Microsensors, Implantable Devices and Rodent Surgeries for Biomedical Applications

TA: Ajay Krishnan A, Course Instructor: Dr. Hardik J. Pandya
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

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Greetings everyone, welcome to the NPTEL lecture, Microsensors, Implantable Devices and Rodent Surgeries for Biomedical Applications. In this lecture, we will be taking a brief look at 3D printing. So 3D printing is a new generation of manufacturing technique where we use layer-by-layer manufacturing to make an object. So let us have a live look at some of the 3D printer devices. So this is an SLA 3D printed object which as you can see is complicated based on its structure. This has a flexible element as well as a ridge in the entire rigid body.

And now you can see an FDM 3D printed enclosure cap which you can see some of the standoff and like connections that you can place on a box-like structure. This is FDM 3D printed and you can see another model that is very complicated to make in conventional practices which might require one week or two weeks to do the same thing in a conventional machine process. This thing can attach to a syringe and it will hold the syringe properly. You can see some of the complicated structures here which have a self-locking mechanism too.

So I will just demonstrate how it works. So this is an enclosure for a PFS. So nowadays 3D printed devices or 3D printed objects are widely used in almost every industry. You can see 3D printed objects in the aerospace industry, healthcare industries, automotive field or almost everywhere you are seeing. Even architecture uses 3D printed models to demonstrate what they are going to build in future.

So the client will get a clear idea about their dream houses or even if there are some areas in the house how it will look in real life. So I will just give you a brief history of 3D printing. 3D printing was first developed by Chuck Hull in 1986. Now he has formed a company known as the 3D system which is one of the most famous and renowned companies in the 3D printing industry. The first system of 3D printers he generated was known as a stereolithography 3D printer.

You can just see the printer on the screen. This was the first printer that he developed. It is known as SLA 3D printer where you use resin, wet or resin and that resin will be cured by UV lasers. So after that around the end of the 1980s new technologies like FDM or fused deposition modeling and SLA selective laser sintering. Such new technologies were introduced.

Around 1996 Chuck Hull made his first 3D printer commercially available which means the public could buy those 3D printers and use them and it took almost 10 years to make the first high-definition color 3D printer. Till now or till then there are only 3D printers that can print in single colours or mono colours. After 2005 Spectrum Z510 introduced a printer that can print in multiple colours and it also had very high definition. So now we are in the era of rapid manufacturing where we used to make an object quickly. So earlier if we needed to make an object then we needed to sketch on paper and convert it into some kind of object.

Now there is software known as CAD software meaning computer-aided designing software where you can design the entire thing in a computer and give that model for manufacturing. So rapid manufacturing can be classified into two main categories: subtractive manufacturing where you will be removing layer by layer and making an object. So we will discuss details about it in the coming slides and then we have additive manufacturing like 3D printing. So what is subtractive manufacturing? Subtractive manufacturing is the process of creating an object or creating a final product by removing material from the initial large piece of material. So in subtractive manufacturing, you can even use wood, plastic or even metal and the main advantage of the subtractive manufacturing process is that through this process we can achieve a very high tolerance and very high surface finish.

So nowadays also in most of the aerospace industries and everything we are using subtractive manufacturing to produce high quality and high surface finish byproducts. Like there are 7-axis CNC machines where you can produce many complex shapes like very intrinsic shapes that have objects inside some of the shapes, those structures can also be manufactured in subtractive manufacturing. So now we will jump to 3D printing. So how can a 3D-printed object be made? There is a list of steps or list of procedures that you need to follow then only you will be able to make it like an object from 3D printing. So the first one is of course you need to make a model.

How will you make it? For 3D printing you must rely on some if you need to make a model from scratch then you need to use CAD software to make a model and then you need to convert that model into some other machine non-language and depending upon which kind of technology you are using you need to like process the object so you can use it for the end application. So, we will discuss more about the workflow. So to make an object to make a 3D printable object first you need a file. So for example just look at this mouse you need to make this mouse if you need to make a 3D model of this mouse you have multiple options. The first one is that you can actually take the dimension of every coordinate of this mouse and then you can use 3D software or 3D modeling software to make that mouse.

