Design Practice - 2
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Lecture - 02
Computer Aided Design (CAD)

Hello and welcome to this Design Practice 2 module 2. We had been discussing about the utility of product design and how it is important to lay out different forms and shapes so that it can basically all merge out to be at least the aesthetic form of the product that we are envisioning. It is a very important process design to be able to sketch and envision what idea you conceive behind the product.

So this lecture is dedicated to learning a little more of the backend processing which is involved in tools like CAD and what is the utility of CAD and how CAD came into existence and how CAD is continuing through. But the involvement here is more related to how you can actually help to scale up, translate, rotate different objects in space by using coordinate geometry and so this is the backend computation which is needed by any CAD design engineer who is actually designing a CAD platform to known about how to handle different shapes on a 2-D screen.

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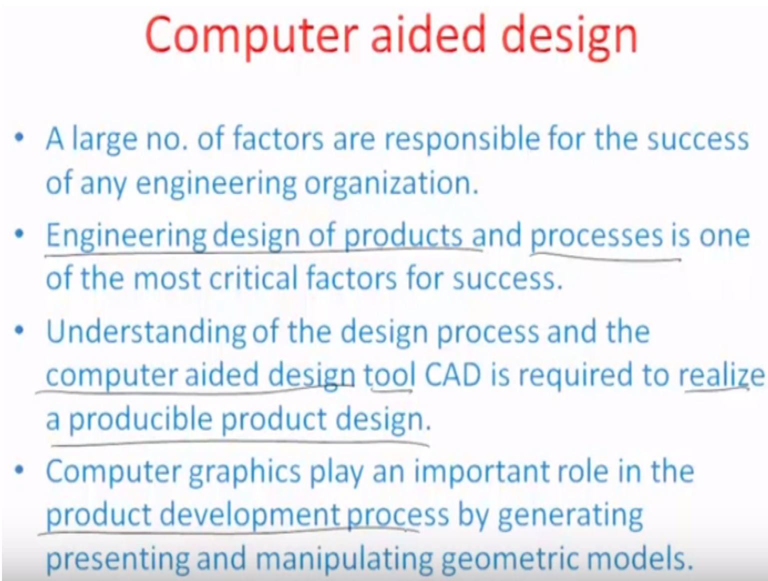

So if you look at this computer aided design, obviously a large number of factors are responsible for success or failure related to engineering organizations. And obviously the most important, particularly when we are talking about engineering products, is the engineering design of products and processes.

So this is one of the key elements for ensuring that an organization is successful and in order to realize a producible product design the understanding of the design process necessitates the use of very flexible computer aided design tool or CAD tool as we popularly know of. So it is a way to represent or re-represent in many forms the basic shape or geometry associated with an engineering part or maybe even a total product.

So computer graphics play an important role in product development and process by generating, presenting and manipulating the geometric models.

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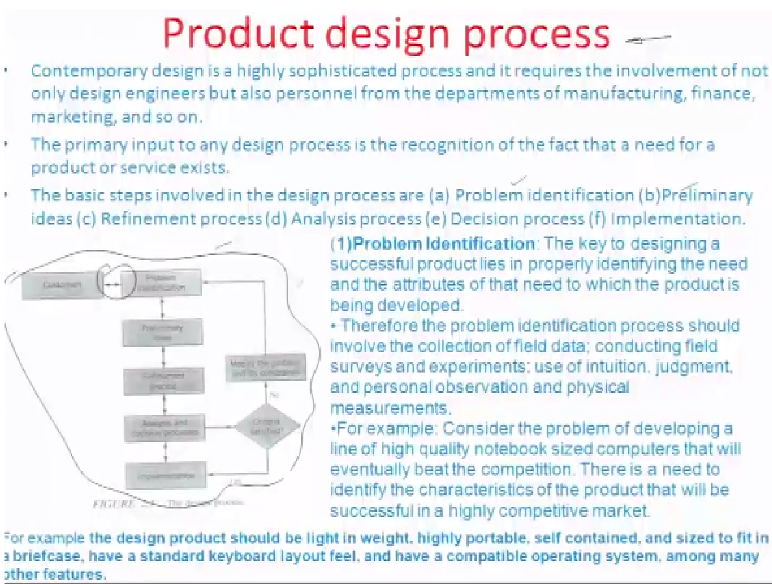

And if I looked at that design process this I think I had extensively done in design 1, design practice 1 course. There are different steps involved in any designing activity which starts from the need finding or the problem identification step, the preliminary ideas step, the refinement process, the analysis process, decision process and finally implementation which is all visible here as sort of a algorithm okay.

