outer surface. For the usual projection, less than half of the spherical portion of the mirror is sufficient. Since most of the projected images are meant for directional viewing, 100% coverage of the dome with the projected image is not possible.

Projection Content

Since the projector is meant to project images on flat surfaces, the image projected on the spherical screen will have an inherent distortion. Therefore, the content for the spherical projection must be created separately, or the available content should be modified to compensate for this distortion. The normal content should be at some stage of projection represented as a fish-eye image. A fish-eye image is a curved hemispherical image derived from the normal broad view or a photograph. This transformation is necessary: normal content cannot be directly used with a mirror projection system. The spherical mirror projection requires a precise calibration in order to create undistorted projections. This requires the exact position of the components, the optics of the mirror, and the size of dome and the mirror. The technique used for correcting is called warping. Since the aim of this project was to build a cost effective planetarium, the content was obtained from the open source software "Stellarium". Even though the content is not modified, it was enough to satisfy the need of observing the night sky. Efforts are under way to modify the software to support a warped output, so that an undistorted image is obtained on the dome.

Future Prospects

A lot of scope remains in improving the existing planetarium. A higher quality mirror would drastically improve the sharpness and colour of the projected images. Upon completion of the warping software, movies and documentaries can be projected onto the dome too. Taking this idea ahead, 3D images can also be projected. Finally, the projection system can be automated to reduce manual error.

One of the dream projects is to build a simulator. The planetarium's curved screen can provide a 3 dimensional view as if a person inside the planetarium is a part of it. The view would be controlled by a joystick Used computer-generated images, virtual worlds of all kinds can be projected - from the microscopic scale to galactic size universes. Using various software, it would be possible to mimic the topography of the red planet to make the audience feel as if they themselves are present on the red planet.

Background image: Stellarium

Hexapod

Anurag Singhal
Atulya Shivamshree
Varun Bhatt
Rajkumar Singh
Vikas Kumar Singh

A hexapod is a unique class of limbed robots. It is used for a variety of purposes, primarily related to research. The inspirations of this design are six-legged insects categorized by the class hexapoda (Greek). Commonly known members of this class include spiders, cockroaches, crickets and grasshoppers, ants, and beetles. Hexapod robots largely mimic hexapoda locomotion. Some robots are designed with the aim of better understanding how insects in this group function from a biological standpoint, while others are created as a means of channelling the efficiency of these creatures' movements into a medium that can be manipulated.

What is a hexapod?

As evident the above description, a hexapod is six-legged robot. Each leg has three joints and hence, three degrees of freedom. In total, it has six legs and summing up, the hexapod has eighteen degrees of freedom allowing it to mirror most of possible movements in 3D. Hence, it can perform various complex steps such as crawling and walking by synchronizing all six legs and eighteen joints. It can be considered to mimic a spider, but with six legs. The body frame and locomotion style of the hexapod is completely inspired from spiders. Like spiders, the hexapod synchronizes the motion of all its legs and moves or walks accordingly. The joints of the hexapod are made of servo motors. Servo motors can generally rotate between 0 to 180 degrees as per the requirement with constant rate up to a specified tolerance of external torque. They control the phi, theta and delta of the particular leg: the three axes of movement.

The six-legged structure is one of the most stable and robust structures as is exemplified by various terrains that are nonnavigable by wheeled robots but are can be easily traversed by legged systems. The most efficient use of the hexapod can be in rocky or sandy terrain where wheels tend to get stuck and so, the legged structure can be a good alternative. Even in legged robots, hexapods prove to be the best choice because they can easily stabilize themselves on three legs. So, whenever any leg is not in contact with ground, any other three manage to balance the body.

Most often, hexapods are controlled by gaits, which allow the robot to move forward, turn, and perhaps side step. Some of the most common gaits are as follows:

- Quadruped
- Alternating tripod: three legs on the ground at a time.

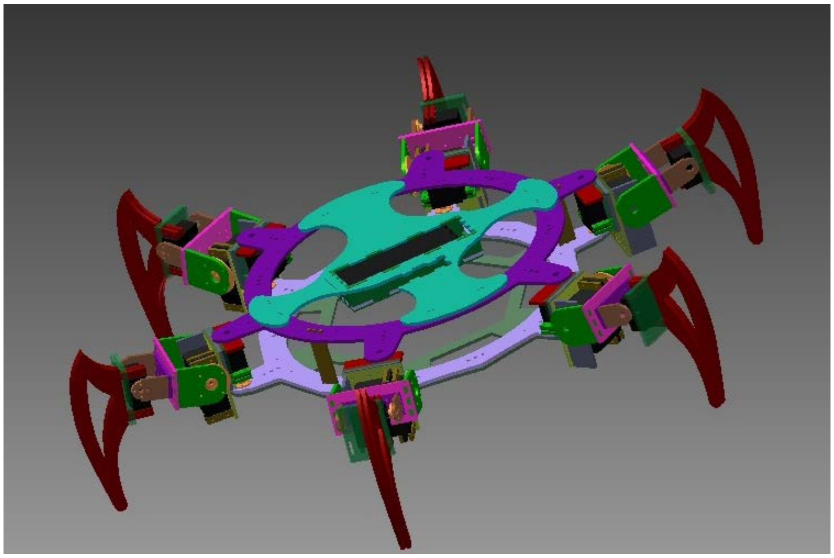
Quadruped Gait

Quadruped gait consists of two major dynamics: picking a leg and pushing the ground backwards to move forward. In simple walking, the hexapod is initially headed towards one of its legs. Then, one by one, all legs but the diagonally opposite leg are picked and moved forward from the mean by a certain angle. After picking each leg, the pushing process begins and all other four legs simultaneously push the ground backwards and the hexapod moves in the forward direction. This process cycles as the robot walks in a given direction. For this mechanism to work, the hexapod legs need to have sufficient static friction so that no slipping occurs.

The hexapod is multidirectional; i.e. if it is headed towards leg 1 and wants to take a right turn, then it can simply rotate 30 degrees about its central axis and start moving along leg 2. If it wants to move at an angle of 120 degrees it can start moving along leg 3 or leg 5.

Tripod Walking

Tripod walking is a revolutionary algorithm of walking which makes the hexapod walk faster and smarter. The whole concept of tripod walking depends on the concept of balancing on three legs and maintaining an equilateral triangle using alternate three legs. In this type of walking, the hexapod moved on three legs at a time and, at any time of walking, the alternate three legs maintain an equilateral triangle to avoid undue stress on any one leg. So at a time three legs are picked (labelled as Tripod1) and are moved forward to some particular points on the ground. Now the robot raises the other Tripod i.e. Tripod2 and, while maintaining contact between Tripod1 and the ground, pushes the ground backwards to gain a forward velocity. Then Tripod2 is brought back down and the same procedure is carried with the other tripod. The angles involved in the movement were obtained by manual calibration of



3D CAD Model of the Hexapod

the robot so as to obtain the desired distance of travel with each cycle of the gait.

Obstacle Clearance

The main motive of making the hexapod was to overcome obstacles in the way where wheeled robots are helpless. For example, on a rocky surface, a wheeled robot cannot pass over rocks or even small stones. In desert surfaces or in sand, wheeled robots tend to get stuck or slip. Since the hexapod locomotion is based on a picking and pushing mechanism, its extensive stability can easily conquer rocky and sandy terrains. Due to this aspect, the hexapod can be used in defence and in military applications such as mine detection and spying. It can also be used extensively in research and exploration in such areas where men cannot reach such as in volcanic research. This concept can be utilized for exploration and sample testing in other planets and asteroids.

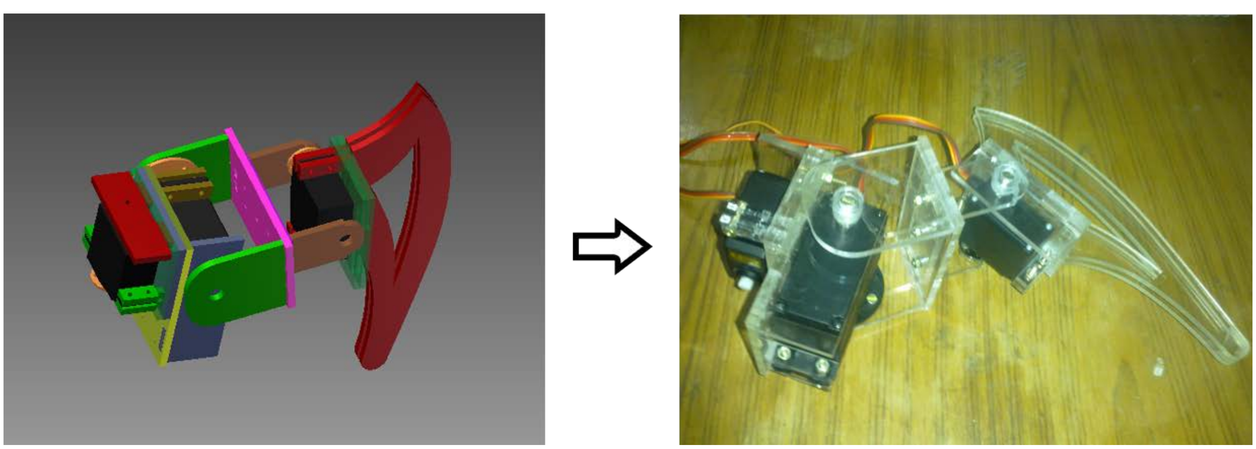
Construction

There are three main aspects to the construction of a hexapod:

