Computer Aided Decision Systems - Industrial Practices using Big Analytics

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Lecture 37
DSS in CAM (Part 1 of 2)

Welcome to week nine of the course, we have discussed various aspects of the Computer Aided Decision Support Systems and some case studies on Big Data Analytics. How is it supporting the Computer Aided Decision Support Systems in a way? Professor Deepu Philip has covered a few basic languages and also, he will try to cover HTML in the coming weeks. It is a markup language that you need to understand to finally display what you have understood in the previous weeks.

I have discussed in the week section majorly the Decision Support Systems for Computer Aided Design and Computer Aided Manufacturing. Majorly the focus was on Computer Aided Design in the last week. I have discussed geometric shapes, what are the geometric shapes, what are different kinds of the Geometric modeling, features that we have, what types of Geometric modeling, we shed light on the Surface modeling, Wireframe models and Solid modeling the different applications and uses of them.

How is Computer Aided Designs supported by the different libraries that we also try to see using the CNN the Convolutional Neural Network system where the different shapes are there and applying to the object that you are trying to replicate that could be taken from different library shapes and you can identify the specific shape, while classifying and matching with the existing one and you can set into a specific class and try to take the features of that class and start to develop the model from there. This is how Big Data Analytics has helped us to have a closer information or understanding of the drawings that we are trying to develop, that means the people who are not from the manufacturing or the CAD-CAM background can also start their own designs.

Yes, final wetting is to be taken by the engineer who is a CAD engineer. That person would help us to have the proper tolerancing and that would be definitely supporting you.

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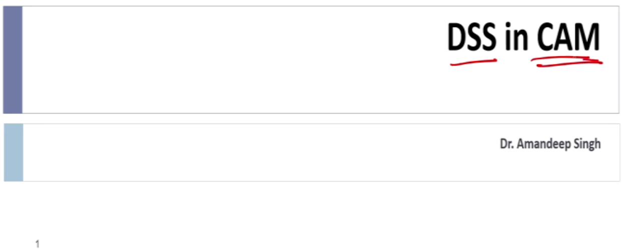

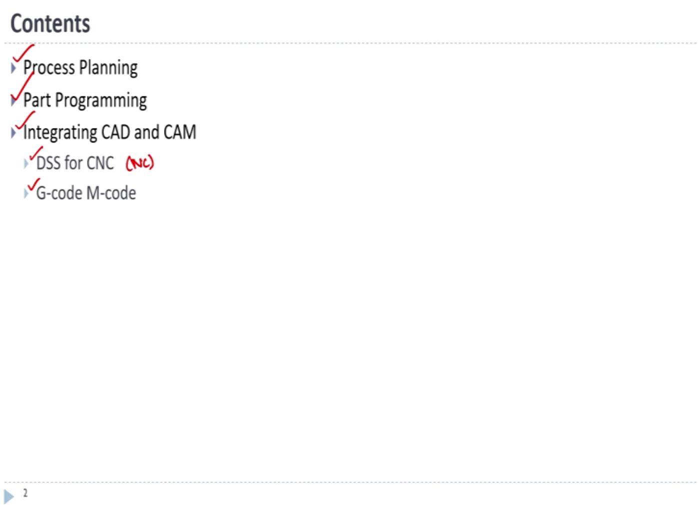

This week would be more focused on the Decision Support Systems in Computer Aided Manufacturing. Since we discussed the Neutral Files or the Product Data Exchange in the last week and also, we understood that the post processor is the one that communicates with the Machine Tools finally.

But yes, there are many other things that are still needed to be discussed because the decisions that are to be taken or to be communicated to the Machine Tools requires certain steps in between, that is why I have designed this lecture to understand first thing is the,

i) Process Planning, what is the Process Planning like we discussed about the Assembly Planning or Assembly Tree in the last week. The Assembly Tree is just like a decision tree as we saw last week. Similarly, there are certain other decisions either to be taken, certain other formats to be made which happen in the Process Planning. Assembly planning is one of the only parts of the Process Planning.

ii) Part Programming is when you have the geometrical dimensions and then, you try to now have a program on them so that you can finally execute them for the manufacturing.