Another one is you can use a 3D scanner. What is a 3D scanner? A 3D scanner is a camera-like device that we can use to scan the entire object. The 3D scanner will scan every point of this if you need to make a 3D model of this mouse. That scanner will scan the entire mouse and generate a 3D file that can be sent for 3D printing. So again the next one is CAD software which I just explained you need to build the item from scratch itself then comes the photo scanning. So what is photo scanning? Nowadays I think you can see miniature models of yourself like you can have a printed model of yourself. So you will be in a photo booth where you will be covered by hundreds of cameras.

There will probably be hundreds of cameras all around you and those hundred cameras will click your picture at the same time and then that will transfer your image to some computer and the computer will do the post-processing and make a 3D file from those hundreds of images. So those images we will convert into a 3D file and then that 3D file will be converted into some of the formats known as STL or OBJ. The STL is the file format that we have been using for decades which is the most acceptable 3D printing file format. So it is a mesh file. Once we generate an STL file or OBJ file we will send that file to a slicing machine or slicing software.

What slicing software is now? Slicing software is software that depends upon which machine we are using. We will be using different kinds of slicing software. So those slicing software will slice our model layer by layer and then it will convert it into a code or a program that our machine will understand. So first we will generate a 3D file then we will convert it into an STL file then the STL file will be given to the slicing software. So the slicing software will slice our file into different layer-by-layer steps and then it will generate mostly G code.

For example, if we are using FDM 3D printers it will convert it into G code and then send that file to our printer for making the end object. So now let us take a glance at what all 3D modelling software is available. So based on what we need to create we will select different kinds of 3D modeling software. There are hundreds of 3D modelling software that are free or paid, which need to be installed on your computer or can be used online or available. For example, if you need to make something that is just for animation purposes which you just need to render and see you can use some software kind of blender which is widely used industry for making animation kind of things and everything or if you need to make something which is dimensionally accurate then you need to go something like solid work or fusion 360 or inventors software and all.

Why do we need to use Solid Works or Fusion 360? Because these softwares can make something that is dimensionally accurate. The reason for choosing the correct software is that we will get more industrial support. Solid Works is the software that is mostly accepted in almost every industry. So if we know solid works then it will be very easy to adapt from one industry to another but the one disadvantage is that there are no free versions or student versions available for solid works. So even if you want to learn it you can use Fusion 360 or Inventor and another beauty is that if you know one software then it will be very easy to shift from one software to another because the basic tools used in almost every software are the same.

So it will be very easy to migrate from one software to another. As I said Fusion 360 and Inventors will be freely available for students and self-study so you can download that thing and you can make some models on Fusion 360 or Inventor, once you have mastered it then you can shift to solid works. So now we will learn or check different 3D printing technologies. There are many, but in this lecture, we will only discuss a few of those. So the first one is fused deposition modeling.

FDM 3D printing is nowadays widely used because of its cost-effectiveness and because of the surface-like finish it can provide. In the FDM 3D printer we will have a spool of filament. It can be either plastic, it can be metal or it can be ceramic and then we will supply those spools of filament to something known as the extruder. What will the extruder do? It has motors to take this filament and then the extruder has a heated element. It has a heater inside that will melt those filaments and this extruder is connected to motors to move in the X, Y and Z axis.

So the extruder can move all around the print bed and deposit the material wherever we want. As I said earlier the slicing software will convert those like models to machine-specific languages and it will load to this printer. So once it is having the sliced machine data the extruder knows where to put material and where not to put material. So there are different kinds of FDM 3D printers some only support one extruder or one nozzle some have multiple nozzles that can support up to 6 or 10 filaments and this specific one is having one like this specific one can support two extruders and two filaments, one which is the main material and another one which is a support material. So in FDM printing you must need a support material for overhanging parts.

Otherwise, we will not get that many high-surface finishes. So this is the print bed and once the print is completed you can just simply remove the printed part if you have a support material that can be removed either manually or there are support materials known as PVA which are water soluble support materials. So once you have the part in your hand you can simply put that material in some kind of lukewarm water and if you just agitate it or if you just mix it that water-soluble material will be dissolved into the water and you can take the object without any kind of support materials and that kind of thing will be much higher in surface finish and all. So coming towards the materials used, the most common ones we use are ABS and PLA. PLA is the one that we are using so regularly because of its low melting point and it can be used because of the low melting point it can be used in almost every 3D printer and it will produce high surface finishes too and even there are high-end printers that can support metals like aluminium, copper, stainless steel etc.

