Computer Aided Decision Systems - Industrial Practices using Big Analytics
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Lecture 34
BDA in Computer Aided Design

Welcome to the next part of this week where we are trying to discuss the Decision Support Systems for Computer Aided Manufacturing.

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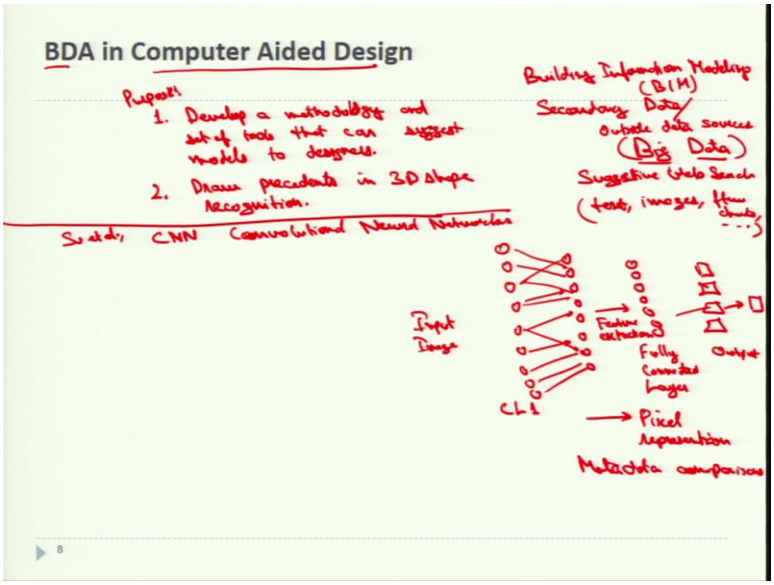

Big Data Analytics plays an important role in Computer Aided Design, there is something known as Building Information Modeling or we call it BIM. So, these are known as BIM engines or BIM engines, where CAD software or architects constantly translate their intentions into lines and surfaces in 3D space. The potential method to improve their design process is to suggest pertinent 3D objects derived from outside data sources, that is we try to use secondary data or outside data sources, this is our Big Data.

Now, there is something they call it as suggestive web search. There are multiple websites which have the database available with different libraries available to them, like we have designs available at the arena chorus or the Glass popper, these are the software's that helps us to design using just wearing the shapes with little information in manufacturing or in architecture. People

can have the basic designs done on the software itself. Software means these are the online platforms which helps us to have the basic information or the idea of the design that could be used later to have a very detailed design that could be finally used in manufacturing, in construction, in electrical engineering, in the circuit design in electronics, wherever you say, in the engine design, in the Rolls Royce so on.

So, at its core, a recommendation engine can search through huge databases for pertinent information. This information that they give us is in the form of text or images, sometimes the flowcharts and so on, the users can use it for a particular interface. So, there are a variety of machine learning or analytics, which helps us to classify the information and try to have the best alternative or comparable and have complimentary design options. So, the purpose of the Big Data Analytics in the Computer Aided Design and Manufacturing is,

1) To develop a methodology, and set of tools that can suggest a model that designer can draw, when I say models, I am talking about CAD models here, models could be suggested to designers.
2) Drawing on the precedents in the area of 3D shape recognition and classification.

So, here two objectives would be to expedite the 3D modeling with the pre-model suggestions, and to motivate designers to have the alternative design while having the basic design within themselves from the secondary information that they have. And, they can complement the existing designs. They can maybe have basic information from them and completely design a new model by themselves. So, this is how we try to use it. There are multiple studies which have been taken on this challenge, I would take a study taken by Su et al. which was published in IEEE explore in which they used the CNN. CNN is Convolutional Neural Networks. Convolutional Neural Networks provide very convenient and thorough alternatives to traditional geometric descriptive matrices in which the images that are taken as inputs, and they send pixel representation to a series of layers of neurons.