So, that is Part Programming in which we will also see how we integrate CAD and CAM, what are the different steps or different languages in it. In which we will see different Decision Support Systems for the Computer Numerical Control Machines. We will start from the NC only that is the Numerical Control. The final communication is taken by the different code systems, this is one of the systems that is the G-code and M-code that will also put some light on.

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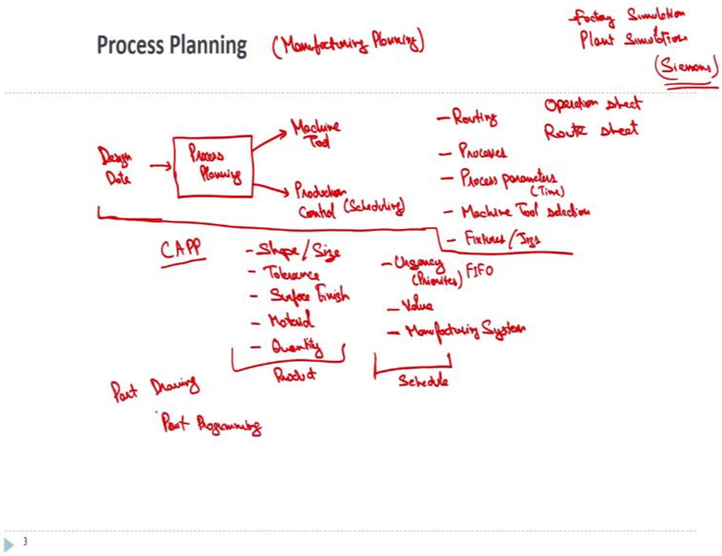

i) Process Planning, it is as a term itself is planning of the process which means that the steps that you are going to execute for the manufacturing that you are going to plan prior, it is also known as 'Manufacturing Planning', it results in an increased output, higher precision, faster turnaround for vital business tasks, it is described as a set of procedures that you follow to have a specific output. So, generally what I could say is converts input into output when we flow through it.

So, Process Planning is my processor in which the input is the design data and as an output we communicate to Machine Tools and production control. In the production control there could be scheduling, there could be routing, certain activities are there, if I try to list those activities,

- Routing- We make certain documents that we call an Operation Sheet or Route Sheet that let us know how the specific job would be manufactured. For instance, if you need to manufacture, maybe this pen stand has a top body, it has a bottom, how would this be manufactured, this is an assembly of two components, these two components would be fractured separately on an injection molding machine, then this would be assembled. For assembly, there would be a different setup of the machines that could do it. So, these steps would be the first two components are manufactured, the next step is the Assembly part. So, this is known as a Route Sheet. So, we have Operation Sheet and Route Sheet which has different headers such as the serial number of the job, the department from which it is coming, the operation number or the job number, or the specific operations that are to be carried on the job, the machine that is there, tools, gigs and fixture which are required for the machines that will also come, then time per piece, date that is the start date and date start time and time this all could come.
- Processes- Along with routing, we have processes, when I say processes, it could be any of the processes that is the machining processes in the Additive Manufacturing, it would be the printing processes what kind of printing are we taking into account that we will discuss in the coming lectures in this week only, the Radio Manufacturing Technology and the Processes. In the general processes for manufacturing, I could say different machines for the rectilinear jobs, it is generally milling or maybe shape tools is there, for the curvilinear jobs we also do some milling and also lathe is also kind of a milling operation some people consider it just as a kind of milling operation where we only control the rotary motion.
- Process Parameters- Process Parameters if I say, it could be surface finish. Majorly, that time is the parameter that is focused upon that is what time it is taking for drilling because time is money that is what is called in a business. So, lesser the time it takes to produce the products to the conformed quality, the more would be the production or throughput more would be the profit. So, Process Parameter time is one of the major parameters that is taken into account.
- Machine Tool selection- Machine Tool could be any of the machines that conforms or that could work on the processes that you have here at the second point.