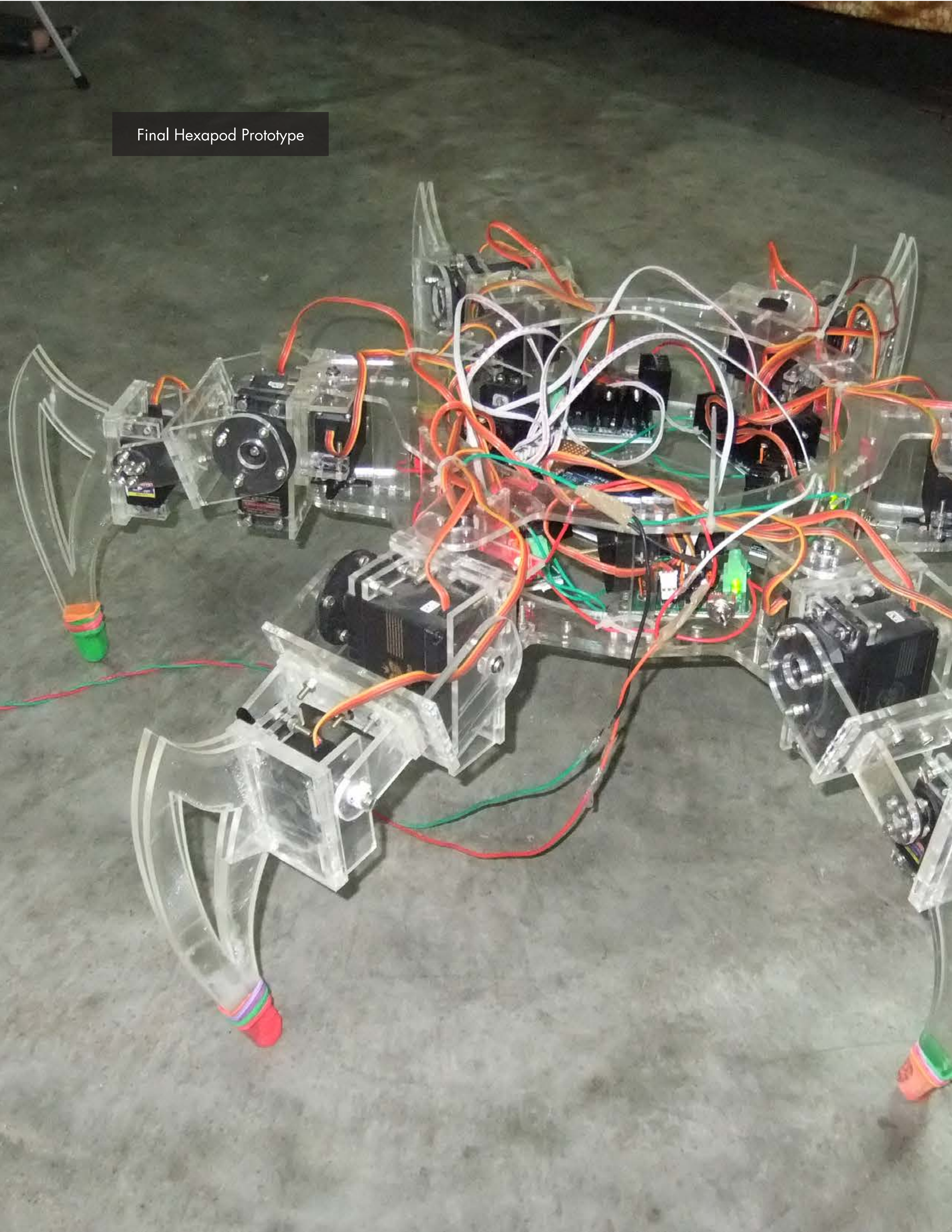
1. Mechanical
2. Electronics
3. Programming

The mechanical body frame was initially designed in Autodesk Inventor, a 3D modelling software. The body consists of six limbs and main chassis with battery holder. Each leg has three servomotors to provide motion in three dimensions. Even the smallest part was designed according to precise dimension.

Two choices were available in the design of the chassis: rectangular and circular. Both designs have their own benefits and cons. The rectangular chassis would have made design and programming simpler, whereas the Circular chassis would have symmetry about its axis and would allow the robot to move along any leg and stay stable just on three legs. Picking function over ease, a circular chassis was decided upon, with six attached legs at an angle of 60 degrees to each other. The body frame was designed iteratively: each design was tested for stress, and the weak points were reinforced in the subsequent design. Subsequently, the moment generated in the joints was estimated to decide upon the ratings of servomotors used in particular joints. The middle joint was found to require higher power, since it carried the burden of the weight. Servos of 19.6 kg-cm rating were used for the middle joints, whereas the rest had servos of rating 14.9 kg-cm. The main aim was to reduce the weight of the



From Idea to Implementation



Final Hexapod Prototype

robot as much as possible while make it aesthetically good as well as resilient. To reduce weight, the chassis was made completely hollow. To distribute load between the top and bottom plates of the chassis, twelve beams were used.

A light and strong material was required to compose the chassis, and acrylic was the perfect solution since it is light, easily machinable and can bear high amount of normal stress while also being easy available. Another advantage of making the robot from acrylic is that it allows for easy assembly or disassembly of the entire structure. Each part was manufactured according its to CAD model on a water-jet cutter. Individual parts were joined by using chloroform as an adhesive. The tips of the legs were covered with rubber to get higher friction.

The electronic components present on the robot include the power modules, batteries and the "brain" of the robot: a processor. Power modules were required to manage the design and organization of the overwhelming amount of wiring involved in powering eighteen motors. The power module distributed power to the each leg from the main supply and controlled each servo as per the instructions received from the micro controller. Six power modules were present in all.

The brain of the hexapod had to be powerful enough and feature-rich to control eighteen motors, and yet not consume much power. The "Arduino 2560" was used for this purpose since it met all the requirements while simultaneously being inexpensive.

The last thing to choose was a battery with a very high current rating. Because of the eighteen servos, the total current draw was very high. Along with high current rating, the battery needed to be light weighted. Li-Po (Lithium Polymer) was the obvious choice since it has a high current supplying capacity for very long durations, is rechargeable, and lightweight.

Programming the hexapod was the most important and complex part of the project, since all eighteen servos have to move in a synchronized fashion. Synchronization was achieved using the "Mean-Delta" method in which the reference of a particular position of a leg was taken, following which angles were calculated for the servo positions, finally issuing commands that assigned the angles.

Limb movement in the natural world follows the principle of least action: in moving from point 'A' to 'B', the "action" of the limb is minimized. On the same lines, the hexapod calculates the least action and moves all the three joints to give the smoothest possible motion.

Future Prospects

Currently, the movement of the hexapod is hard-coded into the brain. There are no sensory systems mounted on it preventing it from obtaining any environmental feedback. In the next phase of this project, the hexapod will be made "intelligent": a self-learning robot that employs neural networks to learn from its own mistakes. An overhead camera, or a 3D sensor can be mounted to map and avoid obstacles. The mechanical frame can be made more resilient by using a metal chassis and high-torque servos. Suspension systems can absorb shocks from the ground. These modifications will make the hexapod a true All-Terrain Vehicle.

Video:
http://www.youtube.com/watch?v=u5d0L93P0DU

Related links:
http://students.iitk.ac.in/roboclub/data/projects/summer11/hexapod.pdf

Apoorva Goyal

Process: Preclude to Success

The Process way of approaching a business has seen a recent surge, and the results have been very attractive.

A survey under SAS (http://www.umsl.edu/~sauterv/DSS4BI/links/sas_defining_business_analytics_wp.pdf) was reported which detailed upon the benefits of processes. Top benefits that respondents derived or expected to derive from a business process based approach included improved decision-making process (75%), prompt decisions (60%), better alignment of resources with strategies (56%), realizing cost efficiencies (55%) and responding to user needs for availability of data on a timely basis (54%). What makes this process based way of working a huge advantage? How are companies able to increase sales and turnaround time by employing this method? This article chronicles a journey to understanding what a process is illustrate that the process way of working is a great way to help businesses leverage the untapped energy of people and resources.

Processes: Understanding

The Business Process way of working is the activity of representing both the current and future processes of an enterprise to analyse and improve the current process. Business analysts and managers typically perform it to improve process efficiency and quality. A process is a specific ordering of activities with clearly identified inputs and outputs that provide business value. Likewise, a business process way of working ensures consistency and thoroughness in capturing relevant information so that both business analysts and the developers can understand the business requirements captured in the model.

The identified improvements may or may not require IT involvement, although that is a common driver for the need to model a business process, by creating a process master.

> “Spanish food giant Pastas Gallo increased sales by 18% by automating the process of new product launching with Polymita.”

Business process approach assists an enterprise in achieving strategic objectives by providing methodologies and tools to develop integrated business process models. The resulting model is used to analyse the links between different types of objectives and form a basis for a practical implementation procedure for the processes.

Business Process Modelling has always been a key aspect of business process reengineering (BPR) and continuous improvement approaches, such as Six Sigma. BPM tools such as Lombardi, Holosofx, and TIBCO are used to represent a business process, run a simulation of the process and for communication purposes.

