It is my hobby to log into the IEEE Spectrum website, and browse through all the cutting edge research activities going on. Last year around this time, while I was doing the same, because I was bored of studying for my final exams, I stumbled upon this article titled "Here's that extra pair of robotic arms that you've always wanted". It immediately caught my interest. It was a research being conducted at MIT which was funded by Boeing.

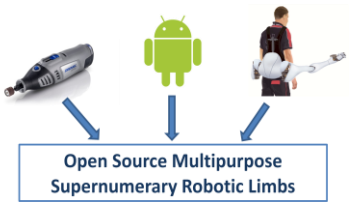
I started reading more about it, and began verifying the applications of this type of robot. As I was doing so, I came across a video of the assembly of Aeroplanes. In the video, a lot of workers perform repetitive tasks inside the fuselage, which can possibly be automated. But it is not possible to bring and install a hefty ABB or KUKA robot inside the fuselage. When observed more carefully, we can see that the tasks that are being performed are of two types: one which does not require much dexterity, such as holding a part to be drilled in place, and one which requires high dexterity, such as positioning a drilling machine to actually drill the hole where it is required. These tasks are being done one after another, or it is being done by two workers. In this age when even the smallest time wasted during manufacturing costs a lot to a company, it would immensely reduce the cycle time of the assembly of an aircraft if some of this work is automated. A possibility here is to provide the workers with wearable robots, which can collaborate with the human counterpart, and perform these tasks simultaneously.

Snapshot from the video, and the SRL research at MIT

Robotic Limbs are a pair of mechanical arms which can aid a human counterpart in performing simple to medium level complexity tasks. In the case of the aeroplane assembly workers, it will help if they are given a pair of wearable auxiliary limbs (not a replacement to the human arms) that can be regarded as an extension of the human body, and can be used to perform two tasks simultaneously. Hence it is called Supernumerary Robotic Limbs, or SRL.

At around the same time, I was fascinated by this tool by Dremel, which can be used for a variety of purposes. Several end-tools are available, which are interchangeable depending on what task is to be performed. It can be used in a household environment as a DIY tool, or in an industrial environment, by just replacing the end-tool, which is very easy to do.

It occurred to me that we can combine the benefits of both these platforms, and develop a pair of robotic limbs, which can have interchangeable end-effectors so that people can use this platform anywhere, including astronauts in space to do some repairs at space stations! So if we make the robot modular and the end-effector design open source, several developers around the world can come up with useful and creative end effectors for different applications. Something similar to the Android platform, where the core platform is developed by Google, whereas the peripheral apps can be developed by anyone in the world. This will give freedom for the users to choose the end-effectors they need, and they do not have to buy a different robot for different applications.



Once we got this project idea, the first risk we took was to *start* the project, because we had estimated that it would cost about Rs. 60,000, and we did not have any financial backup. Then I sent emails about our project to several professors in reputed institutes working on Robotics, and asked them for suggestions on how to reduce the cost of the robot, yet retaining its functionalities. After getting ideas from a few who responded, I made a detailed project proposal, and started spamming organisations and companies with it. Thankfully I was foolish enough to email the proposal to very big companies and organisations, because if I were older and more mature, I may have thought that this would definitely not work. During that semester break, my only agenda for the day was to dig up the internet to find companies and organisations that would probably be interested in sponsoring our project, get their contact information and send them the project proposal, and then resend it every week if they did not respond. I had faith that *someone* would be interested to fund my project, so I did not give up. After over two months of spamming, I received a call from the IEEE Xplore Manager, Mr. Dhanukumar Pattanshetti, asking for more details of the project. I then realised that the email I had sent, had bounced off the highest hierarchies of IEEE managers, before landing to Dhanu. Dhanu has a senior colleague in the headquarters of IEEE at USA, Kristen MacCartney, who manages the IEEE University Partnership Program, which is a collaboration of the top 16 US Universities including MIT, Stanford, UCB, etc, and IISc in India. She asked us to fill up a form with our project details. A week later, I received another call from Dhanu saying that Kristen had agreed to sponsor $750 (Rs. 45,000)! This was great news for us because it would cover the major expenses of the project.