- Fixtures (Jigs)- Now operation plan sequence and summary of the process plan is made that helps us to execute it to take it to the Machine Tool and the production control in which schedules are also made. Scheduling I will put it as ‘S’. To put it in a lecture, I would say the aim of the Process Planning is to identify appropriate supplementary information from the drawing to aid the processes that is to have the dimensional information, the geometric information from the drawing or the design and try to communicate it to the Machine Tool and try to have the final output out of it.

So, Process Planning helps us to communicate the things to the Machine Tool. Nowadays, that we talk about is known as computed aided plus process planning.

The Computer Aided Process Planning or CAPP is something that goes beyond the production control even that means because computers are involved. These days now we do something known as the factory simulation, though the name is Process Planning only but if I say a word process simulation, process nowadays is more typically used as a word for the machining processes. If I say a process that is for manufacturing specific components, if I try to have a Computer Aided Engineering that is the finite element analysis over it that is known as a process simulation. For this process, what would be the simulation of how it would work, or for the specific machining of how it would work, this is known as process simulation, that is the Process Planning helps us to do.

In the factory simulation we can even simulate how do we schedule the machines, how do we put machines in a layout, at what distance the machine could be put so that the material travels from one point to another and where do we keep the material, the work in progress inventory then, who would operate it all this is taken care, this is also known as plant simulation.

‘Siemens’ is a company that took a major lead in it. Being a little out of the scope of this course this could be taken in the coming courses that would be an extended courses to the present course only where we will discuss the product life cycle management, we will talk about the plant simulation softwares and how does these help in a present-day life to make our life easy in a manufacturing concern.

So, majorly in a Computer Aided Process Planning the factors that help or that affect the process plan selections are the,

- Shape/Size- For instance, in 3D manufacturing, if you need to produce a big size of a print, maybe we have a machine the size of an envelope one meter by one meter by one meter. Such a big component as a one piece, in Additive Manufacturing that is possible or would you like to manufacture the components in two three different parts and try to assemble them, that is more important when we consider the design for maintenance. For maintenance, sometimes you manufacture the components so that you can replace them easily. You can maintain them easily, so modular design is more taken into account. Size of the component is also one of the important factors that helps you to plan the process
- Tolerances
- Surface Finish.
- Material type- This is the kind of the material or the product that you are trying to work upon.
- Quantity

When you are talking about the schedule or the routing for that here urgency I will put as one of the points that what is the priorities that you set for the product, that is generally first in-first out option that you try to follow but sometimes some products are required urgently to complete some other assemblies or so. So, then this becomes a more important factor, then the value that product is offering you, then the manufacturing system itself. So, this is the Process Planning. Now, when we talk about the shape, size, tolerances of the product. We always have to consider the part that we are trying to manufacture, that is we need to have a part drawing with us. The part drawing has the geometrical and dimensional information, here comes the role of the Part Programming.

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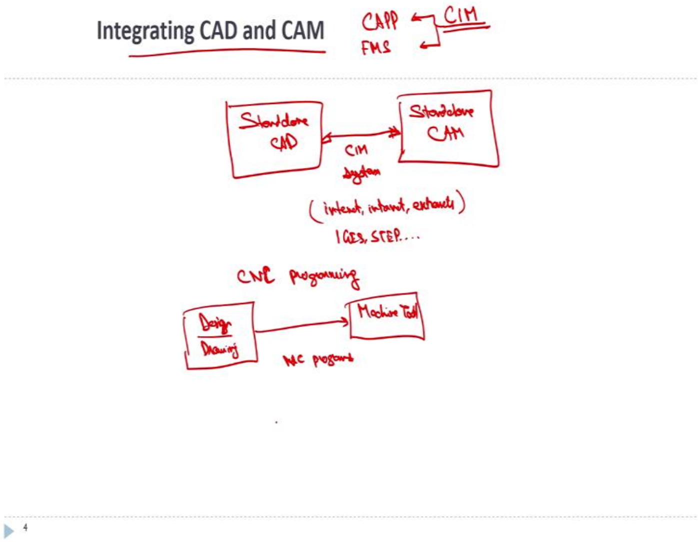

