Digital Image Processing

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Lecture - 35

Mathematical Morphology- III

Hello, welcome to the video lectures series on digital image processing.Forlast few lectures, we are discussing about the mathematical morphologyand its applicationto image processing problems.

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So, in the last class,what we have seen is we have seenwhat is meant by morphologicaldilation operation, we have also seen what is meant by morphological erosion operation and with fewexamples, we have illustrated that the dilation operation if I have a binaryimage and within the binaryimage in the object region if I have some background pixels,some pixelswhich are treated as background and this may happen because of thepresence of noise; in that case,the morphologicaldilationoperationtries to remove those noisy pixelswhich should have been the object pixelsbut because of some noisewhich have convertedwhich have been converted to be thebackground pixels.

And, we have seen thesideeffectof this dilation operationthat as thedilation operation tries to removethe noisypixels within the object area;at the same time, the dilation operation triesto expandthe area of the object regionand the reverse operationthat is the morphological erosion operationthat we have seen that it tries toremove the spurious noise present in the background region and at the same time,as the side effect the erosion operationcontracts theobject region. That means thearea of the object region gets reduced as we apply erosion operation on a binary image. Then, we have also seen some properties ofthe dilation and erosion operations.Then we have seen the combination of erosion and dilation operations whichare termed as opening and closing operations.

So, incase of opening,what we do is given a binary image and we have said thatfor all the morphological operations,our basic assumption is that animageshould be representedby a point set.So, when I say that given abinary image or givena point set; the opening operation,what it does is first it performs an erosion operation which is followed bya dilation operation and in the other case, inclosing operation, first what youperformis a dilation operationwhich is followed bythe corresponding closing operation and for all these operationswhen I go forthe opening or closing operations,for all these operations we have to usethe same structuring element.

Now, by application of this opening and closing operation, in our last lecture, we had taken an example where we had shownthat suppose youhave got two differentobjects;in one ofthe object,there was apatch which appeared to be a backgroundand the two objects were joined by a thin straight line. So, we assumedthat these are because of noises;when two objectsare joined by thin straight line that is because of noise.

Similarly, within the object regionif I have some pixelswhich are convertedwhich appeared to be the background pixels, we also assume that this is also because ofthe presence of noise. So, by using the opening and closing operationson such animage, we have demonstratedthat such a kind of noise can be removedand at the end,what we had obtained istwo different regions belongingtotwo objects.

Andthen finally, in our last class, we have talkedaboutanother kind oftransformation,the morphologicaltransformation which is termed as hit or miss transform. And, we have illustrated that purpose of this hit or miss transform is to locate an object ofa specific shape and sizewithin a given image. So, in that case, what we have done is we assumed that the object of the specific shape and specific size istreated as a structuring elementand we try to find out the presence of such an object within the given image and for that we haveusedthe combinationoferosion and dilation operations and which is termedas hit or miss transform.

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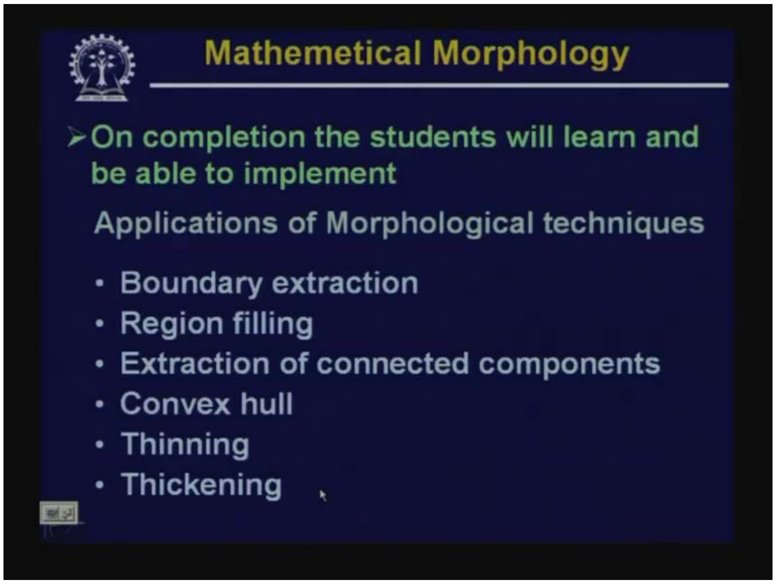

Intoday's lecture,we will talk about some applications ofsome further applications ofmorphological techniques. The first operation that we will discuss is a very simple operationwhich is boundary extraction. Sohere, what we will tryto do is that given a binary image containing some objects, we are interested in finding out the boundary of the object region. Now, in the earlier case, when we discussed about the different edge deduction operation or different line deduction operation;in that case,we have found different operators like Sobel operator,Prewitt operator,Laplacian or Gaussian operator which can be used to detect the object boundaries.

Intoday's lecture, we will try to address the same problem from the mathematical morphology point of few. So, we will try to devise some algorithm,somemorphological algorithm by which the boundaryof an object region can be detected. The second problem that we will talk about is a region filling operation. So, ifI have just the boundaryof an object,we will try to see whether it is possible by using themorphological operations to fill the entire region, entire object region which is enclosed by boundary pixels.

Then, we will also try to find outsome algorithm for extraction of connected components. So here again, in one of the earlier lectures, we had talked about some algorithm forconnected component level. So, there the problem is that if you have a set of points which are similarin nature and they are connected, then what we try to do is level all the pixels, all such pixels with the same level value or you give an unique identification number to the region to the entire region which is formed by all those connected pixels having similar values.

So, in this particular case, in this lecture, we will try to find out an algorithm for extraction of theconnected componentsin a binary image. Then, we willtalk about another operation, another algorithm which is for convex hull extraction. Now, convex hull is a property,we will define later on that what is meant by a convex,a set to be convexed and what you mean by convex hull.