So, in a way there are different connections that we have and we have the basic layer here. We have an input image, which tries to connect to a convolutional layer, we call it convolutional layer 1. And, these neurons have different pixel sizes here. They try to connect to the next layer, which tries to identify, whether what image we are trying to see, whether it is the image of a chair, or the

image of a car, there are certain network points that are different. I would say connections are just like whenever they say neural networks. So, they can connect to each other and we have then after certain layers, we have a fully connected layer, we call it convolutional layer 2 or 3 at one point we get full convolutional, fully connected layer and we get the output here the few outputs are taken in which, finally we get the class where these falls. So, this could be taken from the examples or the animations which are given in their reference slide of this lecture. So, how the neurons do connect with each other and will try to make the decision based upon the past connection. For instance, if you say chair it can take or make me consider a chair, something that is being very similar to a toilet seat, or maybe to a stool, or maybe to something where the person generally sits or so, or depends upon the executive chair. If you are trying to follow it will try to connect and try to see where it is matching that we will see what is a study and where do they try to connect these things.

So, CNN takes images as inputs and sends pixel representation, So, this is we are sending pixel representation. This is sent to a series of layers of neurons. So, instead of matching simple matrices, a process here is known as Feature extraction. So, CNN models produce a prediction at its final layer while fine tuning the weights at each neuron. So, one can estimate the model's accuracy through the iterative training and validation phases. What is it that accuracy could be put? Maybe this is a model of the image that is comparable with a confidence of around, maybe 92 percent, 93 percent, this accuracy can also be determined here how confident the model is. So, that is generally a CNN can give you a class or category where this object or this model falls. The CNN network is a common technique in machine learning. It does not by itself represent a development of or a complex architecture. If the format heterogeneity of publicly available 3D objects makes feature extraction and meta data comparison of difficult processes.

So, we can do meta data comparisons. CNN is more relevant to some applications because of its ability to develop some level of intuition solely based upon the spatial features. So, there are certain studies which were taken, the first study is by Be et al. in year 2021, that you can see.

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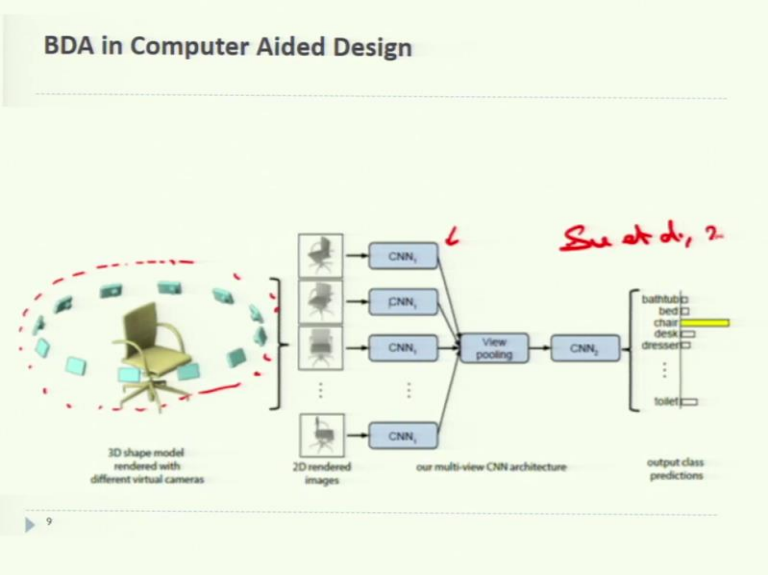

This figure is taken from them, where a chair 3D shaped was to be made, circular vise the camera take different pictures of the chair, we can decide number of pictures to be taken, which are fed as an input to the CNN here, to different neural connections that are there, a 3D shape can be recognized even from a single view at an accuracy far higher than using a state of our 3D shape descriptors or so.

So, this presents a standard CNN architecture, which is trained to identify the shapes rendered views independently of each other. When multiple views of shapes are presented, recognition rates rise even further. Additionally, a recently seen architecture which compiles data from various 3D shapes into a single condensed shape descriptor that offers even better recognition or performance, is also given. This picture is again taken from Sue et al. 2015.