So now we look at some of the commercially available or different kinds of FDM 3D printers. So the one on the top is known as a Cartesian 3D printer. So here you can see the nozzle which is attached to the X-axis. So this nozzle can move in the X axis and this axis is attached to a motor that moves it in the Z axis. So here in this 3D printer, the nozzle can move in the X axis as well as the Z axis where the bed is attached to a motor which can move in the Y axis.

So this nozzle will come down, print a layer and the nozzle itself will go up while the X axis movement is controlled by the motor attached in its bed. This specific model is Creality Ender 3 which is one of the widely used 3D printers because of its cost effectiveness and actually, it can also produce much higher resolution prints. So now you have a metal 3D printer. This works exactly like the one we saw here. Instead of plastic filament it will take metal filaments.

It will take metal filaments and an extruder is that capable or can withstand high temperatures up to some 800 or 1200 degrees Celsius, melt the metal and put it on the like print bed depending upon which kind of printer they are using nozzle will go up or the print bed will come down and opposite the subsequent layers and as such the process will go on. Now we have a Delta printer. The Delta printer is so much different from that of a Cartesian printer. This is the nozzle and this nozzle is attached to 3 motors. Directly it is attached to 3 motors and these are the 3 motors and these 3 motors will control or will decide where to move this like an extruder.

These 3 motors will work simultaneously to move this extruder in X, Y and Z direction. The main disadvantage of this mechanism is that it can only print like its print bed can only be a circular one. So the area that it can print is very minimal and on the other hand, this kind of delta 3D printer has very high speed. Now this is known as core X-ray printers which are the most accurate 3D printers available now. This one is Ultimaker which is a very famous brand.

So here you can see the bed. The bed is attached to the Z-axis. So here the bed will move up and out while this extruder is moving in X and Y direction. So and in the core X-ray printers motors are actually stationary. It won't move. What is the advantage of making a motor stationary? If the motors are stationary it will reduce the inertia on each axis and it will provide a precise control of the extruder.

So here you can see motors are connected to the X-axis. So once we are moving the axis when we are moving the extruder the motor inertia will also come into play. So there will not be that much precise control as we will get in Ultimaker or as we will get in core X-ray printers. And another advantage is that the printed thing is moving in the Z axis like it is moving up and down. So in the 3D printer Z axis is the axis which is having the motion so the slowest movement.

So after every layer it will move up or down by only 0.1 mm or 0.2 mm depending upon the solution that we give. So we will be getting a very high surface finish with very high quality of print out of these kinds of printers. There is something known as layer shift in printers. We will be able to differentiate between two layers if it is like we will be easily able to differentiate between two layers which are very common in this kind of cheap desktop 3D printer.

But it is very like we can differentiate but which will be very minimal in core X-ray printers. Now we will talk about stereolithography printers or SLA printers. As we discussed, SLA printers are the first printers that were invented but the thing is it is a little bit on the costly side because of the technology they are using. In FDM printers we discussed that it uses a solid material to make the object while here we are using liquid materials and these liquid materials are photopolymers. So we will be using a liquid material. We will be filling that liquid in a vat or some kind of container and then we will be shining UV laser light to that.

This UV laser will be very precise in that it will be in the range of 25 micrometres or even less than that and then we will shine that spore to particular places where we need objects or where we need the resin to be solidified. Once the entire layer is completed then we will have the print platform which will go either up or down depending upon which kind of printer we are using it will go up or down and then the same process will repeat once again. So layer by layer we will be getting a 3D object exactly like in an FDM printer but here it will be more precise or more dimensionally accurate. We have a wide range of materials, here we have a standard resin which is just for prototyping and representation purposes and we can even use dental resin which is biocompatible. So I think all of us have seen dental retainers and aligners.