And, this convex hull is very important, givesyou important information for high level image understanding operationsor object recognition operationsand we will see that how we can find out the convex hull.

We will see what is convex, what is meant by aset to be convexedand we will try to find out we devisean algorithm to find out the convex hull ofa given image or a point set.Then we will also discuss two more algorithms; one is thinning and the other is the thickening operations. Sohere again, given a point set,an image;we will try to find out algorithms, howto thin that image because in one of our earlier lectures we have said that the structural information of an object iscontained within the skeletonof that object shape and for that earlier we have said something about medialaccess transformation.

So, this medial accessof an object region is nothing but a thinned version of the object shape. So here,we willtry to find out that how we can thin an object shape or how we can thin a point set by using the morphological operations and thickening is of course,the inverseor the reverse of the thinning operation.So,we will also talk about how the thickening ofa point set can be done.
So, first of all, we will discuss about the boundaryextraction operation.

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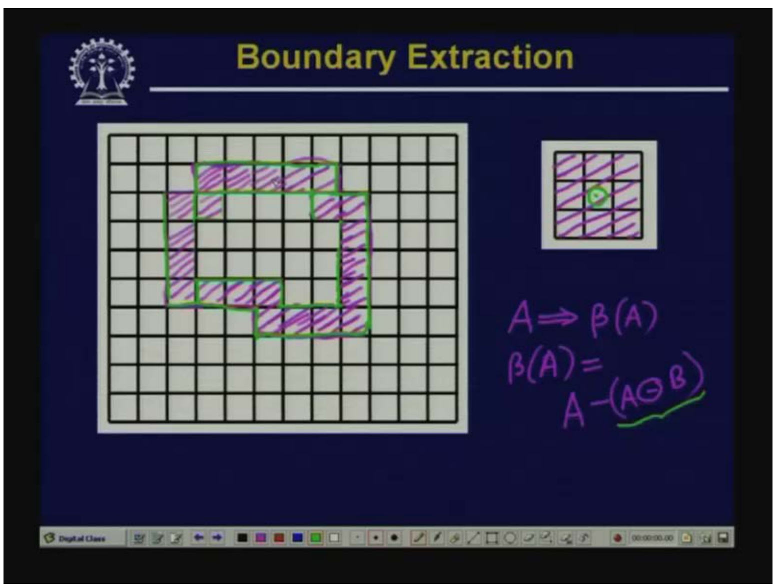

So, by boundaryextraction, what I mean is suppose we are given animage like this, say my object region is the set of this shaded pixels.So, this forms my object pixels or the point set say A and what we are interested in is to find outthe boundary of this objectregion. So, for a given set say A, this is the point set,I canrepresent theboundaryof this point set as say betaA where beta Arepresents the boundaryof the given point set Aand this beta A, it can be shown that it is nothing butthe set A minusAeroded with sum structuring elementB.

So, what we mean by this let us assume that we have a structuring elementwhich is as given here.So, thisis my structuring elementand I assume that the center of thestructuring elementor the origin of thestructuring element is the center pixel.So, first operation that we will perform is this that is we will erode the point set Awith this given structuring element3 by 3structuring element and you know thatwhen we try to erode this given shape with this 3 by 3structuring element;then as we have said earlier that this erosion operation contractsthearea of the object region and by performing this erosion operation, we will findthat all these boundary pixels will be deletedbecause ofcontractions.So, all of thesepixelsare going to be deleted, all of these pixels are going to be deletedafter we erode this point set Awith this particular structuring element.

Sonow, if I take thedifference ifI subtract the output of this erosion operation from the original point set A, then because all these boundary pixelshave been removed because of this erosion, after doing this set difference operation, you find that all theseinternal pixelswhich were there as part of erosion; all theseinternal pixelsare going to be removed.

Sofinally, what we are left with is as,is obvious on this figure isboundary of the object region.So, here we findthat boundary ofa given object region can be veryeasily determinedby performingthe erosion of the original set, originalpoint set Awitha 3 by 3structuring elementand finally whatyou have to take is you have tosubtract the erosion, the erodedimage from the originalimage and then what you are left with is the boundary ofthe given object region.

So, this is a very simple operation.Now, let us try to find out that just opposite to this thatif we are giventhe boundary of anobjectregion; how we can fill up the hollow region within the boundary again by application ofmorphological operations?So, let us take another example for this operation.

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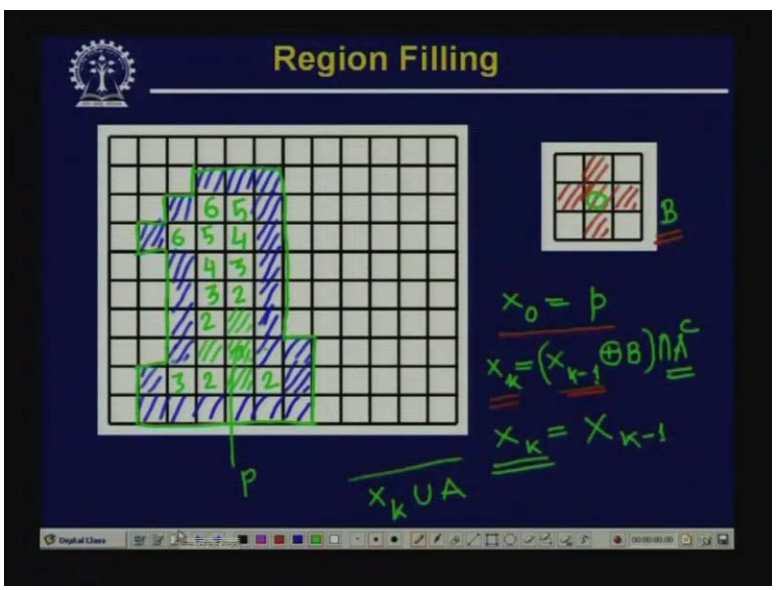

Sohere again, let us assume that we have animage say something like this.So, this is our given point set.So, here we find that we have a setof pixels which forms a boundary and within this boundary,we have a hollow region which is simply represented by white pixels and what we will try to do is we try to devise analgorithmby which thisinternal hollowregion can be filled up.So, for performing this operation,the kind of structuring element that we can use is something like this.Again, we use a structuring element within a 3 by 3 windowbut for in thisstructuring element, you find that the diagonal neighborsof the origin; here again we assume that origin is the center pixel of this3 by 3windowand in this structuring element, we donot considerthe diagonal neighbors of the origin.

