Optical Methods for Solid and Fluid Mechanics
Prof: Deepika Gupta

Module No # 08
Lecture No # 29

Hello everyone I am Deepika Gupta for this course on optical methods for solids and fluids so we have already seen how to implement a DIC algorithm and how can we capture the images while experimentation. So there are briefly three important parts in this in-situ analysis first is how do you capture the images when you do the experiments? The second part is to analyze those images and third, which comes is the post processing.

So I have already shown you how to capture these images and how a typical experimental DIC setup looks like. So today I am going to show you how can you analyze that images on your own. So we have briefly looked upon how can you write a code from scratch and implement by yourself. But fortunately we do not have to write codes all from start there are some open, source DIC software's which are available.

So we can just directly input our images and interpret the results and save the results for our further post processing. So today this session we are calling as a DIY do it yourself DIC session so by the end of this session you should be able to implement this analysis on your own and receive the results.

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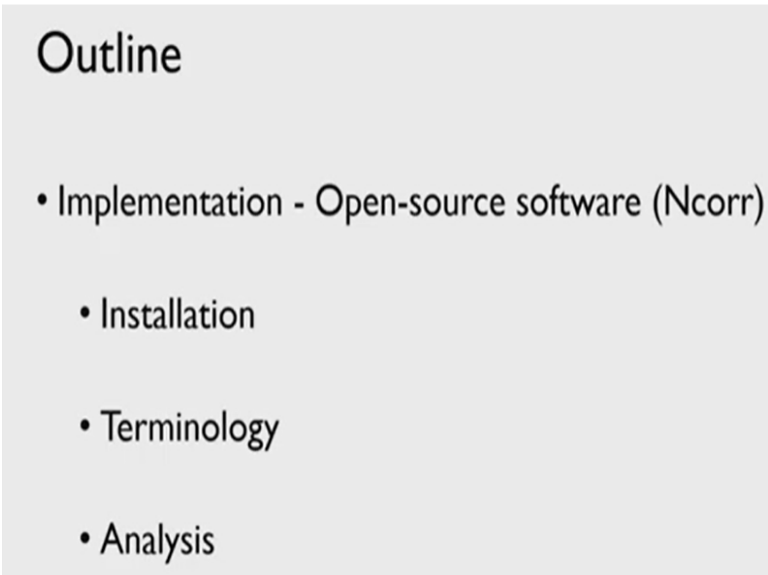

So a brief outline for this session is first I will show you what this open source software which is called as Ncorr is and I will also show you how you can install this software on your system. Then I briefly we mention and explain what all terminologies we are using and then we will analyze some example data sets to get familiar with this software.

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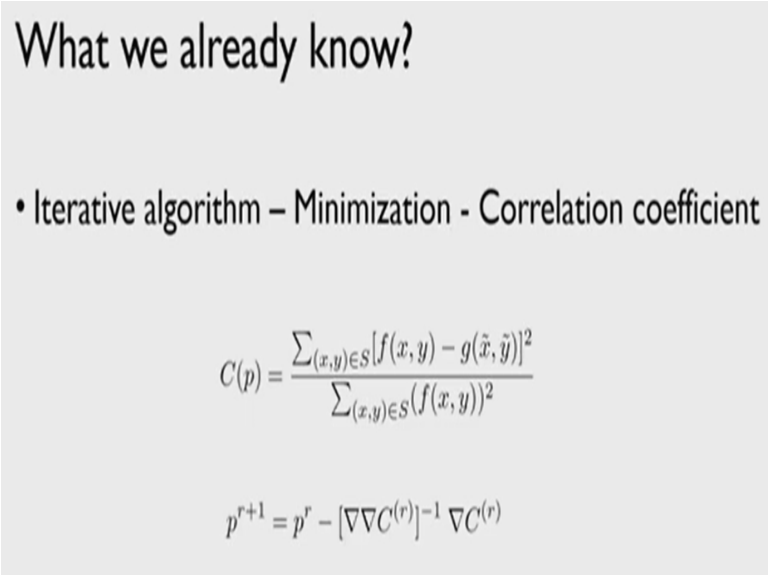

So as we have already seen in our previous lectures that how a typical iterative, algorithm for DIC can be developed by just using a minimization of a correlation coefficient. So we have used the definition for the correlation coefficient which is f - g whole square by f square where f was our reference image and g was or deformed image in our case. But this is not necessary that we use the same correlation coefficient in form definition.

So in this open source software we, will see that the correlation coefficient definition they will use a slightly different but the basic formulation for this algorithms same. And it is just developing this iterative technique for getting deformation a field that is this p iteratively while searching for minima minimum for the correlation coefficients.

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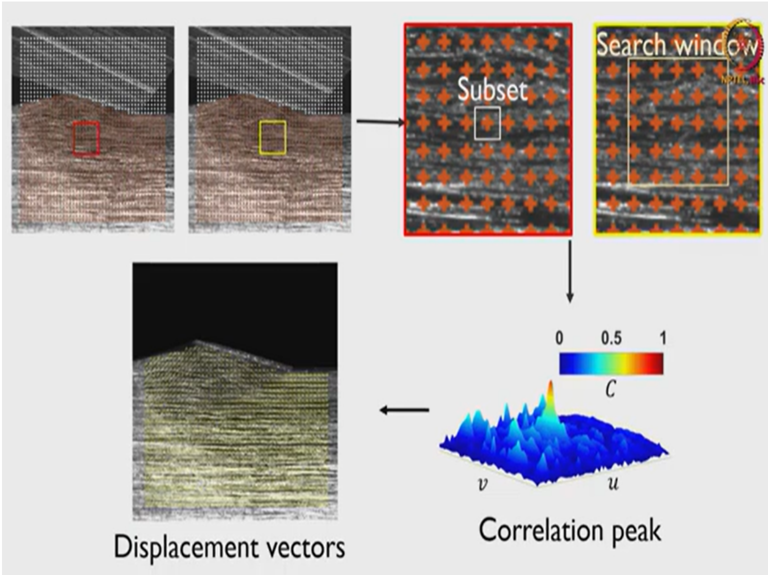

So if let us say we want to implement the codes by our own we have already seen, that we need to first create a grid. And after that we need to search for this like red region and yellow region I am showing on the screen. So this basically red region is in the reference configuration and yellow is in the deformed configuration from the red region will take a small part which we call as a subset.