Processes: Alignment to Customers and Employing Analytics

A business organisation's success is defined by its way of working and the approach that it adopts towards its targets and goals. The way a business is run streamlines the direction an organization would head towards. In the older business models, heads way of working always drove the organisation. They would take decisions arguably based more on gut than data. The people working under them learnt the same art and the whole organisation got stuck in a single-person based decision making process. These decisions were experience-based, which led to success in yesterday's world. Yet some experienced people hold on to them and seem to believe they will work in the new world. They fail to understand the new sweeping changes happening in the world. They persevere with the art of fulfilling the old expectations of customers, but are unaware about the new expectations of customers that demand change throughout the value chain. They are unable to understand the new value drivers of the costumers. This leads to loss of business. To win new orders a host of new value drivers need to be added around the product. The business and its key men cannot afford to perceive that the old world still continues and that employees and customer are to be treated in the old way, since today if a business fails to align with the customers and employees, it is bound to fail.

In this complex world, there are too many variables that constantly fluctuate. If a business doesn't align with its customers, it can lose them at any moment. To survive, one has to meet the expectations of the customer, respond to their changing expectations and respond before it is too late. In this era of cut-throat competition you are either at head or at par. However, if you are behind on each of the value parameters, then there is no saving grace.

A process based way of approaching a problem in business helps to align with the ever changing dynamic situations and demands of customers and keep the organisation in alignment with the customer.

Processes ensure that the decisions are based on data, information, analysis, alternatives, decision, action, feedback from stakeholder and refinement of the process itself. According to a survey conducted by Computerworld, 80% (http://www.umsl.edu/~sauterv/DSS4BI/links/sas_defining_business_analytics_wp.pdf) companies surveyed felt that processes helped them aligning resources with strategies, realizing cost efficiencies and responding to user needs. They improved the organization's competitiveness, producing a single, unified view of enterprise-wide information, synchronized financial and operational strategies, and increased revenues.

Given the current state of the world economy, it is not surprising to see realizing cost efficiencies, improving the organization's competitiveness and increasing revenues as key benefits.

Ah-Hoc vs. Processes: Structural and Efficiency Angle

Let us now journey the internal scenario of the company and extract the benefits of processes against an ad-hoc decision process. The industrial standard of efficiency has also dramatically changed from 60% capacity utilization to 100% utilization. Machines work for 480 min in a shift and so do people. No supervisors are present to drive the people - they have to work on their own and be self-motivated and self-driven. Machines cannot stop if the workman has some difficulty. The worker has to come to the superior if he faces any difficulty and not wait for assistance to arrive at his doorstep. The crux is company cannot drive employees to work hard. They have to realize that they are also the stakeholders of the company and are responsible for its success and efficiency.

Expansion of work makes the management create structures, put people in it and divide the work. When one work is distributed among too many people, disharmony results. Effects on stakeholders like customers, employees, government bodies, suppliers are not as per the management's expectations. Problems such as the following arise:

1. Time misalignment (can be corrected through processes)
2. Incompleteness
3. Poor quality
4. Inconvenience

Few case studies provide interesting result. For example, a financial service was able to reduce staff from 613 to 406 while simultaneously decreasing processing time and increasing customer satisfaction. Similarly, an insurance company trimmed 40% of its staff and increased its rate of claims handling.

Business processes can be determined, configured, calculated and analysed based on different attributes such as cost, time, route, users, etc. Easy and hassle-free deployment makes it possible to monitor end-to-end business processes across multiple system silos without any changes to existing systems. The above problems can be ameliorated by the following components of processes:

1. *Pinpoint and Act on Business Problems Proactively*

A process enables enterprises to identify process bottlenecks and root causes of inefficiency in business so that they can proactively correct them. Users are notified of potential process problems beforehand, allowing them to respond and take corrective action in a timely fashion.

2. *Reduce Risk and Penalties*

Automated processes expose exceptions and noncompliant paths within business processes. Being aware of these risks and ensuring that resources follow correct system practices reduces an organization's exposure to penalties caused by compliance failure, fraud, and other legal and efficiency issues that lie hidden within workflows. These processes make it possible for enterprises to optimise their process flows for better business operations.

3. *Improve the Bottom Line*

Hidden bottlenecks, repetitions, and loopbacks in business processes can be tracked, exposed, analysed and addressed easily and efficiently, which leads to increased efficiency. Exposing these problematic business activities within the processes also allows for a more effective business process optimization, reduces costs, and improves the bottom line.

Processes: A Method to Achieve Greater Goals

Concisely, processes are a more defined and organised manner of working and result in consistent goal achievement. In the old business world, people would wait often for directions due to lack of a defined process. A process is a defined way to connect to the stakeholders in order to promise and deliver a service/ product while iteratively refining the process itself. While a visionary management helps in vectorially changing the direction of business, processes help to accelerate that vision.

An appropriate question at this point is "What is the right situation to use a process?" The following points put up a scenario which would ideally benefit from processes:

1. Product has become a commodity.

2. The customer is becoming elusive despite many tries, or the enterprise is unable to attract new customers on product offerings/ discounts/credits.

3. Functional world cost reduction has been tried and cost reduction is not achieved (on applying function analysis tools like Six Sigma, TPM, TQC, and TPS to reduce variations).

4. Process redesign to deliver new values to customer such as error reduction, time reduction, consistency, reliability, flexibility, responsiveness, variety, lot size reduction, just in time, complete in terms of range, convenience at home and at shop.

Processes: Challenges

People may revolt at the name of process because they could have a misconception that processes tend to limit creativity and reduce the value of individual, just as how Henry Ford's model of assembly line was highly panned when it was introduced. This is worry is unfounded since, in a process world, processes need to be continuously defined, redefined for different customers, and have to be repeatable, consistently while also allowing for customization of a solution for each customer.

Processes: A Bird's Eye View

All stakeholders have to give in their minimum so that they retain their value to an enterprise. The mathematical indicators of TCECF are:

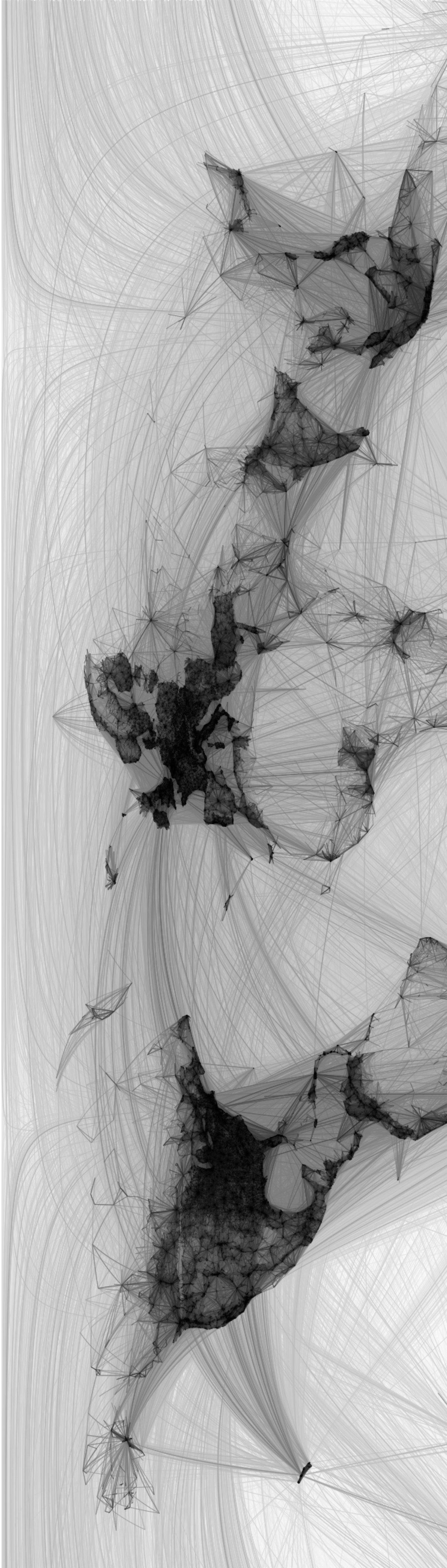
1. Reliability
2. Flexibility
3. Responsiveness
4. Consistency

Companies strive to improve these indicators consistently to retain customers and build customer loyalty. These can only be achieved through processes.

When one designs processes in order to increase reliability and consistency, it may be possible that the increase in manpower may raise the cost prohibitively. In this case, it makes sense to go for technology and automation. After some time if one finds process management to be too daunting a task, one can outsource some processes so as to effectively focus on the core aspects of the organization.

Summary

In a nutshell, processes are a better way of aligning all the small pieces of work done by many people and bringing them together so that the customers, employees and stakeholders are happy every time.



Visualised: Facebook friend connections by country, on December 2010. Source: Facebook

Demystifying the Internet

Anurag Dwivedi

Over the last two decades, the internet has become an integral part of people's lives. As of 2011, it is estimated that almost a third of the entire world population has access to the internet and utilizes online services, with more than three times that number of devices connected to each other. The internet is also characterized by explosive growth: after two decades, the internet now accounts as the medium for almost all of information exchange. Imagine more than 5 billion devices connected to the network and 5 billion gigabytes of data stored on the network, and yet a small message that you send to your friend on chat is received on the other side of the word within milliseconds. This speed and scale is made possible by many technologies and protocols, each of which plays an important part in the structure of the internet. In this article, we introduce and explore the core foundations of the internet that make it tick.

The history of Internet dates back to 1950s when the first computers were developed, along with which came the technology of communicating between a computer and a terminal. By the early 1970s, research into packet switching (see box) led to the formation of the Advanced Research Projects Agency Network (ARPANET), the world's first operational packet switching network. In 1982, the foundations of a worldwide network of interconnected devices called as the internet were laid. The ARPANET evolved and access to websites was made available from research and educational institutions, laying the foundations of the World Wide Web (WWW). In 1995, the use of Internet was made available for commercial purposes, which led to a drastic impact on culture and commerce. Since then, the internet has evolved continuously with the inclusion of email, instant messaging, the World Wide Web, forums, blogs, social networking sites and much more, and is still achieving new zeniths.