So interaction with customers is more or less the reason why a problem can be identified or it comes up and then there are various steps which actually lead to the defining of a solution and then evaluating the solution and so if it is found okay then implanting the solution. So I am not going to delve into the details of this process because this has been taken up in design practice 1, but what is important here is a lot of these steps do involve ideation and sketching and a lot of these steps are involving the feel and touch of a product for which the necessity of using powerful CAD tools automatically come into existence.

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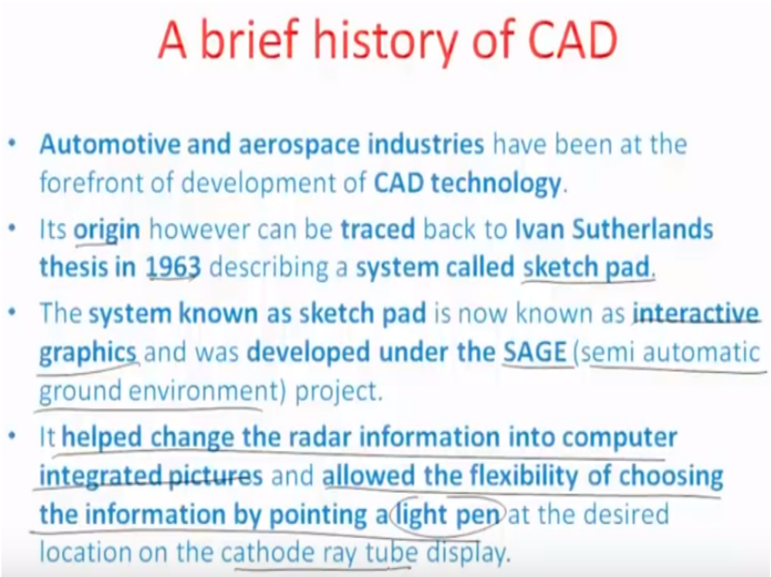

So if I wanted to just see how CAD developed over the years, how it started really the origin can be traced back to almost 1963 when a system called sketch pad was developed okay. System was known as sketch pad. It is now known as interactive graphics. It was developed under you know again a defense project which was sub contracted and this was also known as the semiautomatic ground environment project or SAGE project.

And what it essentially helped in doing is to help change the radar information into computer integrated pictures and that is how the CAD technology, the modern day CAD technology so called evolved. So it allowed the flexibility of choosing the information by pointing a light pen so that it could zoom up into a certain region going to the details so on so forth and the issue was about at what resolution you could save the picture so that you could reflect all those details come up as and when you pinpointed or indicated a certain area.

So the interaction of this light pen was typically with a cathode ray tube which would display the image and then help it to zoom up or zoom down and go to different sections of particular image. So that is how CAD started today, CAD CAM systems are almost always around.

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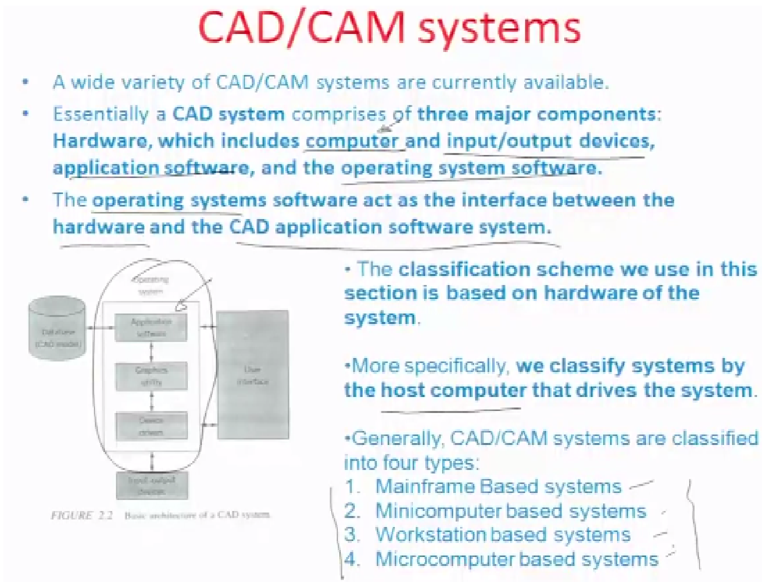

They are currently available in many forms, many shapes. So if I looked at overall how a CAD system is placed, it has 3 major components. One is of course the hardware part which includes the basic mother computer which does all the computation and in fact the algorithms or logic that we will be preparing is for this computer to handle various geometries and manipulate various geometries.