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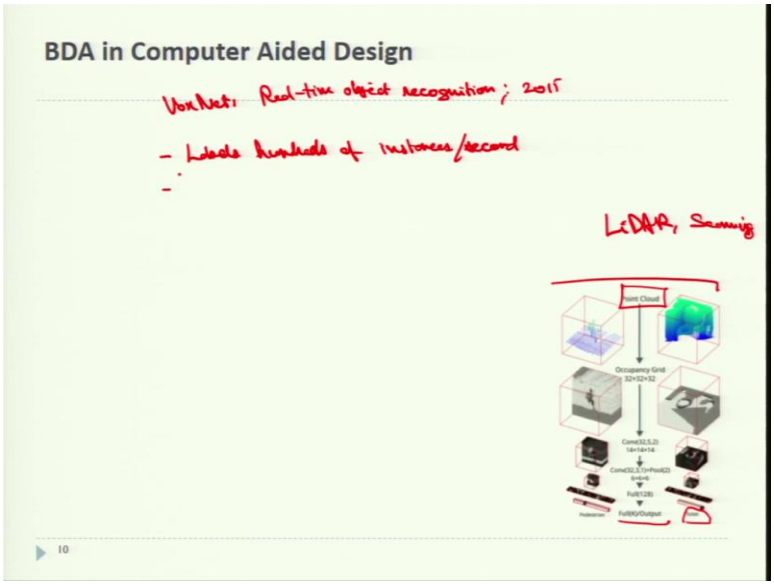

Another study, in which Vox Net architecture, Vox Net architecture are given. This is a Vox Net architecture in which you have a plant cloud data and the occupancy grid and we have a convolution layers and finally, we try to have a full output layer which helps us to let us know that whether the shape that was input here from the point cloud from the input data, which is the class it is falling in, where it is showing it falls in that class of twilight, maybe.

So, this Vox Net real time object recognition study. This was taken by Maturana and Shener in 2015, in which Vox Net helps to take advantage of expanding point cloud databases, which are generally collected through LiDAR data or some big scanning data. That is the data that they got was cloud data, you can see the plant cloud data is here, LiDAR is a big 3D scanner, which helps us to scan maybe the dimensions of this room or it helps us to also scan the geometric dimensions of the full land area that you have.

For instance, in the border area, how is that terrain, how is the farmland or so? LiDAR data helps us to collect a large amount of data from there. So, from there for the construction LiDAR data helps us to get the plant cloud data and what this resembles with, can be taken through a Convolutional Neural Network system. So, using the LiDAR or CAD data the outcomes are assessed against publicly accessible benchmarks to Vox Net labels hundreds of instances per second.

So, this is very helpful in identifying the different models of the shapes, how these shapes are identified, there was another study which was taken where we classify and match the data.

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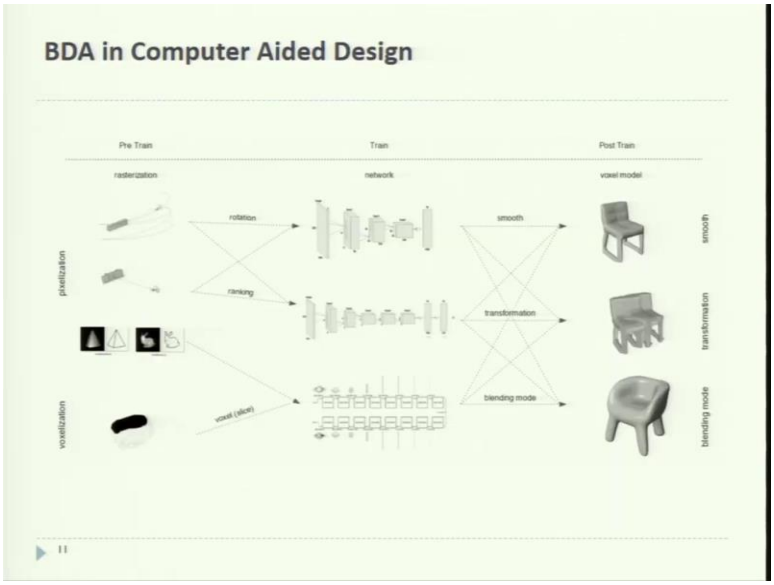