> Packet switching is a method of communicating digital data by dividing it into smaller blocks, called packets. Packet switching leads to a variable data rate, since the number of packets transmitted in one second need not be constant: as packets traverse through network adapters and routers, they are queued up due to traffic and congestion. Packet switching contrasts with circuit switching, a method in which a limited number of dedicated connections are set up between which deliver a constant data rate. While packet switching is prevalent by its use in digital telecommunication networks such as the internet and GPRS, circuit switching is commonly used in wired telephone lines that are managed at a central telephone exchange.

OSI Layers Framework

Successful communication between two computers on the internet requires many "guarantees". At the very least, a physical connection must exist between the two computers: the LAN wire connected to a computer must be connected to a central server, which in turn must be connected to an Internet Service Provider, which connects on to the destination. Additionally, each of these connections should be robust, and should not discard or corrupt data. This last requirement, however, is too stringent, since robust connections are expensive. Consequently, a mechanism is required to detect and correct data loss or corruption.

The internet is made more complex by its heterogeneity. Devices connect to the internet not only through the traditional Ethernet connection, but also through WiFi, GPRS, 3G / 4G, ADSL, and other such mediums. Managing connections across different technologies requires a standard set of rules that is followed globally. A framework, called as the Open Systems Interconnection (OSI) framework, serves this purpose. The OSI framework was designed by the International Organization for Standardization (ISO).

The OSI framework divides the task of communication into seven layers: the Physical layer, the Data-Link layer, the Network layer, the Transport layer, the Session layer, the Presentation layer, and the Application layer; in that order. Each layer provides a certain guarantee, which allows the subsequent layer to function correctly. For example, the Datalink layer ensures correct flow of information between two computers that are directly connected to each other. This guarantee is used by the Network layer to ensure correct communication between two computers which, though not directly connected, are connected through some intermediate network.

Physical Layer

The bottommost layer of the OSI framework defines rules regarding the transfer of raw data (sequence of bits) over a specific medium. For eg. it defines the physical and electrical characteristics of the medium such as operating voltages, maximum data transmission rates for the medium, etc. Different examples of the physical layer include copper wires used in telephone or Ethernet cables, optical cables used between inter-continental connections and discrete wireless frequencies used in wireless communication.

Data-Link Layer

Originally, the Data Link layer was intended to provide reliable point-to-point communication. The IEEE 802 standard defines the LAN specification, for Ethernet as well as WiFi. As per this specification, each device in the network has a unique Media Access Control (MAC) address that is used to identify it. A MAC address is a 48-bit number that identifies a network device. Thus, if your computer has an Ethernet as well as WiFi connection, it will have two MAC addresses: one for each. The task of this layer is two-pronged: to arrange data packets into "frames" for transmission, and to detect and correct errors in transmission.

Network Layer

The Network layer and the Transport layer together provide the scalability and robustness that are characteristics of the internet. The Network layer serves multiple purposes: it provides methods to identify and represent computers in large networks. The Network layer is also responsible for generating a path between the two communicating computers (a daunting challenge). The Network layer also allows breaking down a large network into smaller, hierarchical ones, to make the task of communicating more manageable. Finally, the Network layer is responsible for breaking a large message into smaller, more manageable chunks, sending them across the network, and reassembling them at the source.

The celebrated IPv4 and IPv6 protocols fall in this category. The IP protocols are tasked with delivering datagram packets from the source to the destination solely using addresses. To this end, they define addresses for computers called as IP addresses that are 32-bit long for IPv4, and 64-bit long for IPv6. An IP address is different from a device's MAC address (see box).

> IP works by assigning address depending on the logical location of the device. Thus, the location of the device can be obtained simply by matching its IP address to entries in routing tables. This also means that the IP address of a device can change, depending on where it is connected in the network. On the other hand, MAC addresses are unique, and never change.

IPv4 is the most dominant protocol. A 32-bit IPv4 address implies that a maximum of approximately 4.3 billion devices can be connected to the internet at any time. This number is restrictive, since the number of such capable device is much larger. Indeed, the last IPv4 address were allocated in early 2011. One can understand the reason for this by looking at the history of the protocol: IPv4 was initially intended to be an internal test at ARPA, and was not designed with commercial purposes in mind. To mitigate this problem, a number of technologies are used, such as Network Address Translation (NAT), which exposes a private network with potentially thousands of computers as a single public IP address, Dynamic Host Configuration Protocol

(DHCP), and others.

NAT works by defining a single device in a private network as a gateway. The gateway connects to the outside world through a unique public IP address. Within the private network, devices are addressed using a reserved pool of private addresses. When a node communicates with another node outside the network, it does so through the gateway.

Once a computer's IP address is identified, its MAC address is required to connect to it. This task is served by the Address Resolution Protocol (ARP), which converts an IP address in a private network into a MAC address. Usually, though not always, the ARP works at the gateway.

Transport Layer

While the network layer creates a route between two nodes in a network, the transport layer provides end-to-end communication between two applications running on the source and destination layers. Two important protocols operating at this layer are the Transmission Control Protocol (TCP) and the User Datagram protocol (UDP).

TCP is used where reliable exchange of data is required. A prior connection needs to be established before data can be transferred: TCP ensures that the data sent to the destination has been indeed received. Any data loss arising at the network layer is corrected at this point.

TCP is said to be a "connection-oriented protocol", in the sense that it requires acknowledgements and connections. While this makes TCP reliable, it also decreases data communication rate. Where integrity of data is not of such paramount importance, such as in audio or video streaming, UDP is used. UDP is a connection less protocol. It sends the data whether or not the recipient is available, and does not ensure proper delivery of data.

Transport layer protocols perform multiplexing at the source and destination. Since multiple applications may be simultaneously sending and receiving data on the same device, it is necessary to identify uniquely each application. This is achieved through ports, which are numbers appended to the IP address. At a time, only a single application can send through or listen to a port.

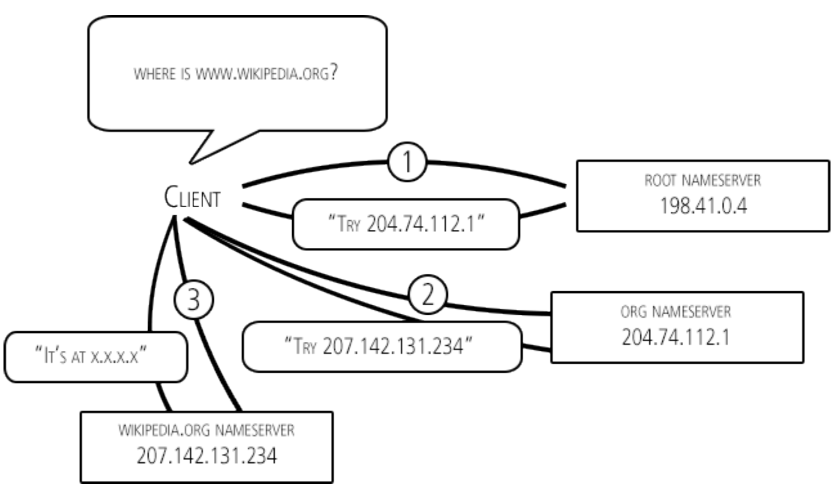


Fig. 1: Recursive DNS Query

Application Layer

This layer is closest to the end-users. It contains data that communicates directly with the applications or the software. HTTP is an example application and lays the foundation of World Wide Web (WWW). It works as a request-response model where the web browser (client) requests the server for the web page and the servers' answers with a response header and data. The HTTP provides various facilities like requesting data from the server, or posting data to the server or even deleting a resource on the server. FTP or File Transfer Protocol as the name suggests is used to transfer files between the server and the client. Another protocols operating at this level are SMTP (used to send mails) and IMAP/POP (for receiving mails).

DNS Servers

Since IP works on numerical addresses, one would be required to remember these addresses in order to connect to a particular destination. Additionally, if the destination address changes, it is difficult to know about this change, and to know the new address. This issue is addressed by the Domain Name System (DNS). DNS can be understood as an address book in which each IP addressed is assigned a human-friendly name. The client side entity that is responsible for querying and retrieving the IP addresses is called DNS Resolver and the server side counterpart is known as a DNS Server. To know the IP address of a machine, given its friendly name, the source queries the DNS server.

If all DNS queries are directed towards a single server, the resulting congestion can cause deterioration in service quality or even a server crash. To ameliorate this issue, the human-friendly names are organized in a hierarchy. This hierarchy is visible

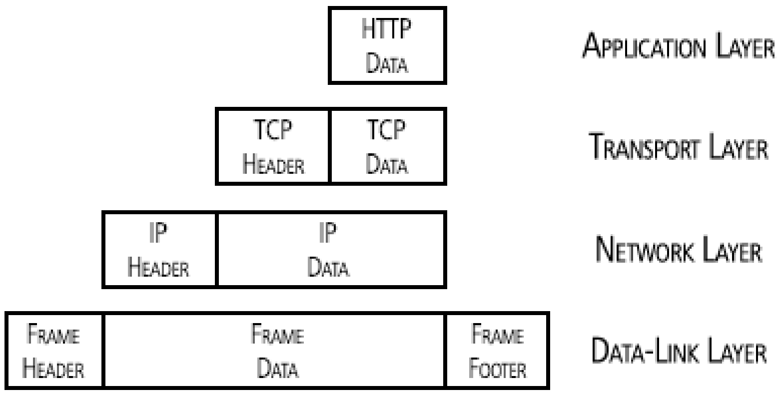


Fig. 2: Anatomy of a Typical Network Packet

in the name itself: each part of the name is separated by a period, with the rightmost name at the top of the hierarchy. All queries start at the root label and recursively go to the lower sub-domains until the address is found. For example, a lookup for www.wikipedia.org goes to the root server, then to the sub-domain ".org", then "wikipedia.org" and so on, as shown in Fig. 1.