There are also input output devices or systems associated with the computer and this is an application software which is in place and then there is an operating system software. So these are the three essential components, ingredients of a CAD system which would help you to handle a lot of data, do a representational form of the data and then you know do data manipulation based on change in representation so that it could be transported back as data and stored into the database of the CAD system.

So typically the operating system is I think all of us are aware it is a software which acts as an interface between the hardware and the CAD application software system and this right here and if you wanted to look at some of the classification schemes or the basis of classifying the various

CAD CAM systems which are available, they are really based on the types of the host computer that drives, that can be mainframe based systems for example, they can be minicomputer based systems, they can be workstations and then they can be microcomputer based systems.

So these are broad set of classifications which can come handy when we talk about different CAD CAM systems and a very important backend computational aspect of all these is how you are taking data and representing and repetition-representing and manipulating so that there can be a data input output to give different orientations, different geometries, different shapes, forms etc. within the RAM space of a CAD system.

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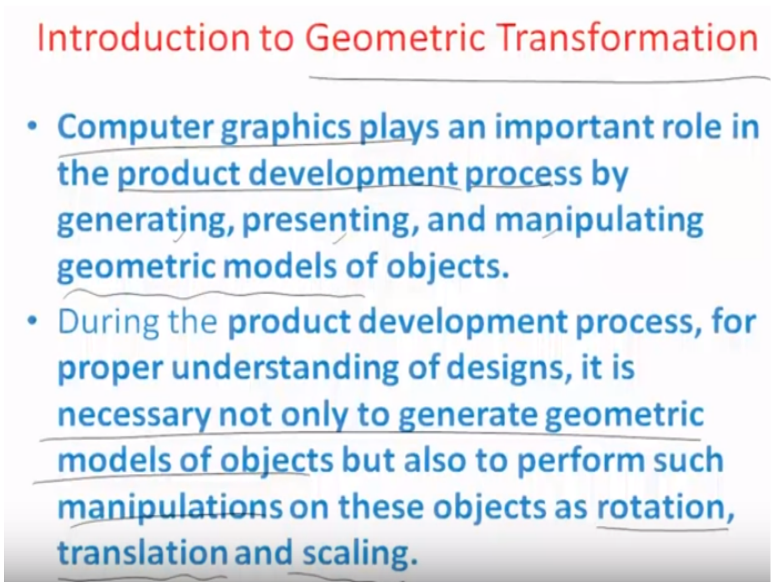

So this topical geometric transformation is really indicative of such data handling and manipulation and it kind of gives you an essence of or a connect between the actual graphic display which is there on such a system with numeric data which is being processed by the processor of a computer. So computer graphics play a very important role.

No need to mention this in the product development process and what we really need to do with computer graphics is to be able to generate present you know manipulate different ideas okay so that it goes towards that intended solution which satisfies the need of a customer and so there are different geometric models which are used off and on for doing this on a very fast pace basis.

So during the product development process for proper understanding of designs it is necessary not only to generate geometric models of the objects but also to perform manipulations of these objects so that they can be able to be watched in different views through the rotation for example or translation or scaling effects or so on so forth.