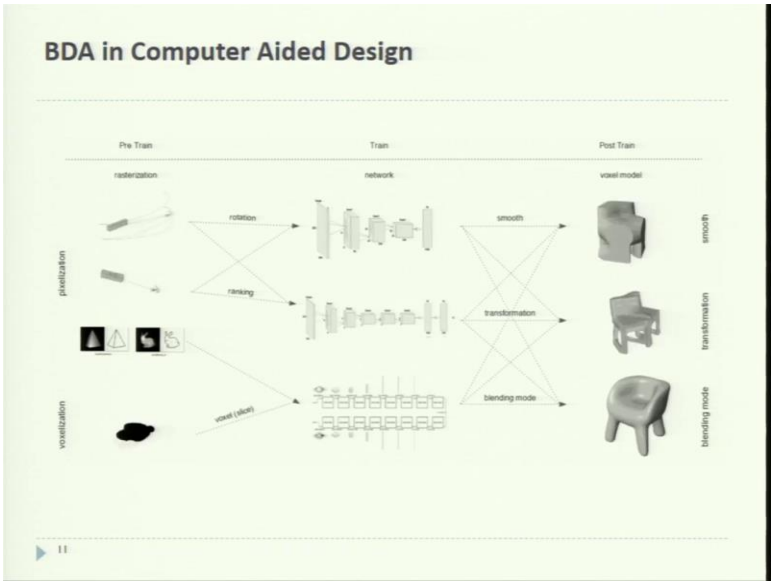

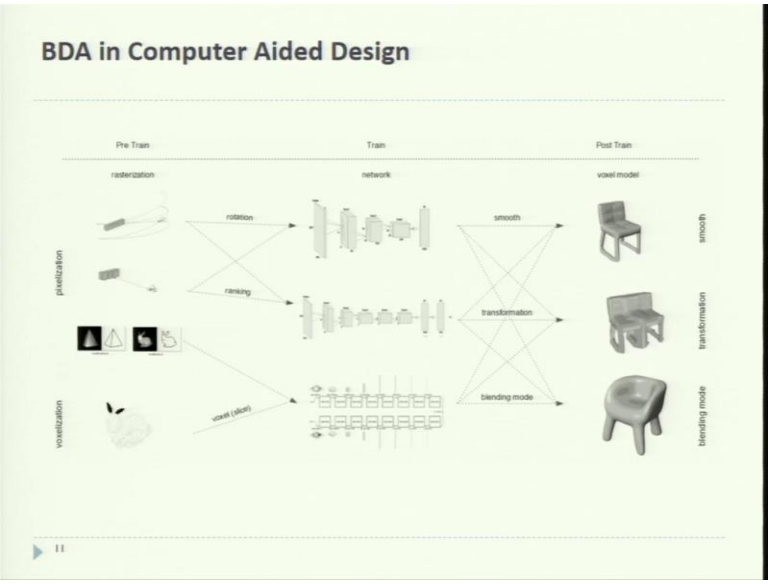

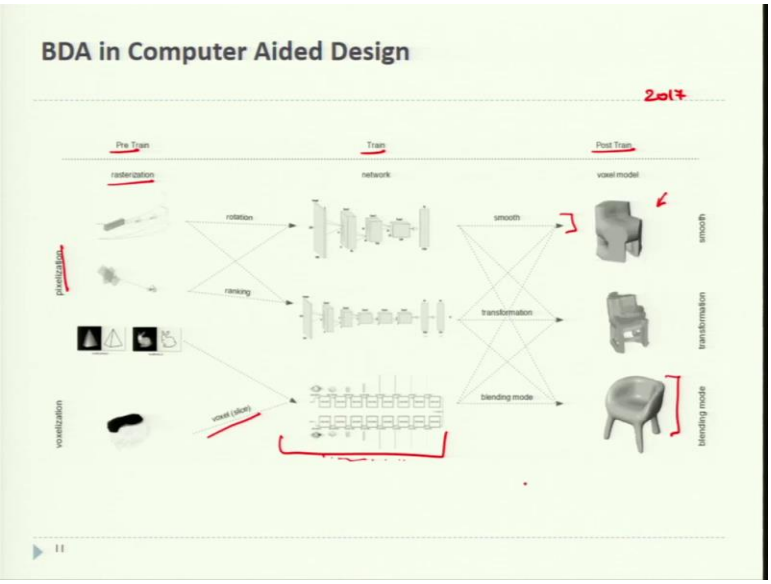

For the volumetric representation was taken from the data. This study was also in 2017. Where you can say the pre train and the train data is there, in the post train what do we get? Pre trained data we get, we put the model or image in the pixelization, we put the pixels of the picture, the rasterization of that happens and it tries to compare it with the various forms we try to rotate the data in different forms. And, we try to get the network. This is how our CNN works and we try to rank them and this smooth transformation smooth data tells us okay this is how it goes from the 2D shapes you can see complete how the data has been transformed into the form of a chair. Now, the transformation is when we try to transform the data we give the ranking to that as well. And,

we get its transformation from the different shapes that we have. It is being transformed into a single chair.