An Example

The following example illustrates the entire working involved in browsing a web page, from entering the URL in the address bar to loading of the page. When the URL is submitted, the DNS Resolver first queries its own cache to find the URL's IP address. If unsuccessful, it goes to the DNS Server of the ISP. There it starts a recursive search starting from the root label and finds the corresponding IP address. Now, when the IP address is found, the browser (client) generates a data packet similar to that shown in Fig. 2.

The TCP header containing connection request is sent to the server with the destination IP Address stored in the IP header. The server on receiving the connection request returns an acknowledgment. Then, the client also acknowledges the server's response and a connection is made. Now the browser sends an HTTP Request contained in the HTTP Data requesting the resource at the given URL and a HTTP Response is received containing the data (a web page in our example). The browser loads the HTML while in turn requesting for the further resources associated with the page, such as images, JavaScript files, etc. This entire process completes within a second or so.

Beyond the basics – AJAX

AJAX or asynchronous JavaScript and XML, is a technique used to send data to, and receive data from the server in the background without affecting the present content of a web page. In other words, it updates a small fraction of the page without affecting the other content. AJAX can be experienced in everyday life: suggestions while typing on a search bar, or messages received by a chat client on a web page, are all examples of AJAX in action. AJAX finds a great utility in today's world, since it does not require the reloading of redundant data, saving a lot of bandwidth while simultaneously providing a better user experience.

Final Words

Everything in this world has a dark side, and the Internet, as it stands so strong and well organized, is no exception. The growing Internet users and traffic has caused a burden on the network and shortage of IP addresses. Security concerns plague the internet, with newer exploits and hacks being uncovered every day. However, looking at the brighter side, the internet as we know is constantly evolving. Speeds as high as 1 Tbps have been achieved in research projects. The introduction of IPv6 is expected to resolve the problem of limited IP addresses. HTTPS, a secure form of HTTP, has helped to create a secure data transmission channel over an insecure network, leading to a thriving e-commerce industry. Buzzwords such as Cloud Computing and the Social Web are the new rage. The evolution of the internet uncovers newer vistas, each that enrich our lives immeasurably.

Asmita Gupta

Cloud Computing

“Cloud Computing is a tool that helps us share resources among the cloud service consumers, cloud partners and cloud vendors in the cloud value chain.”

Does this heavily quoted definition sound similar to that of a home delivery service of a restaurant chain? It surely does to me!

If you are curious about the bizarre correlation, let me elaborate.

As one does not require the physical location of the restaurant and the facilities available there for availing the benefits of its home delivery services, similarly, a cloud client does not require the knowledge of the physical location and configuration of the system that delivers the cloud services.

Cloud computing is essentially Internet based computing in which shared resources, software and information are provided to users on demand. All one requires is internet connectivity to access all service products and software which, otherwise, would have to be separately bought and installed.

The most lucrative aspect of cloud computing for user is that there are no up-front costs involved. You pay as you go along.

Thinking bigger than just using these services for some computational tasks occasionally: imagine that one wishes to set up an enterprise; one which achieves the maximum possible limit of efficiency and profitability simultaneously. To achieve such a feat, the company would require business applications and infrastructure that are usually very expensive and appear to have an entire universe of complexity associated with them. In older, gone by days, one needed an entire data centre with security, storage, cooling and power. Servers and storage facilities were absolute essentialities. Further on, one needed to ponder over the Development, Testing, Staging, Production and of course, safeguarding oneself from Failure and Disaster Recovery. This necessitated an entire team of IT specialists just to keep the show running.

Instead of dealing with all these mind-boggling concerns all at once, one can just switch on to cloud services just as easily as plugging in any utility service. All the above concerns then escape us to move into the ‘Clouds’! It is much faster to get started and involve considerably lesser cost.

Here we’ll compare Gmail and Microsoft Exchange to illustrate the point further.

As one might be well aware, Microsoft Exchange is a popular collaborative and messaging server in the world. Enterprises relying on Microsoft Exchange are required to have servers, storage facilities and a technical team to perform updates and keep it running. Gmail on the other hand, does the same job but with an apparent advantage, for it requires none of the above support structures to function. Using Google applications is a ‘click & go’ game and one does not need to pay for all the products used or for the people employed to run the same. Upgrades are performed automatically, ensuring security as well as performance.

As is apparent, switching to Gmail much significantly reduces the cost incurred: even the mode of payment becomes more convenient. One does not need to buy software and hardware anymore ;all costs are included in a predictable monthly estimate.

Cloud based services virtually eliminates the need of installing one’s own IT infrastructure or owning extensive software licenses. The labour cost declines as both the number and the work time reduces. It keeps up one’s application security and performance enhancement along with the benefit of additional features. So, a lot of worries are already dealt with by switching on to cloud, allowing one to dedicate more time and resources into fulfilling the ultimate aim i.e. developing the company.

The most eye-catching example of an exceptionally successful enterprise, which uses cloud utilities, is Twitter. Yes, the most happening social networking site, handling unbelievable traffic with the enormous number of tweets and posts, does not have its own servers. The entire system works on paid servers from Amazon.com. Possibly, this is the reason that the enterprise has expanded so much in a very short period, for its developers are able to put their undivided attention to the cause at hand and channel their resources in a better way, thanks to not having to look after a huge server storage facility.

The most attractive attribute of the cloud is its massive scalability. Public Clouds allow all users to access the cloud from the web. Many large-scale companies lease public cloud resources from providers such as Amazon, Google and Rackspace, amongst others. Autodesk Seek uses computing and storage resources from Amazon's web servers to store models and building components. Building designers can then quickly find and import these models from the web into their design projects. As requirement fluctuates, Autodesk can easily scale the amount of Amazon's Cloud resources used.

Cloud computing helps tackle elastic demand. Since set up of servers takes time, an enterprise might not be able to create availability in accordance with the rate of increase in demand. This results in the loss of customers for the company. With the cloud and the concept of virtualization of resources, enterprises can tackle the unpredictable nature of demand effortlessly.

Let us give in to our fancies and humour ourselves by building our own concept of a cloud based enterprise.

Coding is a task required for all jobs, from the most trivial ones to the most complicated ones. It would be a boon to not have to worry about separate development tools: licensing, installation and setup, not to mention taking care of the environment, such as the operating system or processor architecture. Finally, it would be a godsend not to have to wait for an hour every time a large piece of code compiles and is tested for bugs, only to repeat the process over and over again.

Yes, it is conceivable that an online editor and compiler is being hinted at. But the question arises: Why?

True, that it is not a novelty; but using this idea as a foundation and then employing cloud computing tools as the building blocks, constructing a new enterprise is!

Hosting a variety of compilers on our cloud, it is possible to provide user access to any compiler desired where codes can be edited, compiled and executed in a sandboxed terminal, all on the cloud. The client systems becomes merely a medium of communication with its limited computational power left unused: the main server takes care of all the computational tasks.

Let's make it even better: How about an online platform as a social forum for developers all across the world? One can have a login, an account with user space provided where one can upload, save, and share projects with colleagues and friends. Additionally, team project efforts would be supported: 10 people, or even more, would be able to work simultaneously on a project. After all, technology aims at making our life simpler and organization always helps.

Since cloud computing has virtually eliminated the effect of variability of cost by determining per unit cost of a computational task, users benefit from a much faster, reliable and secure service at a much lower price. Here, being a new firm doesn't hamper customers' confidence in the firm's services since the task is delegated not to just any other team but 'The' team of cloud providers which has already won over the market's confidence.

On the labour front, one doesn't need a technical team for maintenance of servers since there are none. Neither does one need to fear about loss of data by stolen hardware or hardware failure. Cloud services provide automatic back up support to clients which ensures that any data the client enters on the system is automatically saved in the cloud and a back up copy is generated immediately which ensures that no data is ever lost.

According to a study by Google, an enterprise of a hundred employees can save around $30,618 per year by switching over the Google Apps. The employees function 2.8 times more efficiently since data accessibility is tremendously increased. 2,450 GB of email storage space could be added to company's existing account. A hundred man-hours are saved per year since updates are automatic, as well as security patches. Company could also potentially save thousands in data recovery services.

The figures seem too good to be true, but it can very well be true, since cloud services costs comes out to be nominal. This reduces the gap between the inception of an idea and its implementation.

Cloud computing can prove to be a revolutionary paradigm in the corporate as well as the educational sector. Providing cloud based services to the entire community of a university would reduce a lot of financial burden on institutions. With students able to post their projects and come in direct contact with the buyers, there would be a massive acceleration for the local business time to market, reducing it from days and weeks to minutes and hours.

The best thing about cloud computing is that it has no boundaries. It allows one to make more efficient, productive and innovative designs.