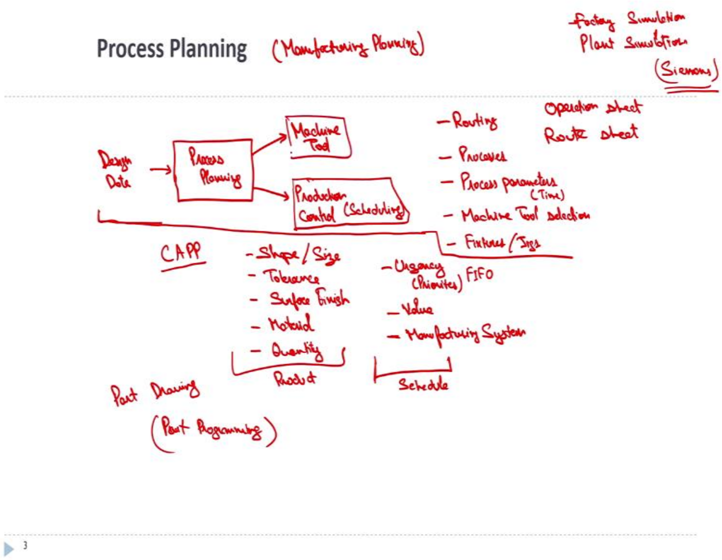

But to Integrate the CAD and CAM Computed Aided Process Planning plays a big role and to increase productivity and reliability in an increasingly competitive market nowadays, this integration is imperative. This is something taken into an umbrella of Computer Integrated Manufacturing where we have computed process plans, we have flexible manufacturing systems where CAD, CAM, production, management on automated assembly all come into a single channel and try to communicate with each other.

The achievement of a true Computer Integrated Manufacturing system is a challenging task because CAD and CAM data are heterogeneous and incompatible. Though Neutral Files helps you to transfer the data to the Machine Tool, but to have the data for the production control as well, you need to understand the data in a better way. So, sometimes the geometrical data that is stored in a CAD database is of no use to the production management directly.

On the other hand, that data related to the production management sometimes is of no use to the design department, those all go in different directions so that is why I need to have a common system that tries to integrate them, so, that is what we call computer integrated manufacturing only. So, to meet a challenge to have a centrally integrated CIM database we need to have an attractive practical link between multiple standalone CAD and standalone CAM communication between them.

Now, the linked CIM system would rely heavily on the communication software that links these hardwares mainly the computers, so, with the advent of internet, intranet and extranets, we have solved many of the networking problems nowadays, that is the communication protocols at the software level such as we have the programs or the formats such IGES, STEP or many such have achieved a similar success.

Now, we have a crucial step in CNC programming that helps to communicate between the Machine Tool and the Design, here I said Design I could also say my Drawing. So now, not only the Neutral File would help us to do it, the post processor also needs to understand something and it needs to convert the drawing into the final usable format. Now, this is somewhere we have geometrical entities of the part which must be ordered properly. And, the Numerical Control information might be pushed in on a separate layer.

So, imposing these requirements on the generation of engineering drawing enables the automatic generation of the NC programs. When a program that is Numerical Control is taken using a computer it is a Computer Numerical Control when I say NC it is just a Numerical Control which is generally taken using a punch tape or a magnetic tape, this is the challenge where we need to have to work upon the Part Programming.