Then, this blending mode, when we have almost similar objects to chair the voxel slices, helps us to get the different images and try to select and try to blend it into the shape that is given here. So, this was also one of the ways where the data that is already stored in the different libraries. It can be taken from those libraries and we can have a comparatively matching between them.

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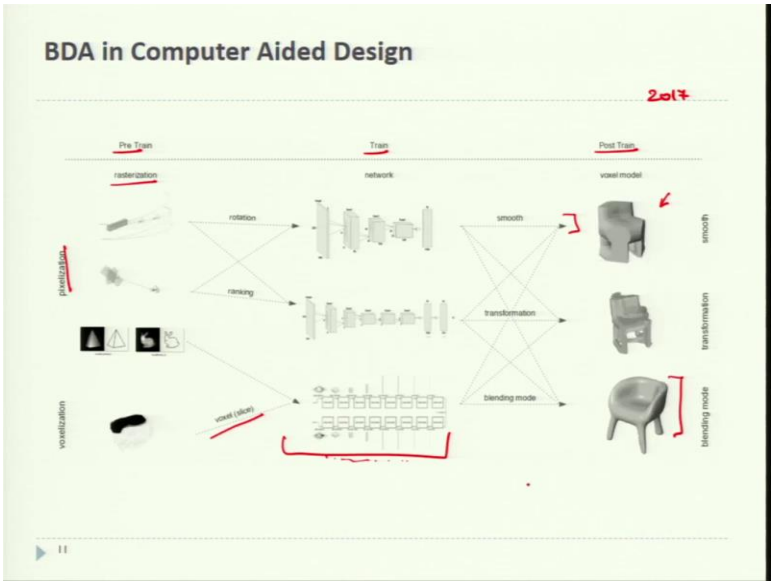

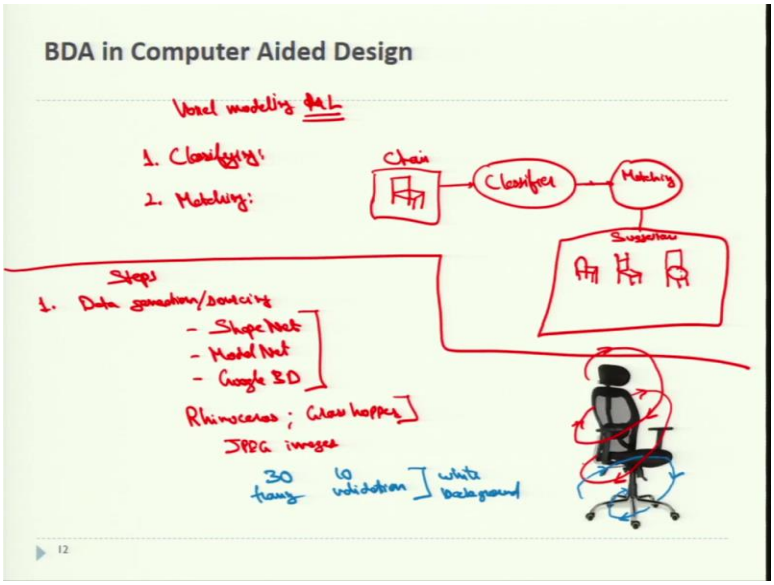

So, in the voxel modeling data I would say voxel modeling machine learning. So, this was examined in this recent study, in which the voxel model is first described and contrasted with the conventional model building techniques, to examine the pro-typical implementations of suggestive design systems or workflows based upon the process from restoration of the space or the geometry within the image. So, this is how the concepts like pixel maps and graphic representation, those were determined here.