There is nothing better than to see dreams take shape. Cloud computing is the thing which has motivated a group of students from IIT Kanpur to take up this project of an online editor and compiler, which was, till now defined in hypothetical terms, but has already begun acquire wings. Starting from small leaps, it would not be long that they sore high to take on their full flight.

NITROX
FULL THROTTLE

ANUJ AGRAWAL
ABHISHEK SRIVASTAVA
AMBER SRIVASTAVA
AJINKYA JAIN
RISHABH KATIYAR

The Idea

It's a well-known fact that cars have been identified as boys' toys since their inception. While people fantasize about racing and experience it through video games, a real-life race on the Buddha International Circuit is nothing like gaming in a virtual environment on a computer - it's a million times more exciting and equally challenging. This pulled a group of car fanatics together and who decided to fabricate a Radio Controlled (RC) car powered by an Internal Combustion (IC) engine as bare beginnings to the ultimate challenge.

What is an RC Car?

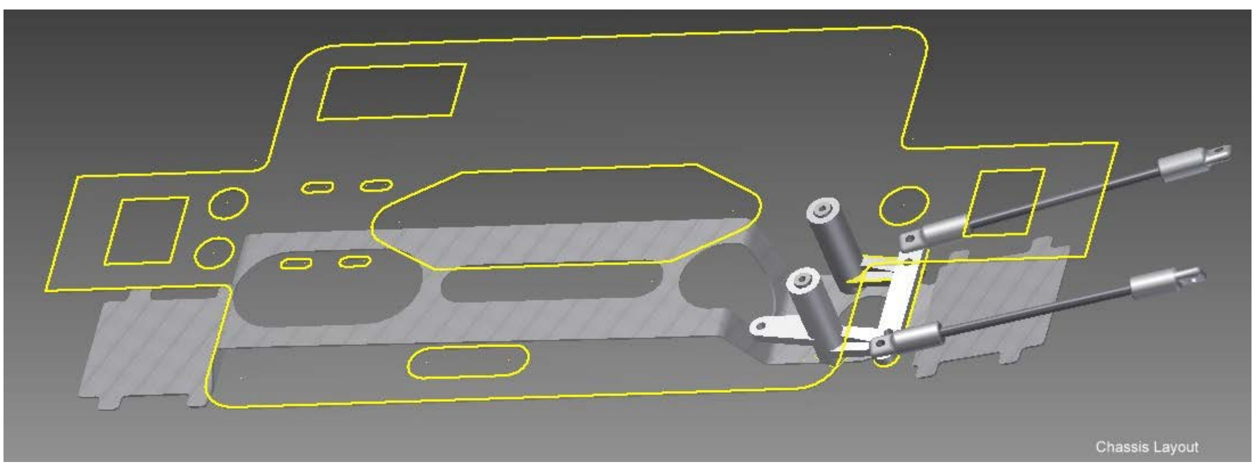
An RC car is a scaled down version of a real car, with typical scaling ratios of 1/6, 1/8, 1/10 and 1/12. It is controlled by a wireless controller that uses radio communication and thus the name "RC racing." It has an internal combustion engine of its own that powers it. The engine capacity may range from 2 cc up to 6 cc. Note that the engines used in ordinary cars normally have capacities of 1000 cc to 1500 cc. However this apparent small size of the RC engine compared to a real car's engine is perfectly justified considering the difference in scale. With a scaling ratio of 1/8, the volume ratio of the cars turns out to be (1/8)3 i.e. 1/512. Roughly assuming this to be the mass ratio of the cars, a mere 2 cc engine would be equivalent to a 1000 cc engine for an RC car. Indeed, it is, and these cars can reach speeds up to 60 km/h with tremendous accelerations.

RC Racing

Radio Controlled (RC) car racing is a popular sport in countries such as the US, Germany, etc. with regular tournaments and races held all round the year. RC racing isn't limited to monster trucks or Formula One modelled cars: there are events which focus on helicopters, airplanes and even boats. The race tracks vary from on-road straight, smooth drag tracks to off-road dirt tracks. This variety lends itself to a plethora of designs being able to compete in events. In India, however, RC racing is just catching pace as a hobby, but is still in its infancy. The sport is gaining popularity at the collegiate level in. Over the last few years, a number of colleges from India have started to conduct such races at collegiate technical festivals; nevertheless, this sport remains largely unnoticed at the professional level.

At the beginning of this project, our team, a group of sophomores, had no prior experience in building a car. We had to design an indigenous steering, braking and suspension system along with a strong chassis for the car.
We started over by going over the requirements that the car would have to fulfil in terms of the racing tracks and conditions.

Race Tracks



Layout of the Chassis

There are two kinds of RC Racing tracks:

1. On-road: An on-road track is a smooth even track, much like the ones used in Formula One racing. The number and the sharpness of the turns decide its difficulty level. The cars need to have a low centre of gravity, a high traction coefficient between the tyre and the surface with an aerodynamic design that produces a huge downward force on the vehicle while negotiating sharp turns, thus preventing slipping and enhancing control.

2. Off-road: As evident from its name, these type of tracks have an uneven surface. The rides generally are bumpy and hence call for a sturdy suspension design. The cars modelled for these tracks have larger wheels, a high ground clearance and generally Four-Wheel-Drive.

The Design

After a lot of research, we decided to go with the model of an RC Monster Truck suited to the off-road tracks since they are a much more challenging and exciting. The first requirement was a strong and stable chassis on which all other systems could be assembled. We started modelling the car using Autodesk Inventor, a CAD software. We separately designed all the part files of the chassis, suspension, steering, etc. and then integrated them in assembly files. Developing a CAD model beforehand proved to be of great help. It not only helped us visualize how exactly all the components are to be integrated but also helped us with exact measurements of each part. We manufactured the parts using a water-jet cutting facility. A water-jet machine is a computer controlled machine that uses powdered abrasives mixed with a fine jet of water at extremely high pressures. The power of this machine is such that it can cut a variety of materials ranging from hard alloys like stainless steel to soft wood. Aluminium sheets of thickness up to 15 cm can be cut quite easily within the accuracy of approximately 100 microns All it requires is a CAD drawing of the profile to be fabricated, which can then be fed into the computer that controls the machine.

The Chassis

The parts needed to be manufactured in the chassis were the chassis plate on which the engine, differentials and the gearbox etc. would be mounted and the shock towers (framework for mounting the shockers). We had many options for the materials we could use for it such as steel, aluminium and carbon fibre. A steel chassis would undoubtedly be the strongest but it had to be turned down for its higher weight. Carbon fibre seemed to be an ideal choice owing to its reasonably good strength and light weight but its higher price let us down. We finally settled down for an aluminium chassis. Not only was aluminium cheaply available in the local market but also has excellent machinability characteristics. Moreover it is light and sufficiently strong too.

Engine & Transmission

Our car was powered with a 4.2 cc 2-stroke IC engine, which used a special methanol based fuel known as Glow Fuel. It is not only is the source of power for engine but also acts as a lubricant and keeps the engine cool. The fuel-air mixture is ignited in the bore of the engine using a special device known as a Glow Plug, unlike the conventional petrol engines that use a spark plug for ignition. We needed the engine to run efficiently to reduce the fuel consumption and tune it accordingly. Tuning is all about setting the right mix of air and fuel that goes into the engine. Too rich a mixture and the engine would die upon itself. Too lean and the engine would start grunting badly, giving off a spurt of speed for a second but depriving the engine of the coolant - the fuel, thus ultimately harming its internal parts badly. After this, we focused on throttling. Throttling is the way the amount of air that enters the carburetor of the engine is controlled. At lower speeds, less air should enter the carburetor and some fuel left unburnt, and vice versa for higher speeds. We achieved throttling using a wirelessly controlled Servo Motor that controlled the opening of an inlet air valve through which air entered.

The power from the engine may be transmitted to only the rear wheels through an axle (Two-Wheel-Drive) or it can be transmitted to all the four wheels equally (Four-Wheel-Drive). On an uneven track with a lot of stones and potholes, there is a high chance of a 2WD vehicle getting stuck because the rear wheels, at times, might not be able to make contact with the ground. In 4WD, no matter how the vehicle is stuck over an uneven or rocky terrain, even if one of the wheels makes contact with the ground, the car would still be able to power its way out of the mess. Consequently, we chose 4WD and installed differential gears on the rear and front wheels. It also had an option of reverse gear to change directions. The gearbox had a slipper clutch, one that automatically toggled between the first and the second gear depending upon the engine RPM.

Suspension System

The suspension used is known as a double wishbone suspension system. It consists of an upper and a lower arm connected to the wheel hub. The shock absorbers are placed in the middle of the upper arm. A shock absorber is essentially a spring loaded on a damper.

The spring absorbs shocks while the damper dampens the oscillations of the spring to ensure a smooth ride.

In our car, the suspension springs and the dampers that were to be used were bought off the shelf, while the suspension arms and the shock towers were fabricated.

The Steering System

The steering system we fabricated is known as Ackerman's Mechanism. A wireless receiver on the car that accepted signals from the wireless controller and a control unit attached to the receiver controls a servo motor that controls the steering. The mechanism is driven by a linkage attached to the servo horn of this motor. Steering rods were manufactured from aluminium. A certain camber angle (the angle between the vertical axis of the wheels used for steering and the vertical axis of the vehicle when viewed from the front) was calibrated to the tyres for a better grip while cornering.

Braking System

The braking system employed a disc brake mounted on the driveshaft with brake pads attached to it. The brake disc had to offer enough friction to stop the car within the shortest distance possible. Brakes were actuated by a servo motor mounted on the chassis that also handled throttling.