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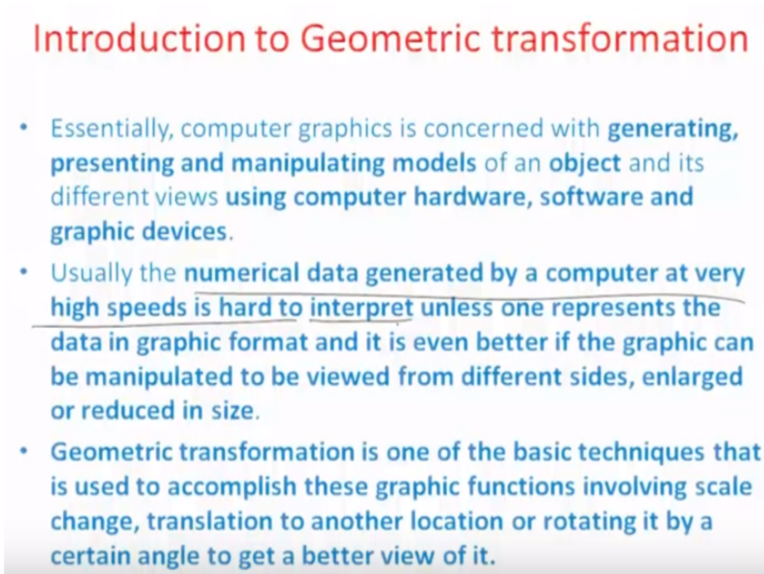

And in order to do this usually the numerical data which is generated by computer at a very high speed is hard to interpret unless representational mode is used to represent the data in form of a geometry okay and so as the geometry changes obviously the back and forth basis the numeric data also should change for which organized algorithms should be in place. So let us look at some of those algorithms which play an important role in determining the data when a certain graphic is manipulated on the computer screen.

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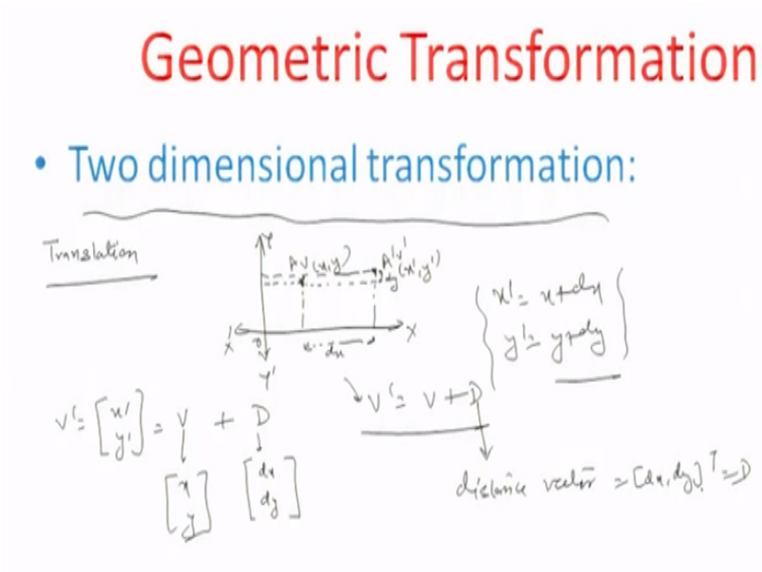

And if I looked at the basis algorithm of doing such a transformation we would rather prefer to have first a simpler representation on a 2-D mode and then translate this into the 3-D space so that you could have even 3-D forms, shapes being incorporated within the CAD system. So the first transformation that I will work out here is for the simplest possible activity which is about translating of objects in 2-dimensional spaces.

So let us say we had a point xy in a coordinate system which I am laying out here. So you have a 2-dimensional coordinate system and there is a point A somewhere in space which is read by a coordinate x and y and you want to take this point to another place A dash led by a coordinate x dash and y dash. So obviously there is a movement along the x and there is also a movement along the y which leads the point to move from A to A dash.

And there should be an organized way of representing it in terms of numbers which is very easy for a process to handle which would give you an outcome in terms of what you call translation. So if I wanted to call this a vector V xy and this is another vector that is V dash x dash y dash, so I would be able to write this translation in terms of the vector V dash which is given by the coordinates x dash y dash equals to vector V.

Which is actually given or you know you can interpret this as the matrix xy plus certain distance matrix which means how much the point has moved in the x direction and the y direction. So let us say if this point has moved by distances dx and dy in the x and y direction which typically means that this right here is dy and similarly this right here is dx. So I have a vector equation now V dash in place which is equal to V + D which shows the effect of translation on the point vector V okay which is point A when it translates to the vector V dash or point A dash.

So this is a very simple way of expressing translation. So x dash becomes equal to x + dx, y dash becomes equal to y + dy and obviously this is on the one point but when it comes to a set of points for example if you are looking at a triangular form or shape or we are looking at a rectangular form and shape it is defined by more than one points and so typically all of them would execute similar kind of translational efforts so that the new coordinate can be quickly computed on the basis of what the old coordinates were.