Now, forregion filling operation,what we have to do is first let us consider say any pixel P within this hollow region. So,I consider a point within thehollowregion and let me call this point as the point P and our algorithm will be something like this;first we set this point P is equal to 1 and I takeand I assume assign a point set say X_0wereX_0 is initially the point P and a region filling operation will be performed by iterative application of dilation operations.

So, the algorithmfor thisregion filling operation in the form ofan iterative algorithm can be written like this; say at stage at the iteration stage k,I say thatX_k will be given byX_k minus 1, dilate this with our structuring element B.Sonow, in this case, this is our structuring element B and what we do withthisdilated point set is thatwe take the intersectionof this with the complement of thepoint setA.

So, these are the points inour pointset A and obviously the complement of this will be in the complement all this points will bemade equal to black and allother points will be made equal to white.So, if I do this particular operation, let us see how this algorithm is going to work.So initially,what we have done iswe have assumedthat our $X_0$is equal to is just the point Pand next what I do is I dilate thisX_0following this iteration that $X_k$is equal toX_k minus 1 dilation with B andtake the intersection of this with A complements.

So, if I dilate this X_0 with ourstructuring element Bas given over here;in that case, you findthat these are thepoints which will be set equal to 1 and since thishas to be intersected,so this point also will be set equal to 1 but since we will take the intersection with A complement, inA complement this point will be equal tothis pointwill be black.So, if I take theintersection, this particular point will be removed.So, what I have?X_1, $X_1$is all these points.

Now, what will be X_2? X_2 will be dilation of all these points.So, if I just give the level,say these are the pointswhich will be made equal to 1 afterperforming dilation in the second iteration.So, these are the points which will be made equal to 1 afterperforming the second iteration and taking the intersection with A complement.These are the pointswhich will be made equal to 1after the third iteration and performing the intersection operation.These are the points which will be made equal to 1after the fourth iteration and performing this intersection operation.These are the pointswhich will be made equal to 1 after fifthiteration and performing this intersection operation and these are the pointswhich will be made equal to 1 after sixthiteration and performing this intersectionoperation.

Now, we find that once I get this, if I perform for the dilation with the samestructuring element and followed by intersection with a complement,this set is not going tochange any further.So, I achieve a convergence when I find that $X_k$becomes equaltoX_k minus 1. So, whenI get the point set identical point set in two subsequentiterations,that is my point ofconvergence and at that point of convergence, whatever X_kI get,this $X_k$is nothing but all the points, this $X_k$containsall the points which are filled upbecause of this iterative operationsand finally,the final set will be when I achieve this convergence,the final set will be given by $X_k$unionwith our original point set A.

So, at the end, you find that all these points within this boundary,they have been made equal to 1and you willfindthat such a region filling operationis very very useful when wetalk about it will be seen that when we talk about the object description or object representation,we realized that this kind ofregion filling operation is very very important because unless we do such a kind ofregion filling operation,our object description will not be compact.So, you find thatwe have devised a verysimple algorithmfor performing the region filling operation.

The next kind of algorithm as we have said the morphological algorithm that we will discuss is the connectedcomponent extraction algorithm. Obviously,we have talked aboutthe connected component leveling problem earlier but here the sameproblem we will tacklewith themorphological operations.

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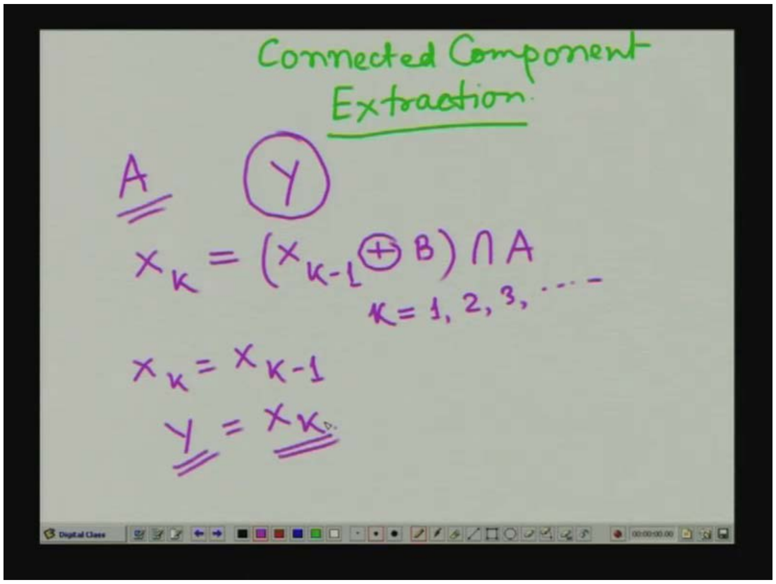

So, let us see how this connected component extraction can be done.So, here again,we are given a point setsay A.So, wearetalking about the connected component extraction.Sohere, we are given a point set A and supposeY is a connected component in set A.So, you are given a set of points a point set A and we assume that this Y is a connected component in A; so what we will try to do iswe will try to extract all the points whichbelong toY where Y is the connected component.That means we are trying to extractall the connected points of a subset of A which isconnected.Sohere, this subset is ourconnected componentA.