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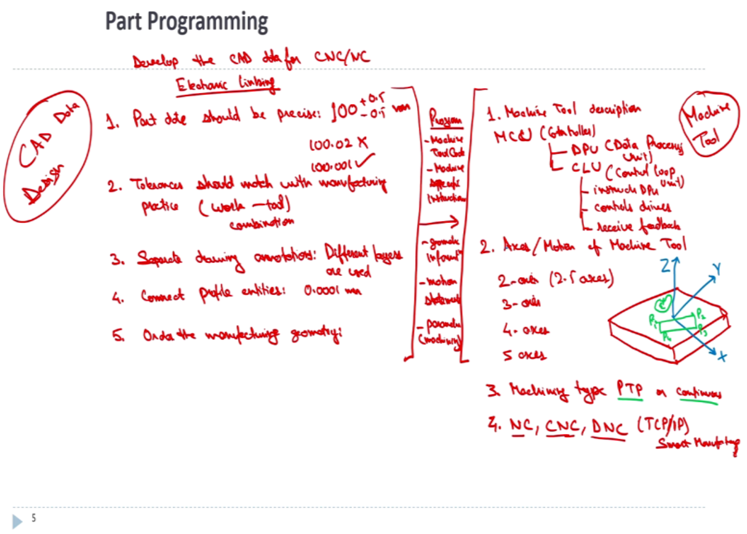

Now, in the power programming the first thing is we need to develop the CAD data for CNC or NC that means an engineering drawing that looks fine from the drafting viewpoint sometimes is not completely something that could be used, that is NC packages include translation routines that automatically format the drawings and convert them into the usable form and we prepared the drawing for the programming for successful what we call it as ‘Electronic Linking’. In these few points I will have to jot it down here are;

1) Pat data should be precise which means the coordinates must be accurate before the drawing is sent to the NC package. The accuracy of data is actually used within a round off of the truncation of the errors of the computer running the CAD software. For instance, if I have a tolerance of about maybe 100 plus minus 0.5 millimeter, I am giving a Binary tolerance here. So here, the nominal dimension if it is stored it has to be 100.000, if the nominal dimension is stored that nominal means the central dimension for the tolerance, if it is stored as something maybe 100.02 or something, this is not acceptable, yes 100.001 is okay. So, that is the path data should be precise depending upon the precision that we are trying to get through our program.
2) Now second is, now, since the tolerances have to be given properly the drawing tolerances should match with the manufacturing practice which means in the practice if the certain dimensions are given based upon certain standards which are there and we need to take into account certain allowances such as material deflection, such as the cutter wear out, all these tolerances, all these allowances are to be taken into account, when we are trying to give the specific tolerances here, that is the work tool combination

or matching. When since we need to give certain allowances for different kinds of the tools sometimes, or different kinds of the jobs that we are using, maybe the cutter if we have the specific virtual combination, for instance, if I need to grind a mild steel workpiece using an aluminum wheel or maybe from a ceramic wheel, the aluminum will be wear out faster. So, for that, allowances are to be given, or different workload combinations are there for a harder workpiece. For example, maybe a high-speed steel workpiece has to be then grinded, it could be more useful to have a ceramic wheel only. So, it depends upon what kind of combination we have. So, this is an important point that is considered.

3) Then separate drawing annotations from the drawing data to be given which means we place the annotation that is the nodes and dimensions and data. That is the geometrical entities on different layers, that is why I put two letters their G-codes M-code what are those other than G and M we have N, C other kinds of codes as well these are all different layers for to put annotations, to put the machine information, to put the geometric information, so all these are put through the different layers in a code. In a code when I say it is a communication language for the Numerical Control or computer Numerical Control.
4) Now, an important point here is that the profile entities must connect, which means a typical Machine Tool will cut continuously only within maybe 0.0001 centimeters, so, these entities should be connected in a way, so that within this tolerance, maybe say 0.0001 I would say, millimeter. So, therefore, it is important that CAD databases meet or exceed the Machine Tool accuracy.
5) Now, dimensionality requirements must be specified, so we need to have an order that is why we call it as rooting there for the manufacturing input, order the manufacturing, which means the geometric entities should be input in an order they are connected to each other. Maybe it could be clockwise or anti-clockwise; the pat has to be unidirectional that the cutting tool might follow. So, these require the designers to enter geometry in a manufacturing order, so that they could have a good creativity and productivity in their designs.