So here, there were major two steps:

1) Classifying
2) Matching

When I say classify, it tries to classify whether the object that the user is drawing. Is it correctly labeled as chair or is it a chair, bench, bed, or any image similar to that.

Matching is, finding in a database of 3D objects, some shapes that closely resemble the feature, that the user's model input is. So, returning a list of objects from the database in a descending order of similarity.

So, in a sense, we try to input a model of the chair. Let me say a model of chair is something like this. So, it goes to a classifier, then once the classifier has almost identified what is this class falling to? It falls in the class of chairs, then they try to match it to, what kind of chair it is, I will put matching. Then, it gives various suggestions. Suggestions could be, it is a chair of shape with a round at the back, it is a chair with kind of the edges at the top, or it could say this is a chair in which the base is round.

So, it depends upon what suggestions it is giving and how intelligent our model is. So, nesting two different models that are a classifier and the matcher, each model first is tested based upon the images that user has modeled, then it is trained on the images of the three objects. The typical steps to execute this model is,

- Data generation or sourcing. In data generation or sourcing, making a database is taken, I would like to describe this as an important step because we share the tools which are built and what are we are trying to accomplish what methodology are we trying to see, the data

is generally gathered by the study which I just mentioned through platform such as Shape Net, Model Net and Google 3D. So, from there different label 3D models could be downloaded. For instance, they downloaded the shape net database and divided it into 14 distinct classes. These classes were of different objects, these were chairs, tools, beds. So, when the objects which could be taken maybe, so far bathtub, plant, door, ways, bench, bookshelves or so. So, then it was taken to a tool known as Rhinoceros. And, another one is Grasshopper which I just discussed. This helps us to provide the basic information.

So, this script creates JPEG images in this specific directory. So, by rotating the camera around each of the subsequent objects and taking pictures from specific angles, this could be created. Generally, what happened, which I showed you in the previous slide, the image is rotated in a circular fashion, but this is a circular fashion where the image is rotated. So, here, the new methodology saves and snap. This is a chair, a spiral base is made like this is the rotation how it goes. It goes in this direction, then another spiral could be made down here. Then, this chair stands tall, then the chair is tilted at 90-degree in which spiral images were taken, the chair is tilted at 90 degree and sideways also tilted, then another spiral is taken.

So, this way we get multiple images of the chair and then we try to connect those images to the available database that we have and the classes that we had that were taken from the shape net website.

So, in this study, they took 30 images of each object for training and 10 for validation. So always, the background was kept neutral and white. So, this was the data generation where they generated the data and the 30 sets of the inputs were taken in.

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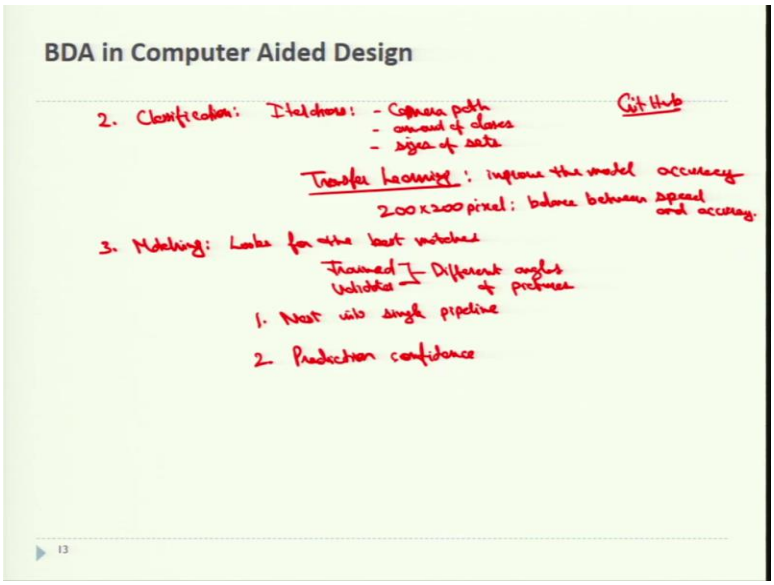