Sohere again, we will use the similar kind ofiterative algorithm and now ouralgorithm will besomething like this,saythe iterative algorithmwill be X_k is equal to again you take theresult from the previous case, the pervious iteration X_k minus 1, dilate this with the structuring element Band this dilatedresult has tobe intersected with the original point set Aand this operation has to be computed for various iteration steps.So, it has to be donefor say K is equal to 1,2, 3and soon.

Finally,as before,we reach a convergence or the algorithm will terminate when we findthat $X_k$remains same as X_k minus1. That is in two subsequentiterations,the result does not change and at that point,the algorithmterminatesand in that particular situation when the algorithm terminates or you reachthe convergence;in that case,we will findthat Y is nothing but $X_k$where we said that Y is the connected component in the point set A and by this algorithm, we have been will be able to include all the points inset A in our point setX_k which we achieve at the end ofthe algorithm or when the algorithm converges.

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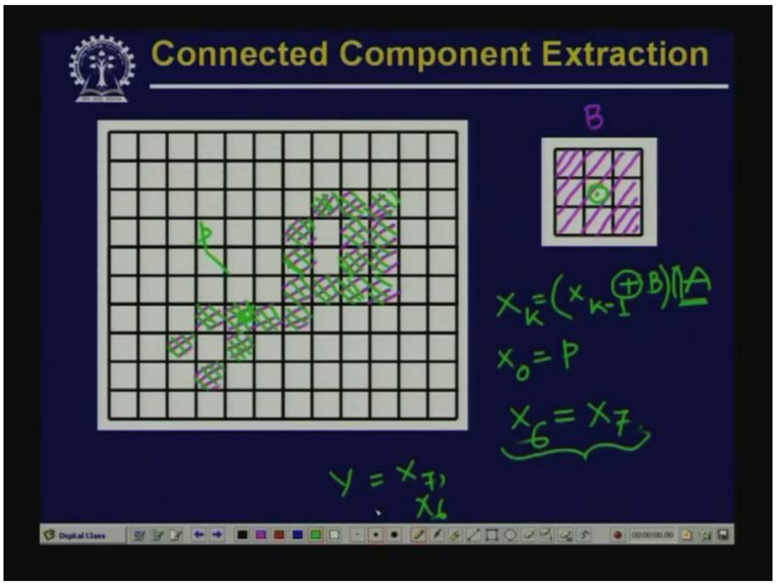

Soagain, let us take an example for this. So, what we will do is as before, let us take a particular set ofconnected pixels, so something like this.So, these are the set of connected pixels andI assume a structuring element B,this is my structuring element which is a 3 by 3 structuring element and as before,I assume that the origin of the structuring element is the center point.

Sohere, what we have said is our iteration algorithm is something like this; we have to have X_K is equal to X_K minus 1, dilation of this with our structuring element B and this has to be intersected with our original point set A. Nowinitially, what we do is i take a point P, say this is my point P which belongs to Y and I initialize X_0 is equal to point P. Now, again from here, you find that because X_0 is equal to is nothing but our point P; so if I dilatethis X_0 with our structuring element B, then whatI am goingto get is X_1. After doing this dilation, if I intersect that with our original point set A, then what I am going to getis nothing butthe pointsetX_1.

Sohere, this being our initial point P if I dilatethis with thisstructuring element; in that case,you find thatall thesepointsare going to be set to 1. But after dilation operation, as I am taking the intersection with our original point set A, we find that only points which will be in set X_1 at theend are only these points.

So, these are the points which are going to be in our set X X_1. If I dilate this further, then these are the pointswhich are going to be inset X_2, if I dilate further and do the intersection, then these are the points which are going to be inset X_3,do it further, then these are the points which are going to be in set X_4, dilate it further, these are the points which are going to be in set X_5, dilate itfurther,these are the pointswhich are going to be in set X_6andfurther dilation and intersection operation is not going to change ourX_6 anymore.

So, you find that at that point,I get $X_6$is equal to X_7. So, this is ourpoint of convergence and from this figure,from this output, what you observe say that when I reach this point of convergence; in that case, as I said that our original connected set of points, the connected point set Y is nothing but our point set X_7which of course is same as point six point set X_6.

So, you find that when this algorithm converges, then the points all the connected points in set A which is in our case set Y, this is the connected set of points; so all these points will be accumulated in the point set X_6which we have got as a result of this iterative operation of X_k is equal to X_k minus 1 dilation with B and take the intersection with our original set A.

So, what we have done in this case is in this particular case, we have started from our original point set, we have started with the point belonging to the set y and then we have try to grow the region starting from that particular point. So, the next algorithm that we are going to discuss iswhat we will call as convex hull.

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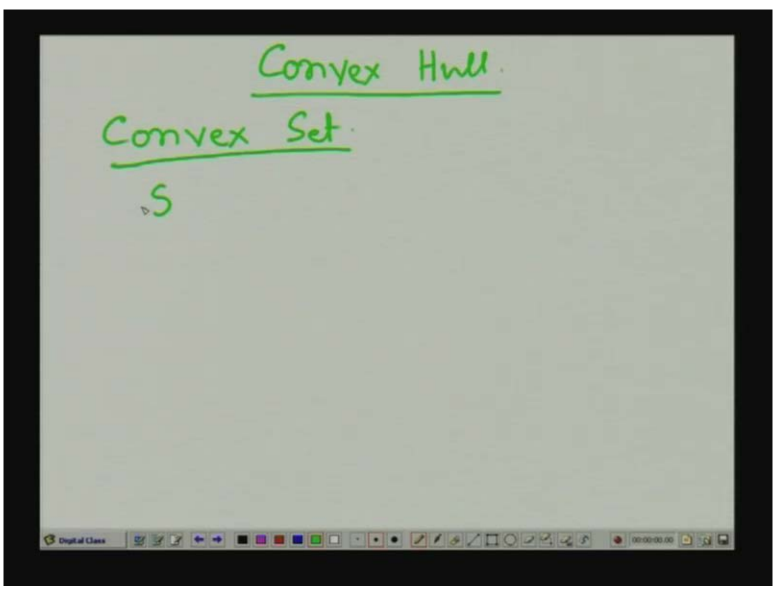

Whenwe talk about convex hull, the first thing that we have to see that what is meant by a convex set or what do we understand by a set to be convex. A set say S, a point set S is said to be convex if I take any pair ofpoints, take any pair of points in the set S and join a straight line connecting these two points. So, if I find that all the points lying on this straight line also belong to this particular set S, then we will say that set S is convex.