So this is one very elementary form of translation. D of course can be recorded as a distance vector and this distance vector is again written as the compliment so can be used as dx, dy transpose and we can apply this to again a set of points. For example if I were to consider a triangle which is an array of 3 points.

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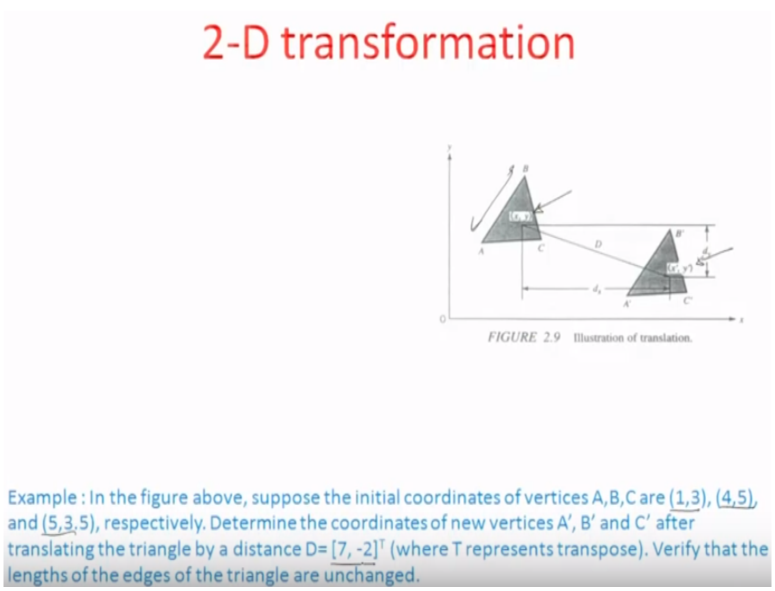

Let us say there is a triangle placed at A, B, C location coordinates with respect to this xy plane and it moves to a point A dash B dash C dash by virtue of a translation of the centroid of the triangle which was initially at xy, 2 x dash y dash where the centroid translates to a differential distance corresponding to dx and dy. What is important to be seen here or the aspect that is important to be seen here is that really after this translation is the relative distance between A and B or B and C going to change because of such an effort.

So in this particular figure, we are mentioning the different coordinates A, B, C as (1, 3), (4, 5) and (5, 3.5) and the distance vector as 7 - 2 transpose and we would like to find whether the shape or size of the triangle changes because of this translational effort.

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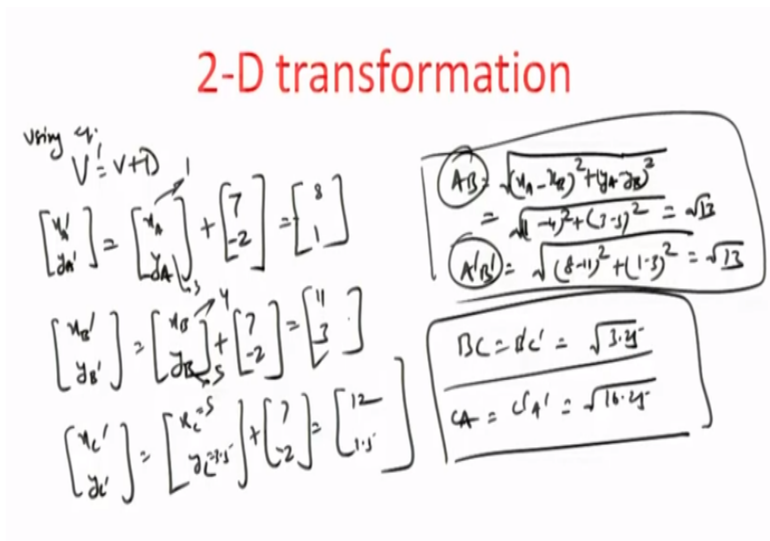

So for doing it, let us compute so we are using this equation V equal to or V dash equal to V + D and we will do this for all the different points. So the points xA dash yA dash translated from the point xA yA through the transpose of the distance vector within this case is 7 - 2. So obviously this being given as 1, 3 okay would translate to the V dash vector xA dash being equal to 8 and 1 okay.