So, this part is my CAD data or my design, this has to communicate with the other part which is my Machine Tool. Now, since the NC program is a combination of the Machine Tool code, we have a program here which is

- Machine Tool code
- Machine specific instructions
- Geometric information.
- Motion statements
- Parameters such as cutting speed, feed or we call it some auxiliary functions or so. When they say parameters, these are machining parameters.

1) Now, the Machine Tool code and machine specific instructions would be definitely depending upon the kind of Machine Tools that we have. Here, we need to have a good description of the Machine Tools, that is we need to understand that the Machine Tool has a central processing unit that is known as MCU. Which is a Machine Control Unit. Machine Control Unit, that is one which is connected to the machine which controls the machine. It is also known as the controller unit or maybe the controller only as a short, people call it controller. So, it is the brain of the machine which reads the part program and controls the Machine Tool operations. It is not a single unit, it majorly has two functions that are DPU and CLU.

- DPU is my Data Processing Unit and
- CLU is my Control Loop Unit.

The Data Processing Unit reads and decodes a part-program statements and processes the decoded information and provides the data to the Control Loop Unit, the Control Loop Unit receives the data from DPU and converts it to a control signal. The data usually provides the control information such as the new position of each axis, its direction of motion, velocity, and some other controls.

- CLU instructs the DPU to read new instructions of the part program and control the drives that are attached to the machine lead screws and receive the feedback signals. So, CLU I would say instructs DPU, control drives and receive feedback.

2) Each axis of the machine could be set in a different kind of the axis or different kinds of the capacity that it could be moved or the kind of the motion that it could have, that is 2 axis, 3 axis, 4 axis, 5 axis machines could be there. The robotics which are not using the cartesian system we have the robots which are working in the polar coordinates that also work in the 6 axis or different degrees of freedom are given to them. So, to design the machine each axis has its own lead screw, control signals and its feedback control. So, that is for sure because each axis has to move independently that is how it goes. So,

this becomes our second part of the Machine Tool characteristics that is the axis of the machine, axis or motion of Machine Tool. So, because the workpiece is machined to finish shape by allowing a relative motion between the work piece and a cutting tool.

This relative motion is provided by either keeping the workpiece stationary and trying to move the cutting tool over it or sometimes the tool is stationary and the workpiece only moves. This relative motion is known as the motion of the Machine Tool. This motion of the Machine Tools can be into different axes as I said, it could be 2 axes, it could be 3 axes with 2 also, we have 2.5 axes, it is plural axes we have 4 axes and 5 axes machine. So, in NC Machine Tools each axis motion is equipped with a driving device to replace the hand wheel of a conventional machine because in the conventional machine suppose drilling to be taken, it is a hand wheel that helps us to do our drilling.

In NC machines it is a drive or a motor drive or some mechanical or hydraulic drive that tries to drive your drill down to do the drilling. So, a driving device may be a DC motor, axis of motion is defined as an axis where relative motion between the cutting tool and workpiece occurs, the primary three axes X Y Z are there, so, I will just put these axes here let me say I have a workpiece with me. So, we have in the X direction, Y direction and Z direction, X, Y and Z direction. So, we have two axes machine either the bed of the machine or the tool moves in a single plane. It can move in X direction, it will move in Y direction, it can control both the drives together to have a diagonal movement as well, but it moves in two directions only 1, 2, X and Y.

In 2.5 axes this third axis is independent; it cannot be controlled together with X and Y but bed can move in two directions X and Y and also it can be set into a third direction that is Z that is 2.5 which is controller which is manually controlled.

Then, we have the 3 axes machine in which X, Y and Z all of them can be controlled together that is my point can move not only in the planar motion from one direction to another in an angular way it can also go to a diagonally into 3D space in any way, so that is why we get the third axis here.

In a 4 axes machine, on the top of these three rectilinear motions this is a rotational motion as well. For instance, the bed can move in X, Y and Z direction. And, the tool can also rotate, this is the fourth axis.

In the fifth axis, maybe the workpiece can also rotate, there could be sixth axes machines as well, so this is the Machine Tool description on which axis motion that we have different kinds of here in the Machine Tool.