Whereas, if there is any point on the straight line connecting those two points belonging to set S, so if there is any point on this straight line which does not belong to set S; in that case, we will say that set S is not convex.

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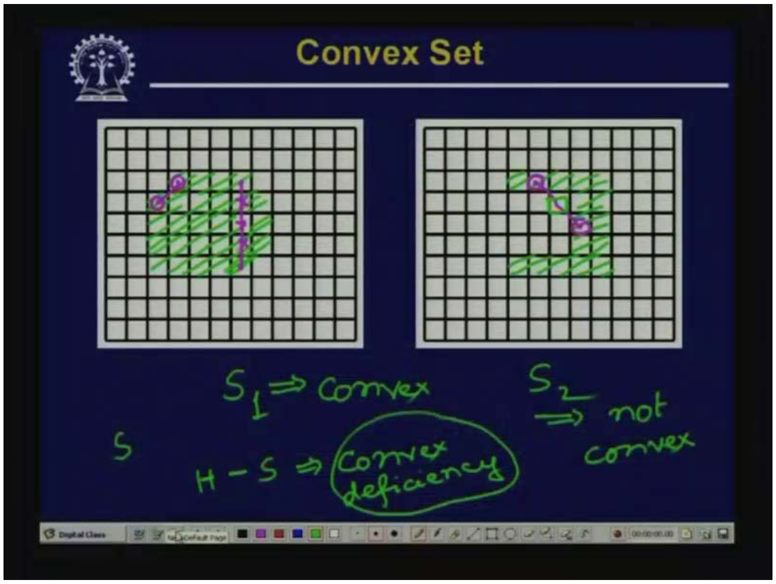

So, coming to an example, say I have a situation something like this; say I have two sets of points say one set of point is something like this, this is one set of point and maybe I have another set of points which is something like this. So, this is my set say S_1, this is say S_2. You find that in this point set S_1, say suppose my set is something like this; so you find that in this point set S_1if I take any pairof points, any two points and join a straight line, draw a straight line through that pair of points, so something like this; you find that all the points lying on this straight line, they are within set S_1.

But here, in this particular case, if I take say these two points and join a straight line, then youwillfind that I have apoint on this straight line which does not belong to set S_2. So, in this particular case, you willfind that this set S_1, this is a convex set, you say that set S_1 is convex whereas this set S_2, this is not convex.

So, given a set S, the convex hull of this set S will be the minimal set containing set S which is convex.So, that is how wedefine convex hull. Given any set S, the set S may be convex or it may not beconvex.
So,a point set which contains S, some minimal point set that contains set S which is convex is called the convex hull of set S and if I say that H is the convex hull of set S; then H minus S, this is what is called as convex deficiency. So, the difference, the set difference of the convex hull with the original set of points is called the convex deficiency and we will see later that this convex deficiency can be usedas one of the descriptors of a given set which may be useful which is useful for high level understating purpose.

Now, let us see an algorithm, how we can devise an algorithm that given a points set S; how we can find out the convex hull of that given set S.

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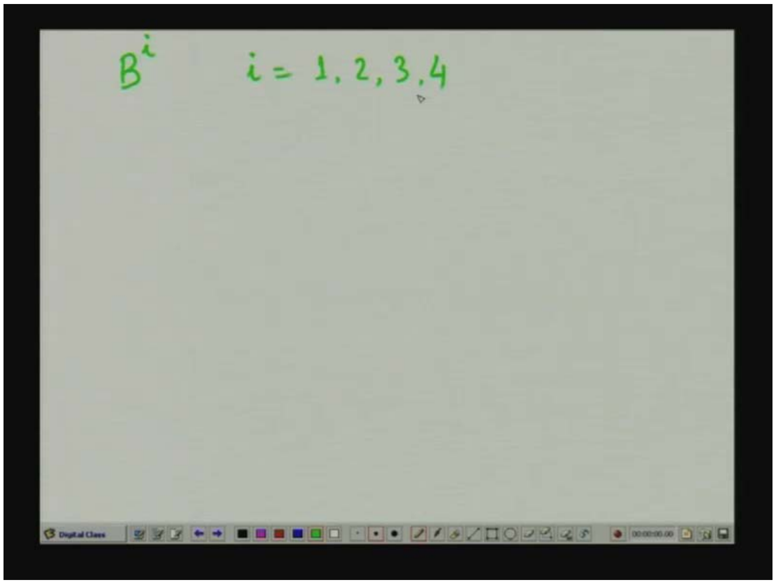

So, let us see that what will be the nature of this algorithm. So here,instead of using single structuring element,we use a set of structuring elements. So,I assume that B^i is a structuring element wherei varies from say1 to 4.So,I use 4 structuring elements for performing in this particular operation.