Similarly, for the point B, the new position xB dash yB dash is represented as xB yB + (7 -2). So this becomes equal to 11, 3 because obviously xB and yB are in as written in the question is 4, 5 and similarly, xC dash yC dash becomes equal to xC yC 5, 3.5 plus 7, -2 gives equal to 12 and 1.5. So if I were to look at the distances Ab, BC or CD and whether they change or not and the value AB could be written as xA - xB square + yA - yB square.

So this is between the points A and B and this comes out to be equal to 1 - 4 square + 3 - 5 square root 13 and similarly A dash B dash equals to 8 - 11 square, the new values plus 1 - 3 square which again becomes equal to root of 13. So we see that the distances AB and A dash B dash are not changing. Similarly, you could find out for yourself that BC and B dash C dash also do not change put together root of 3.25 or CA and C dash A dash again root of 16.25.

So these are the different numbers in terms of the distances and so as the distances do not change. The triangular shape or the orientation also does not change as it moves in the translational matrix or as it moves using the translational matrix. So that is how you could define the process of translation.

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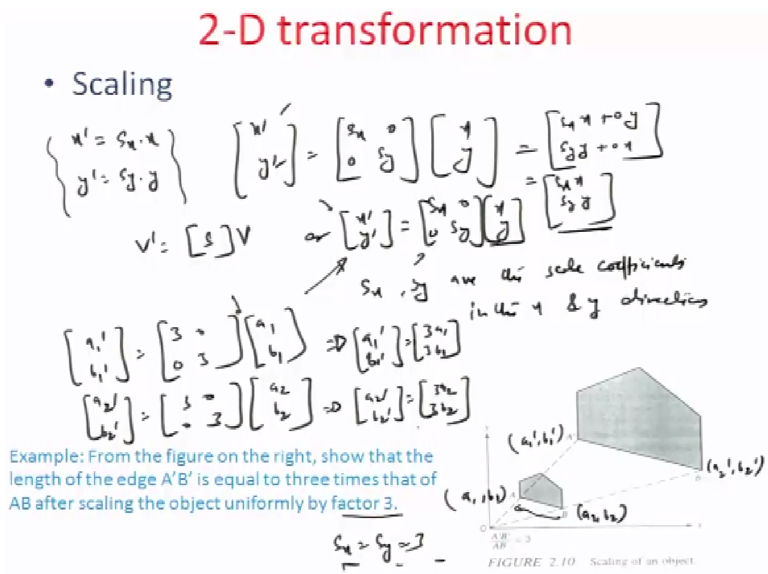

We also have another scaling process which basically would mean you know you are stretching the points to a certain extent let us say if I say that the distance were D between two points A and B in space, now it has become 3D or 4D that means you are stretching the whole line to almost three times the length.

And obviously if the set of lines which are describing a surface which is actually the you know the basis of a shape then obviously if the stretch of a line happens the shape would also like to stretch to that particular dimension and we want to find out whether the shape changes because of that okay. And so in order to do that let us formulate a matrix just as we did for the translational effort what would happen if such kind of a stretching is done is called scaling and scaling of course can be done you know because we are talking about a 2-dimensional plane in terms of scaling towards x axis and the y axis.

Typically if the aspect ratio were locked to be 1 then the scaling effort would have a single scale okay. But otherwise you could have differential scaling along the x and the y planes as well. So let us say we are talking about a generic form of differential scaling along both directions and we have a certain point having x coordinate of x let us say, small x let us say scaled up by a factor as x.

So we can say that x dash should be equal to Sx into x and y dash would be equal to Sy into y. In other words we are restricting ourselves to not having scales similar in the x and y direction and basically what it means is that we are taking the point x dash in the x axis to another point which is about Sx times away from the point x dash or from the point x and we are taking y dash to a point along the y axis which is about Sy times away from the point y.

So if I were to look at you again a simple way of representing in terms of linear the x dash y dash in this case could be represented as scaling matrix Sx 0 0 Sy times of x and y. So obviously the result of this would be Sx times of x + 0 times of y as conventionally the matrix multiplication is done and Sy times of y + 0 times of x okay. So this again same as Sx x and Sy y okay. So this is how x dash and y dash are defined in this particular matrix.