These can be 3D printed using SLA machines and even jewelry resin. So if there is a very complicated or very high-end model that is very difficult to make in the conventional processes we can 3D print it and then we can use that as a mold and engineering resins are used for making something that is rigid and needs height or alterations for making some prototypes or something. So these are some of the commercially available SLA 3D printers. This one is an industrial SLA 3D printer which is very big and is used for making some of the prototype level application industry. For example in the automotive industry if we need to make a car body or a car structure then actually you can use this kind of 3D printer to make the part piece by piece if you need to make a door you can print the entire thing in a single machine and then you can assemble it check whether it is fitting or if it is having some kind of modification required or something like that.

And then you can move on to final processing like actual die-cast mold making a door. This is Formlabs 3BL which is desktop 3D printing which we will see and discuss more in on lab sessions. This is a desktop 3D printer where you can make a smaller-sized object for engineering applications and even for prototype developments. Both of these things work similarly with similar technology only the size is varying here and industrial 3D printers can work for hours without shutting down and all.

These are the post-processing machines. In SLA 3D printers post-processing is a very necessary part. So what we do is that once the part is printed we will take out the part from the printer bed and then we will put it for an IPA wash. We will be putting the part on the IPA washing chamber. What it will do is it will wash the remaining resin that is tucked or stuck onto the object that we printed. So in which way even if we print layer by layer there will be an unwanted resin which is attached to that part.

So once the IPA wash is completed IPA will dissolve all the non-cured material on the printed object. And once the IPA wash is completed we will generally go for drying it, mostly air drying it. Once it is air-dried it then we will place it in a UV chamber. So once the part that is straight out from the printer is almost 90 to 95 percent cured it might not have the complete mechanical properties of the resin or what the material is supposed to have.

So we will cure it. We will cure it again in a UV chamber for different kinds of resins will have different times and different temperatures to cure. Once it is done then the part out of the squaring chamber will have the most or will have the actual mechanical properties that the material was supposed to have. So now it is selective laser sintering. The next technology is selective laser sintering technology.

First, we saw solid wires to make a 3D model. Then we saw liquid which is used to make a 3D model. Now it is a powder-based manufacturing process. So in SLS what it is like how SLS works is that we will have a chamber filled with powder and this will be the bed which will be going up and down. So at the initial stage, this bed will be at this level and we will have surplus powder filled in these chambers. So we will have a laser unit that will deflect the laser beam and will be deflected through mirrors. This laser is used to sinter the powder so it will make it bond the powder molecules together to make a solid mask.

I hope you understand it. This laser will deflect the light to the exact point where we need to make a solid object and all other remaining parts will be left like left as it is like powder is as the powder is. So once this layer is completed then this thing will the print bed will move down by for example 25 microns or 50 microns depending upon what resolution we need and then this roller will again fill a uniform layer on top of the previously printed and this laser will again sinter the area only which we need to have a solid mass of material. So this is a step-by-step process and once everything is completed we will remove this powder or remove the printed object and then we will go to the post-processing stations. So the major advantage of this SLS machine is that, unlike the previous two mechanisms, it does not require any kind of support because the unsintered powder material will itself act as a support material. So the surface finish will be like it is not that much greater compared to SLA but it is like post-processing will become a little bit easier and those are not used powder we can reuse it that is one of the advantages.

These are the different kinds of materials that we can use. We can use plastic, we can use nylon, metal, ceramic and composite. There is a wide range of materials that are like new materials are invented each day. So now we can see some of the commercially available SLS machines. This is one known as fuse. This is a fuse one 3D printer, SLS 3D printer which works on the same mechanism that we just discussed. We have a build chamber or a powder chamber here and this thing will heat the material like the chamber will be heated to a particular level and then like after every layer there will be a build platform which will down by for example 100 micro one another then it will again sinder the part where we need the like solid mass and it will continue. This is actually a desktop SLS machine and here we will be having an industrial SLS machine which is quite big and which can run for a long time the same as the SLA machine here also we need post-processing.

Here what we will do is that once we take the part out of the print chamber we will bring it to a post-processing unit then we will first remove the excess material that is attached to the printed part. Those parts we will be using high-speed compressed air to remove those excess parts and then we will be taking those clean parts to another sintering machine which will heat it a little bit more. So the particles will be perfectly bonded together and this kind of printer would not have that high level of material accuracy or high level of print accuracy. So we will be taking it to a sandblasting chamber or something and then we will be getting a relatively better quality and a better surface finish than earlier.