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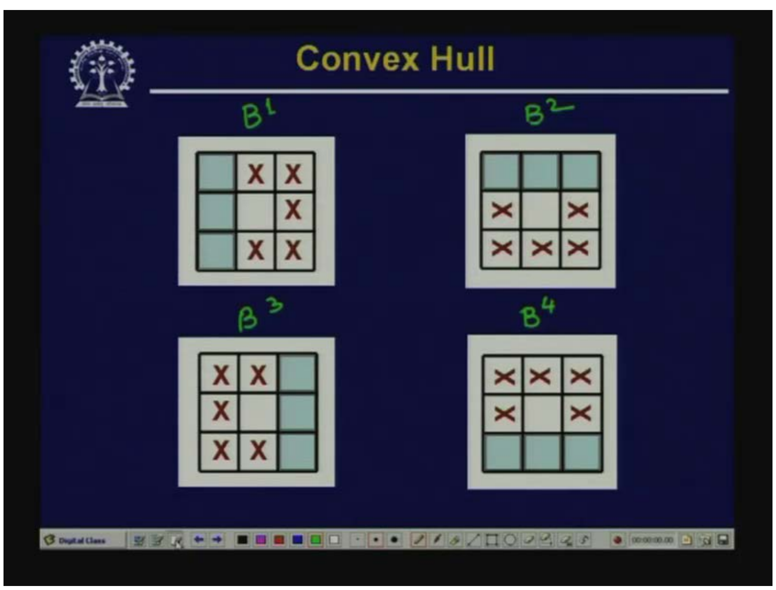

So, the 4 structuring elements which are used for determining the convex hull is as shown here.So, this is the structuring element, let us call this the structuring elements B^1, I call this say structuring element B^2, I call this the structuring elements B^3 and I call this the structuring element B^4.So, I have 4 such structuring elements which will be used to find out the convex hull.

Thenthe algorithm for finding out the convex hull will be like this;I take a particular structuring element B^i and using that particular structuring element B^i, I go for a similar kind of iterative algorithm and this has to be this iterative algorithm has to be applied for each and every individual structuring element in our set of 4 structuring elements. So,the iterative step or the iterative algorithm will be something like this.

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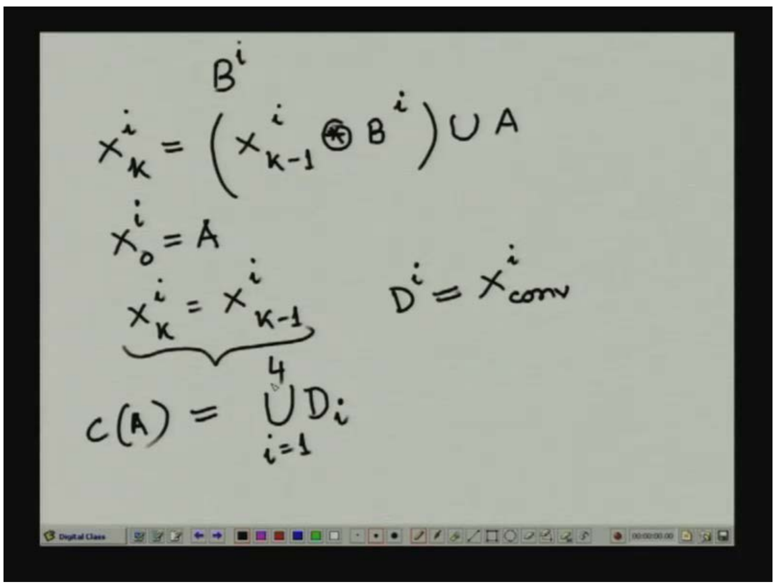

So,for a given structuring element, for a particular structuring elementsay B^i , wewill perform an iterative algorithm like this say;X_k^i is equal to $X_{kminus\ 1}^i$. Take the hit or miss transform of this with the structuring elements B^i and then perform the union of this with our original point set A. Sohere, A is the original point set and this iterative algorithm has to be done independently for each of the structuring elements B^1 B^2 B^3 and B^4 and in this iterative algorithm, what is our initial condition?Initial condition is X_0^i is equal to our original point set A.

Nowagain, as before, the algorithm this iterative algorithm with each of the structuring elements will converse when we find that X_K^i is equal to $X_{kminus\ 1}^i$. That is in two subsequent iterations, the output does not change. So, in that case,our algorithm converges and if I say at that particular stage say, what I get as output is nothing but X^i,X^i superscript because this is what we obtain with the i’th structuring elements B^i, so I represent the set as x^i conv.That means the output that I get when our algorithm converges and I represent this as set say D^i.

Thenthe convex hull of A if I represent this as C(A), say C(A) is the convex hull of A, convex hull of A will be represented by union of D^i for i is equal to 1 to 4. Soeffectively, what we are doing?We are taking 4 different structuring elements, then for each of the structuring elements, we employ an iterative algorithm.Inevery step of iterative algorithm, what we are doing is we are performing the hit or miss transform of our given set of the output at is this k minus 1 with the structuring element B^i and then taking the union of the output of this hit or miss transform with our given set A and after union operation, whatever output the point set that you get that is assigned to point set X_k.

So, we are generating X_k from point set $X_k$minus 1 by hit or miss transform, by applying hit or miss transform with one of the structuring elements and subsequently doing the union operation with our original point set,the given point set A and this iteration will continue until and unless the algorithm converges and the algorithm will converge or convergencecriteria is that in two subsequent iterations,the result does not change.

So, since we are having four different structuring elements,I will get four different point sets at the end of converges; when the algorithm converges,I will get four different point sets and the union of all those four different point sets is the convex hull of the given point set A. Now, let us see how this algorithm actually works.

So, as we have said earlier that these are the four different structuring elements which are used for extraction of the convex hull. Now, to demonstrate the operation of this algorithm, what we have is say we take an image like this.