And so I can say that you know the scaling can be expressed in vector form as V dash equals the scaling matrix S times of V or x dash y dash equals Sx 0, 0 Sy times of xy okay. Sx and Sy are the scale coefficients in the x and y directions. Let us look at really whether such a scaling event or transformation if happening to a certain shape would really scale up the length to as many times as the scale factor.

The example in the right here shows that there is a length of otherwise pentagonal object, the side AB shows the initial length and let us say this object is now scaled up to about three times in size and the side A dash B dash shows this scaled length AB by just using the scaling transformation matrix and we can find out what is A dash or coordinate of A dash with respect to A or B dash with respect to B and we can find out really whether the lengths change to so many times as the scale factor was in this particular case.

So the factor in this case is 3. Let us assign some coordinates here to A and B. So let us have the coordinate of A as a 1 b 1 and the coordinate of B as a 2 b 2 and because the scale factor is homogenous in the x and y direction so the Sx and Sy in this case is both equal to 3 which means that if I applied the geometric transformation formula here which says that the coordinates x dash y dash becomes equal to the scale factor times the initial coordinates, let us assume that the coordinates a 1 b 1 translate to a 1 dash and b 1 dash and similarly a 2 b 2 translate to a 2 dash and b 2 dash.

So a 1 dash b 1 dash in this particular case would be represented as 3 0 0 3 mind you, the Sx and Sy in this case are both equal to 3 times of the coordinates of A which is a 1 b 1 and similarly a 2 dash b 2 dash should be equal to again the skill matrix here times the coordinate of B which is a 2 b 2 okay and in other words we have a 1 dash b 1 dash equals thrice of a 1 thrice of b 1 apply the multiplication rule in this matrix okay and similarly a 2 dash b 2 dash as thrice of a 2 thrice of b 2 okay.

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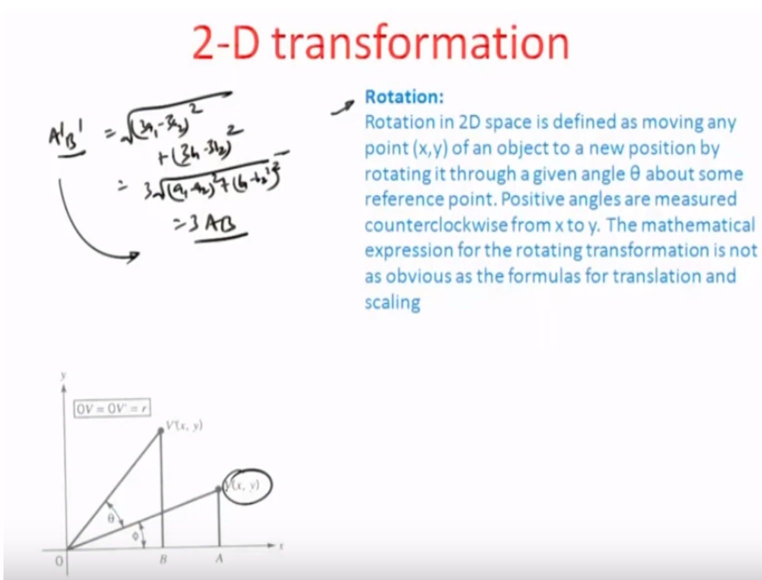

And if I were to calculate the length in this particular case the length a dash b dash would actually be equal to root over 3 A 1 - 3 A 2 square + 3 B 1 - 3 B 2 square I am sorry is equal to thrice root of a 1 - a 2 square + b 1 - b 2 square which is equal to AB. So as you saw that if you use the scale factor consistent in both x and y for a single factor 3 the length gets modified to exactly three times in such a case.

So the scaling transformation works pretty well and you can do this for all the sides together which means that the intended area which is inside also gets modified to almost nine times. So and the third transformation that we will need to understand is rotation and the rotation what we mean is that in a 2D space if there is a point vector lets us say V x, y and it is rotated about the origin let us say by a certain angle theta what is going to be the final coordinates because of such a rotation.

Now you have to remember one thing that the rotation may or may not be along the origin and therefore there is a question of moving back to the origin and rotating. So I am going to cover this in great details in the next module but in the interest of time I will close this particular module. So in the next module we will talk about rotation and then we will talk about the respective 3D forms of the 2D transformations that you have visited so far. Thank you very much.