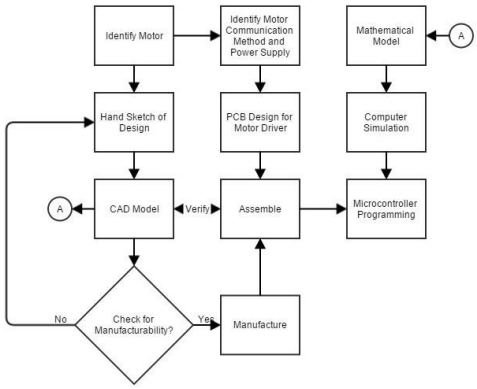
These were the organisations that responded positively – All of them except IEEE expected us to be a registered company, but nevertheless, it gave us confidence about the potential of our project.

At around the same time, we wanted to start a Robotics and Automation Society Student Chapter in our college, and coincidentally, Kristen was to visit Bangalore for official purposes during the same time. So we invited her and Dhanu as chief guests for the inauguration. Before the event, Dhanu told me that we were in for a big surprise during Kristen's speech. And that was true. She announced that she was doubling the funds that she had allocated for our project! Over lunch that day, we learnt that the funds that were initially meant to be given to GeorgiaTech and IISc, were being given to us! This made us all really proud.

After getting so much funds, we did not want this project to end up as just another hobby electronics project. We really wanted to involve some core Robotics concepts. For that, we required very good guidance. So we met Prof. Ashitava Ghosal of IISc, who has a PhD from Stanford, and does research on robotic manipulators. After that, we had very little time before our final exams, but we still managed to work on a miniature model that ran on mini RC servo motors, but we weren't able to complete it.

Miniature Model

As soon as exams got over, we resumed our work. We hardly had four months to complete the final prototype, so we decided to discontinue the miniature model and start the work on the actual model.



This is how we proceeded since then. At this point, we faced several people who told us that we cannot build such an ambitious robotics project in India, and definitely not within four to five months, but we continued to work on it. Until the 3D CAD model stage, everything looked rosy, because we assumed that we can 3D print the entire robot, and that we do not have to break our backs getting them manufactured separately. We got in contact with senior managers in Bosch to help us out with the 3D printing, but we did not completely rely on Bosch. Once we got a hint that we couldn't get much help from Bosch, we set out looking for alternate 3D printers. But we realised that 3D printing the entire arm itself would go way beyond our budget. This was when we had to look out for alternate materials and manufacturing methods. It turned out that this was the toughest challenge. Even though India is considered the manufacturing hub, it takes a lot of patience and persistence to find the right materials, and manufacturers who are ready to fabricate just one or two quantities of the parts. It is possible to find several manufacturers who will be eager to take up over 10000 numbers, but not one or two. This was the time when we faced a lot of criticism for our design, and many suggested us to entirely change the design to make it very easy for manufacturing. It was too late for that, and we would be compromising some of the functionalities of the arm. At this point, we were almost clueless about what to do next.

Around that time, there was a conference at IISc, where we met Prof. G.K. Ananthasuresh of Mechanical Department. We showed him the 3D CAD model after the conference, and he suggested some minor modifications, which reduced the amount of 3D printing required by about 80%! This was a great relief for us, so we set out getting the rest of the components manufactured. After two months of back

breaking rides to Peenya under the hot sun, standing there from 11 AM to 9 PM, explaining the design and negotiating with workers who looked like they could murder us anytime, we finally got all the parts manufactured. We also found an inexpensive 3D service dealer where we got the minor parts printed. Not getting help from Bosch turned out to be a blessing in disguise, as we were forced to learn about different materials and manufacturing methods.

Simultaneously we learnt how to design a PCB for motor control, and got them manufactured. We put together everything, assembled all the parts, and everyone, including us, were surprised that we actually got the real model very close to the computer model, which is very rarely the case in R&D.

We hardly had a few days before the Project Open Day in our college, when we started programming the robot to perform simple tasks, but we got through it. The project attracted a lot of audience, and it became a favourite among several lecturers and juniors. Many of them could not believe that we, as mechanical engineers, were able to work on the electronics and the programming parts of the robot as well. The motors and the power supply were the only ready-made components that we had bought. Rest of the 20+ parts were designed by us, customizing them for our required dimensions. Not a single part of the Robot was imported from another country. Everything was designed and manufactured right here, in India. We were fortunate to get the Best Project award by the Department of Mechanical Engineering on that day, but what really made us happy was the little inside information, that not a single staff of the Mechanical Department had voted for a project other than ours.

We were very fortunate to get help from the right people at the right time. And In the end, we learned that anyone who thinks Make in India is next to impossible, just doesn't know where to look, or does not have patience, or both. Though the project is on-going, we know that it is definitely possible, to Make in India.

The Multipurpose Supernumerary Robotic Limbs saying "Hi" to the audience on the Project Open Day.