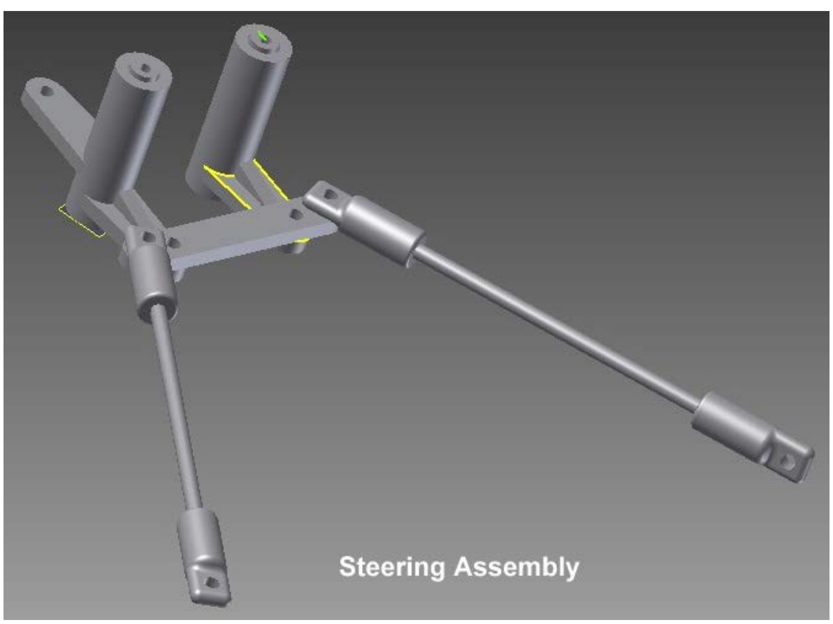
The Assembly

Assembling the chassis and the numerous other components proved to be the toughest task of all, being plagued by small problems that kept cropping up in the oddest of places. The first thing to go bust was suspension: there wasn't enough room between the upper arms of the suspension so that we could slide in the shockers between them. We spent more than two days filing the aluminium arms manually to create room for shockers. Running against a deadline time was of the essence. However, in the end we managed to integrate all the parts by doubling the time devoted to the project. However, we managed to complete it in just the nick of time by doubling our efforts towards the end.

The project was nearing completion and approaching was Techfest 2012, biggest of its kind in India. It featured a RC Racing competition named Nitrox, which seemed to be a perfect platform to test the car. We registered for it, but before that, we tested the car for its first run.

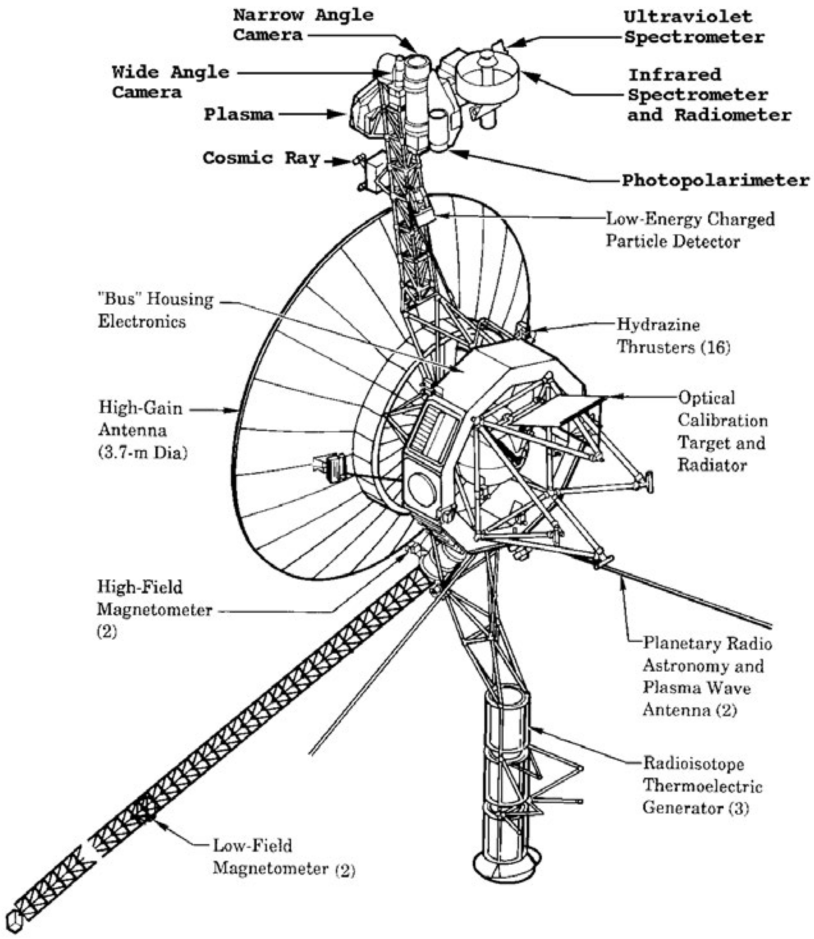
The test went extremely well, until it collided with a concrete bench at full throttle. The result was that the chassis was completely deformed, a steering system broken and brakes rendered useless, all within two days of the competition. Not losing heart, we kicked into overdrive and attempted to repair the damage, miraculously managing to pull it together on the last day. However, just before departing for the competition, we realised that the car had an improper meshing between gears (one metallic and the other made up of nylon) which resulted in a worn out nylon gear. We could not arrange a replacement at such short notice. We hoped to find a proper replacement of the gear at the venue itself, and left for the competition with an untested car lacking in a very basic component.

In the event, we missed the prelims on the first day owing to lack of gears. The next day, we managed to get the car ready. We were glad to be able to take a run at the arena but the lack of proper testing resulted in sluggish lap times. We were disappointed with the results but had some solace taking into consideration the problems faced and are more than determined to have another crack at the national level competitions regularly.


Steering Assembly

Voyager

Suman Kumar



(Spacecraft Shown Without Thermal Blankets for Clarity)

The Voyager program is a great success story for NASA. Voyager 1 and Voyager 2 were sent to space in 1977. They have been travelling and sending information back to earth for 34 years. Voyager 1 is currently the farthest man-made object from earth, and it seems that it will hold this record for many years. Although Voyager 2 was sent earlier, Voyager 1 is farther away because of its faster trajectory. As of February 08, 2012, Voyager 1 is about 120.069 AU (1.7962176×1010 km) from the Earth and Voyager 2 is about 98.358 AU (1.47141×1010 km) from Earth. Currently, they are in the "Heliosheath" - the outermost layer of the heliosphere where the solar wind is slowed by the pressure of interstellar gas. Voyager 1 is escaping the solar system at a tremendous speed of about 17060 m/s (61400 km/h), 35 degrees out of the ecliptic plane to the north, in the general direction of the Solar Apex (the direction of the Sun's motion relative to nearby stars). Voyager 2 is also escaping the solar system at a speed of about 15447 m/s (55609 km/h), 48 degrees out of the ecliptic plane to the south (as of October 2011).

The Voyager program was originally conducted for a brief study of Jupiter, Saturn Saturn's ring and the moons of the two planets. However, as the mission went on, and with the successful achievement of all its objectives, it was subjected to study the two outermost planets, Uranus, Neptune, and beyond it.

Each Voyager space probe carries information about Earth: they have a 'gold-plated audio-visual disc' that carries photos of the Earth and its life forms, a range of scientific information, spoken greetings from the people (such as the Secretary-General of the United Nations, the then President of the United States, and the children of the Planet Earth) and a medley, "Sounds of Earth", that includes the sounds of whales, a baby crying, waves breaking on a shore, and a variety of other music. Do you think that, if there existed an intelligent but aggressive species in the universe, the information on the Voyager would be enough to destroy human kind? The answer to this is found in the FAQ of 'Voyager Interstellar Mission': "The fact is, for better or for worse, we have already announced our presence and location to the universe, and continue to do so every day. There is a sphere of radio transmission about thirty light years thick expanding outward at the speed of light, announcing to every star it envelops that the earth is full of people. Our television programs flood space with signals detectable at enormous distances by instruments not much greater than our own. It is a sobering thought that the first news of us may be the outcome of the Super Bowl".

Voyager has been functional for the last 34 years. This requires a reliable and long-lasting power source and, at such long distance from sun, solar energy is definitely not enough. At the current position of the Voyager probes, the Sun is only 1/5,000 times as bright as here on Earth. The probe can continue to operate at such great distances from the Sun because it has radioisotope thermal electric generators (RTGs) that create electricity. The generators produce about 1800 watts of heat by the radioactive decay of plutonium. Thermocouplers convert this heat into approximately 400 watts of electric power. This energy source will allow operations to continue until at least 2020. The fact that the spacecraft is still returning data is in itself a great technical achievement.

Voyager 1 and 2 are identical in terms of the design. The question is, how can they communicate with Earth over such long distances? The spacecraft is now so far away from home that it takes nine hours and 36 minutes for a radio signal travelling at the speed of light just to reach Earth. That signal, produced by a 20 W radio transmitter, is so faint that the amount of power reaching our antennas is 20 billion times smaller than the power of a digital watch battery. Voyager has a large, 3.7 m parabolic, high-gain directional antenna to transceive data with the Deep Space Network on Earth. Signals are transmitted at a very high frequency in the range of 8 GHz. At such a high frequency, noise is not present in the Earth's environment. Therefore, the antenna on Earth can use an extremely sensitive amplifier and still make sense of the faint signals it receives. Communications are conducted over the S-band (13 cm wavelength) and the X-band (3.6 cm wavelength), providing bandwidth as high as 115.2 kbps. When the spacecraft is unable to communicate with Earth, the Digital Tape Recorder (DTR) is able to record up to 62,500 kb of data to transmit back later when communication is re-established. Data is captured on Earth in real-time through the 34 m big Deep Space Network (DSN) antennas located in California, Australia and Spain. When data is transmitted to Voyager, a very high power signal of the order of tens of thousands of watts is sent, so that the spacecraft can receive it properly.