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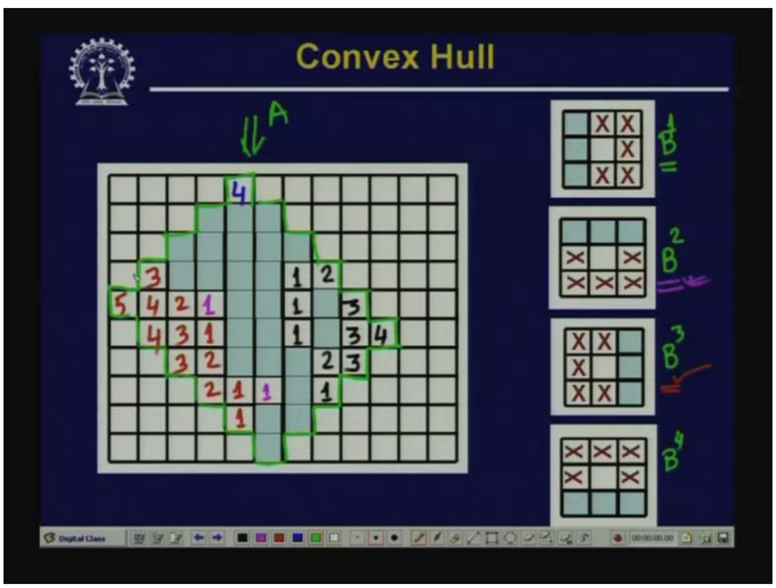

So, this is our point set A and these are the structuring elements,I call it the structuring element B^1, this is the structuring element B^2, this is the structuring element B^3 and this is the structuring element B ^{4}.So, what we want to do is we have to perform the hit or miss transform of this particular given point set A with these different four structuring element.

So, first of all, let us take the hit or miss transform of this given set A with the structuring element B^1 and let us see that what we will be the nature of the output in each of the iteration stages. To demonstrate this output, let us take different colours.So, all thehit or miss transform of this set A with this structuring element B^1 will be represented in black colour.So, if I take the hit or miss transform of this set A with the structuring element B^1, then you find that in first iteration, these are the points which are going to be filled as you have marked with 1.

So, these are the points which will be filled after applying after the first iteration when I do the hit or miss transform with this particular structuring element B^1.Then, at the end of second iteration, these are the points which are going to be filled up.Atthe end of third iteration, you find that these are the points which are going to be filled up and at the end of fourth iteration, you find that this is the point which will be filled up. Similarly, when I perform the hit or miss transform of this same set A with respect to or structuring element B^2, then you find that at the end of first iteration, this is the point which is going to be filled up.So, I the represent $B^2$with this pink colour, the output of hit or miss transform with this pink colour.

So, this is the point which is going to be filled up at the end of first iteration, this is also the point which will be filled up at the end of first iteration and if I do subsequent iterations on this point set, you find that I cannot fill up any other point. So, this is where I reach the convergence and this is the set union with my A, original set A that gives me the output set at the end of convergence with hit or miss transform with the structuring element B^2.

Now, if I take structuring element B^3. Now,I represent this as with red colour.So, with B^3, you find that at the end of first iteration; this is one of the points whichwill be filled up, this is another point that will be filled up, this is another point that will be filled up. So, this is what I get at the end of first iteration. Atthe end of second iteration, this is the point that will be filled, this is the point that will be filled up,this is also another point that will be filled up.

Atthe end of third iteration, this is a point which will be filled up, this is a point that will be filled up,this is also a point which will be filled up. And at the end of fourth iteration,you find that this point will be filled, this point will be filled and at the end of fifth iteration, this is the point which will be filled. So, we find that which structuring element B^3 and in subsequence iteration,I cannot fill up any other point by performing the hit or misstransform with my structuring element B^3.

So,we find that when I reach convergence, by applying this structuring element B^3, then all these red set of points, all the set of points represented by this red along with the original set of points that represents the set of points that I get at the end of convergence with our structuring element B^3. Similarly, when I apply the structuring element B^4, now let me represent it in blue colour.So, with B^4 at the end of first iteration, you find that these point,I can fill up but after this, when I go for second iteration,I cannot fill up any other point.

So, at the end of convergence, this is the only point that can be added tomy original set and then what we have said is that when I reach convergence by performing that iterative algorithm with independently with each of the structuring elements; all those converged sets,I have to take union,I have to take union of all those converged sets and this output of the union, the point set that I get afterperforming the union operation that is what gives me what is called the convex hull of the given set A.

So, in this particular case, you find that all these points, all these points; it actually forms the convex hull of the given set A because if I take the union, then I get all these different points. These are all the points that i get.Now,you find that this particular algorithm has a drawback, draw back because when we defined the convex hull, we have said that it is a minimal set containing the set A but the set has to be minimal,I mean, the set has to be convex. So, it is the minimal set containing the original set A which is convex is called the convexhull of the given set A.

Now, if you look at this particular set, you find that it is not the minimal set.What I can do is I can remove these points from this set. So, these are the points that I can remove from this set.So, these are the point that I can remove from this set and the resultant set that I get is still aconvex set. So, the minimal set is actually this set, not the set that we have obtained by applying those iterative algorithms.

So, now the question is how we can get the real convex hull in the sense that the set is minimal?So, that can be done by limiting the expansion of the region beyond the horizontal and vertical limits of the original point set. So,you find that the horizontal and vertical limits of the original point set is like this; in the original point set in the veridical direction,I donot have any point beyond this. Similarly,in the horizontal direction,I donot have any point beyond this.

So, when I am performing this iterative steps if I put a limit that I will not allow to grow the region beyond the horizontal and vertical dimensions of the original point set,then what I am going to get is a convex hull in true sense that is it will be minimal and of course, not only limiting the expansion beyond horizontal and vertical dimensions, if I expand if I limit the expansion in the diagonal directions as well; in the diagonal dimensions of the original point set, then what I will get is convex hull of the given set A in the true sense that is it will be minimal and at the same time, convex.