- Next step here is the classification. Classification and matching are definitely the two next steps. In the classification, the objective was to train the first model that is a classifier on a large number of images of 3D objects once the data set is prepared. Here, the iterations were taken such as the significant factors that are the size of the validation or training sets, the amount of the classes and the amount of objects in each class. So, certain iterations were taken. For instance,
- camera path of capture,
- amount of classes,
- sizes of the validation

And, training set or you have a set that was 30 and 10 were taken that I told you in the previous slide, and in this case the only images were taken. So, in some cases, the images and the text data both could be put as an input depending upon the database that we have and depending upon the analytic system that we are using.

Now, alternate between various options with the goal of improving the model overall accuracy on the validation set was set.

- ❖ So, here transfer learning phenomenon was applied which is useful because it allows to improve the model accuracy. So, it helps to improve the accuracy without having to go

through the days of training. So, a pre-trained model was taken in which the accuracy was improved by around more than 30 percent.

3) Then comes the Matching. Since, in the classification itself, the model that was selected was 200 x 200 pixels which proved to be the best model to balance between the speed and accuracy. In the matching phase, the model looks for the best matches. So, these best matches are taken from the large collection of 3D models, that is the matching model ranks the 3D models from the given class to the most resembling to least resembling. It can be classified into various levels from maybe 1 to 5 or 1 to 10 most, moderate, least could be 3 levels. So, these matches were made. So, this matching model is another CNN, which was trained on pictures of objects belonging to a particular class and it was well detailed on pictures of the same objects, but from different angles. So, trained and validated. So, these were different angles of the pictures which were taken.

A) Majorly it helps to nest the Classification and Matching models into a single pipeline.

B) Now, the input image could be processed and classifying it before matching it with the related objects. So, it also generates some prediction confidence which enables us to assess the degree of similarity between the origin model and the match. So, here even a small number of surfaces could guide the classifier and the matching step could help to take them to the right direction, where the object is modeled. So, one can determine the class of the model and one can cut down the time required for 3D modeling. So, this is a quick study that is taken to have more detail on that, you can definitely go to the references which are given at the end of the slide.

So, 3D shape recognition and suggestions is a very large idea. So, the qualification of the mechanical or the architectural forms are taken through machine learning and Big Data Analytics helps us to select the model. There are certain platforms which I just mentioned here to get the sources of the data like ShapeNet, Google 3D. We can process the data to have the classification. Those could also have been taken. GitHub is also very helpful in the classification.

So, in the matching, one can design a system to match, one can develop its own system or one can also use the models which are available. So, this is how the Big Data Analytics in Computer Aided Design also helps to have a more informed decision on the basic shape and we can take the quick decision. Even the amateurs or the people who are not from the core mechanical CAD background

can have an overall view. For instance, the startup companies were trying to develop a complex, maybe an oxygen concentrator or so.

They do not have much information about the electronics component of that, or the shape factor of that. To have the shape factor, to understand the shape factor, they can have quite a good study using these kinds of the models where they could classify and match the models and try to understand what the overall shape of the specific kind of the product that you are trying to manufacture could be.

I am saying it could be because the final shape would only come when finally, they would contact a mechanical engineer who would try to help them to get the final shape that could be finally produced. produced means manufactured. So, final manufacturing definitely has to go through a certain tolerance in setting and certain matching with the CNC machines or the other machine setters, which will actually manufacture or produce these models.

So, Big Data Analytics helps us to have the information from the existing data. CNN is only one of the methods there could be multiple other methods, multiple other heuristics, that could be used. Such as maybe genetic algorithms could be used, artificial bicol could be used, which helps us to have a matching close to the final product that we are trying to see based upon the input that we have given. Let us talk about the part programming as a Decision Support System for manufacturing in the next lectures. Thank you.