The spacecraft contains 11 scientific instruments to study celestial objects as it travels through space. The components of voyager are:

Imaging Science System (disabled)
The imaging system is a pair of television cameras attached to telescopes with focal lengths of 200 mm (8 inches) for wide-angle coverage and 1500 mm (59 inches) for high resolution. The cameras also have various filters to capture colour pictures. It provides imagery of Jupiter, Saturn and other objects along the trajectory.

Radio Science System (disabled)
This system utilizes the telecommunications system of the Voyager spacecraft to determine the physical properties of planets and satellites (ionospheres, atmospheres, masses, gravity fields, densities) and the amount and size distribution of material in Saturn's rings and the ring dimensions.

Infrared Interferometer Spectrometer (disabled)
The spectrometer investigates both global and local energy balance and atmospheric composition. It has investigated the vertical temperature profiles of planets and their satellites as well as the composition, thermal properties, and size of particles in Saturn's rings.

Ultraviolet Spectrometer (active)
This instrument is designed to measure atmospheric properties and radiation.

Triaxial Fluxgate Magnetometer (active)
This system investigates the magnetic fields of Jupiter and Saturn, the solar-wind interaction with the magnetospheres of these planets, and the interplanetary magnetic field out to the solar wind boundary with the interstellar magnetic field and beyond, if crossed.

Plasma Spectrometer (defective)
It investigates the macroscopic properties of the plasma ions and measures electrons in the energy range from 5 eV to 1 keV.

Low Energy Charged Particle Instrument (active)
This instrument measures the differential in energy fluxes and angular distributions of ions, electrons and the differential in energy ion composition.

Cosmic Ray System (active)
This system determines the origin and acceleration process, life history, and dynamic contribution of interstellar cosmic rays, the nucleosynthesis of elements in cosmic-ray sources, the behaviour of cosmic rays in the interplanetary medium, and the trapped planetary energetic-particle environment.

Planetary Radio Astronomy Investigation (disabled)
This setup utilizes a sweep-frequency radio receiver to study the radio-emission signals from Jupiter and Saturn.

Photopolarimeter System (defective)
This system utilizes a telescope with a polarizer to gather information on surface texture and composition of Jupiter and Saturn and information on atmospheric scattering properties and density for both planets.

Plasma Wave System (partially disabled)
It provides continuous, sheath-independent measurements of the electron-density profiles at Jupiter and Saturn as well as basic information on local wave-particle interaction, useful

in studying the magnetospheres.

Many instruments of Voyager have been remotely disabled for reducing power consumption. As the Voyagers have reached at the boundary of solar system, the instruments made for the study of planets are no longer of any use.

Achievements

The Voyager program has given us enormous information about outer space that we previously were not aware of. A comprehensive list of the achievements of Voyager 1 and 2 would be too extensive enough to accommodate here; some of the very few results that would rank near the top of many such lists are:

- Discovery of the Uranian and Neptunian magnetospheres; both of which are highly inclined and offset from the planets' rotational axes, suggesting their sources are significantly different from other magnetospheres.

- The Voyagers found 22 new satellites: 3 at Jupiter, 3 at Saturn, 10 at Uranus, and 6 at Neptune.

- Io, a moon of Jupiter, was found to have active geological activity, the only solar system body other than the Earth to be so confirmed. Triton, the largest moon of Neptune, was found to have active geyser-like structures and an atmosphere.

- Jupiter was found to have rings. Saturn was found to having more than 1000 ringlets, its rings were found to contain spokes in the B-ring and a braided structure in the F-ring. Two new rings were discovered in Uranus and Neptune's rings, originally thought to be only ring arcs, and were found to be complete, albeit composed of fine material.

- Large-scale storms (notably the Great Dark Spot) were discovered on Neptune, originally thought to be too cold to support such atmospheric disturbances.

Even today, the Voyagers continue their operations, taking measurements of the interplanetary magnetic field, plasma, and charged particle environment, all the while searching for the heliopause (the theoretical boundary where the Sun's solar wind is stopped by the interstellar medium).

If nothing happens to them, NASA should be able to remain in contact with the two Voyager space probes until about 2030. Both crafts have enough hydrazine fuel to last till 2040 and 2034.

Voyager Timeline

1977: Mariner Jupiter/Saturn 1977 is renamed Voyager.

1977 Aug. 20: Voyager 2 launched from Kennedy Space Flight Centre.

1977 Sept. 5: Voyager 1 launched from Kennedy Space Flight Centre, Voyager 1 returns first spacecraft photo of Earth and Moon.

1979 Mar. 5: Voyager 1 makes its closest approach to Jupiter.

1979 July 9: Voyager 2 makes its closest approach to Jupiter.

1980 Nov. 12: Voyager 1 flies by Saturn, Voyager 1 begins its trip out of the solar system.

1981 Aug. 25: Voyager 2 flies by Saturn.

1982: Deep Space Network upgrades two 26 m antennas to 34 m.

1986 Jan. 24: Voyager 2 has the first-ever encounter with Uranus, Deep Space Network begins expansion of 64 m antennas to 70 m.

1987: Voyager 2 "observes" Supernova 1987A.

1988: Voyager 2 returns first colour images of Neptune.

1989 Aug. 25: Voyager 2 is the first spacecraft to observe Neptune. It begins its trip out of the solar system, below the ecliptic plane.

1990 Jan. 1: Voyager 1 begins interstellar mission.

1990 Feb. 14: Last Voyager images - portrait of the solar system.

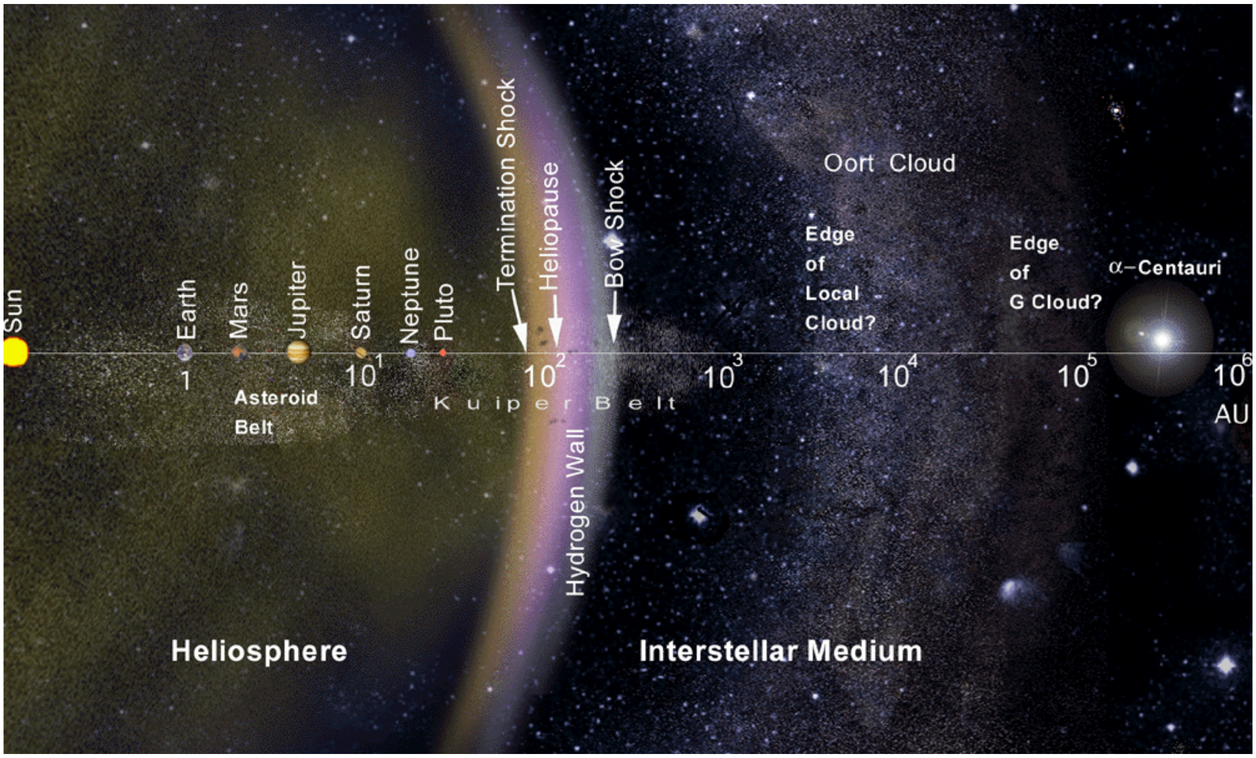
1998 Feb. 17: Voyager 1 passes Pioneer 10 to become the most distant human-made object in space.

2004 Dec. 15: Voyager 1 crosses Termination Shock.

2007 Sep. 5: Voyager 2 crosses Termination Shock.

Till this date: Voyager enters interstellar space.

Source: Voyager: The Interstellar Mission (http://voyager.jpl.nasa.gov/)



Solar system map on a logarithmic scale

Saturn, as seen by Voyager 2