So, as we have said that convex hull is one of the very very important set, important concept which can be used for high level image understanding operation because we have said that the convex deficiency which is the difference between the convex hull of a given set and the given set. So, for a given set S if the convex hull is H, the set different H minus S which tells you what is the convex deficiency.So, this convex deficiency is one of the very very important properties which can be utilized for highlevel image understanding operations. So,we will discuss about those high level image understanding operations in our subsequentlectures.

Sonow, today let us talk about another morphological operation, another morphological algorithmand we call it as thinning.

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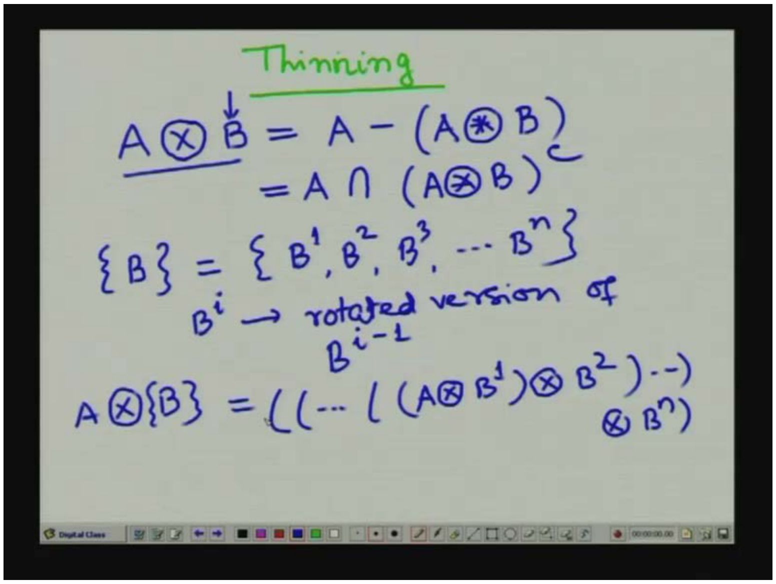


So, as we have just said that this thinning is an operation which is useful to find out the skeleton of a given object shape and we have said earlier that this skeleton maintains the structure of the shapeor the structural property of the shape and we can get an object descriptors, object description from the skeleton which can again be used for high level image interpretation or image understanding operation.

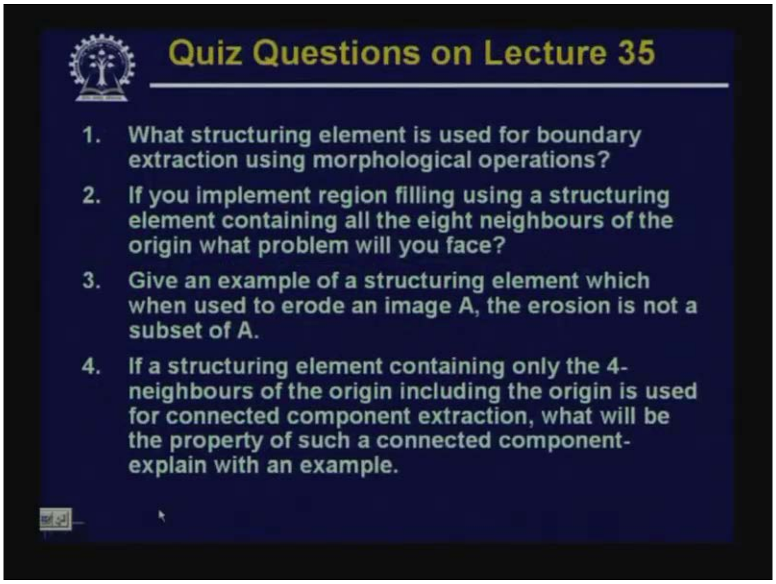
Sonow, let us see that how we can obtain the skeleton of a given shape of a given object shape by using the morphological operation. Sohere, the thinning operation is defined like this; see if I thin a given point set A with a structuring elements say B; so this thinning operation is defined as A minus A again hit or misstransform with the structuring element B. So, this is what is by thinnedimage when it is thinned with the structuring element B and the same expression as you know from a set theory that it can be represented as A intersection with A hit or misstransform with B, take the complement of this.

Again as before, instead of using a single structuring element, we use a set of structuring elements. So,we will assume that this structuring element B is a set of structuring elements which a say B^1 B^2 B^3upto say $B^n$where every structuring elements B^i is nothing but a rotated version of structuring element $B^{\text{iminus } 1}$. Then, given the set of structuring elements B^1 to B^n, the thinning ofa given set A with the structuring element B and in this case, it is a set of structuring elements; so this is defined as first use thin set A with structuring element B^1, this result you thin with structuring elements B^2, you continue like this and finally this output you thin with structuring element B^n. So, this completes one iterative step of the thinning operation.

So, for this given set of structuring elements B^1toB^n, we are doing successive thinning operations with different structuring elements present in our set and once you complete one particular iteration, you have to do this entire operation in a number of iterationsuntil you reach convergenceand in this particular case, the thinning with aparticular structuring element in our set of structuring elements follows the same definitions that we have given here.
So, this entire operation that is thinning with all the structuring elements present in our set of structuring elements is done iteratively over a number of processes until and unless we reach the

convergence. So, we will continue with our discussion on this thinning operation as well as we will see some more morphological operations which are applicable in the image processing in our subsequent lectures.Now, let us see some of thequiz questions on today's lecture.

(Refer Slide Time: 58:20)



So, the first question is what structuring element is used for boundary extraction using morphological operations? The second question, if you implement region filling with a structuring element containing all the eight neighbours of the origin,then what problem will you face? The third question, give an example of a structuring element which when used to erode an image A the erosion is not a subset of A. The fourth question, if a structuring element containing only the four neighbours of the origin including the origin is used for connected component extraction, then what will be the property of such a connected component?You have to explain with an example.

Thank you.