3) Also, we have two kinds of machining:

- Point to point
- Contour or continuous
- When I say point to point motion, the machine moves from one point to another point, that is from one point to another point my tool moves. So, maybe to cut a square or to cut a rectangle it will move from point 1 to point 2, to point 3, to point 4. Point 3 and point 4 on this plane. So, point to point it will first move the second point, third point will keep on moving, for each movement if you consider it as a linear motion between two points, that is it draws a line segment.
- In the continuous or contour machining, it will start from one point and try to make a curve, so, this is contour, the starting point and end point is all same, I will call it as C. So, Machine Tool can perform these two types of the operations or two types of machining, the point to point and the continuous, point to point machining is the simplest type of machining. So, the obvious example of this is drilling a hole. Drilling a hole at one point, then going to other point, drilling a hole another point, all these things are taken and when we write a G-code, when we try to develop the Decision Support Systems, the machine nowadays always understand by itself, the system is automated but we need to understand whether we are working with a 2 axes machine or we are working with 3 axes machine. If it is a simple drilling machine the point to point is only the type of the process or machine that it takes. The exact path of the tool is followed by moving from point to point, immaterial of assuming the time whatever it takes. So, tools should not collide or the work spot should be holding fixtures properly, these we will discuss when we will talk about the certain tool pat verification. In the tool pat verification with although we see whether collisions should not be there, or the double movement of the pass should not be there.

4) Also, it is up motor to understand that there are three kinds of systems in the Machine Tool it could be a Numerical Control, it could be Computer Numerical Control, it could be Distributed Numerical Control, when I say Numerical Control as I just discussed it is just a machine or program that is stored in a CD or it is stored in a system other than a regular computer. But nowadays whatever we have is the Computer Numerical

Control machines but the base is only, the GUI is only the Numerical Control machines. This is analogous to now we have Python, now we have Anaconda, different kinds of languages that you try to work and in the MATLAB you have different modules to work upon different kinds of languages, the base is generally the C language that you have learned. In this case we are trying to learn the NC program that helps us to make decisions in the Computer Numerical Control and the Distributed Numerical Control.

Now Computer Numerical Control is simply a Numerical Control where computer tries to control all the system and the feedback since information is also generated by the Computer Numerical Control and it is taken by understanding different variables such as machine down times, the work in process in the machine, the production rates, scrap rates and some other production data that goes as a data input in my production scheduling as well.

On the other hand, we have Distributed Numerical Control in which a central computer is there to which group of CNC machines are connected because separate CNC machines are to be put the data into. For each of them the data or the process would be taken as an individual process. For instance, if I have installed four exactly the same or similar machines. Let me say the Amco 250 drill I have installed, four machines are there. For each of them I have to operate them or put them the data together in a Distributed Numerical Control that can make a one program try to put workpiece at the specific location in the work table that I have and try to give a single program to all those machines, so, this is Distributed Numerical Control.

So, communication in a Distributed Numerical Control system is usually achieved by using a standard protocol that is we use the TCP-IP using the internet facility that we have, or maybe within a program, or within a system, or within your server it could be an intranet program itself. So, the central computer has various functions, that is it stores NC programs and it downloads these programs to any number of CNC Machine Tools.

It performs the feedback task for them, it provides communication between various components of the overall distributed network system. So, the major advantage of the distributed electric system is that it can be centrally monitored. It is very important when we are dealing with different operators, when we are dealing with different working shifts and when we are dealing with different kinds of machines.

So, DNC is the one of the systems that we work upon, so that is what we call overall, when we use TCP-IP systems in conjunction with the recent Internet of Things or Industrial Internet of

Things, we call it ‘Smart manufacturing’. It is too narrow a term at this point of time to discuss because we are basically talking about the GUI of the Part Programming that we develop for a CNC machine.

So, now I would like to take a small halt here and meet you in the next part of this lecture where we will discuss the Part Programming features and how we actually design a G and M-code. Thank you.