And then search for this small region in the deformed configuration which we call as a this larger region is which we call as a search window. So the same idea will be used in the open source implementation also so this will help us understand the meaning of various parameters that we will see in this implementation. And once we have this search grid setup then we search for this correlation peaks or valleys based on what definition we are using iteratively and then get this final deformation fields.

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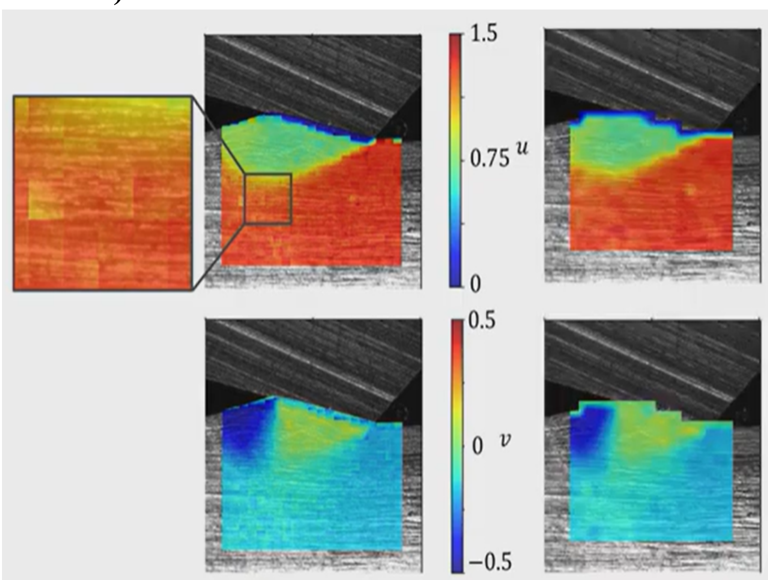

And in this process there were some issues that we briefly mentioned last time in the lecture. So this is how a typical displacement fields look like but if you see the in this search process we end up with the issues such as this discontinuities across the subset search the regions. So that we have to handle using some type of curve fitting or some type of interpolation, techniques. So we will briefly see how these issues also are addressed in this open source algorithms.

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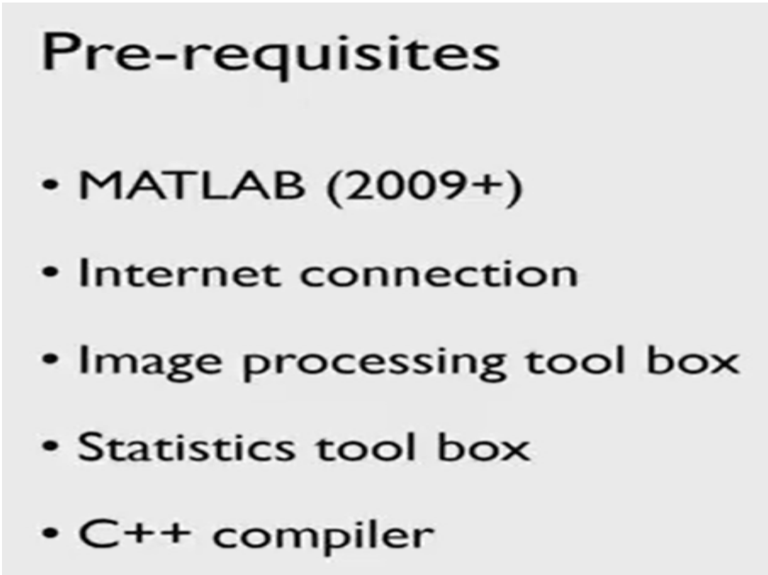

So before we start I will just briefly mention what are prerequisites are required for this implementation first you need to have a Matlab version later than 2009. And we will need a internet connection because we have to install this software from their website. And in the Matlab we need, 2 toolboxes first is the image processing toolbox and the second one is statistics toolbox. And in Matlab we need to have a c plus compiler coupled.

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So I will briefly show you how to do all this process by yourself so let us gets started (video starts: 05:17) here is the website which is this encore. Com. So this software was developed by Justin Blaber and his team and maintained from Georgia tech and maintained by him, he also has a Github page. So you guys can see the updates of this software on his Github page but today I am just going briefly over this implementation.

So on this home page you can see the introduction of what all this software is capable of and how are typical DIC algorithm works which we have already seen in previous lectures. So we will just directly go to the installation part so once we go to, this downloads we see that on the left side of the screen these 3 sections are there. So this is the main source code that you have to download so once you have this you are going to have a zip file which you can extract in one of the folder.

Here we have also the manual where all the information that I will be giving also and how to install and everything you can find here in case you have any, problem installation you can refer to this manual also. And there are the sample images which you can just use and implement it by yourself so I will use one of this test case also today to show you how to implement this analysis and will go over them one by one.

So I have already downloaded this files so these are the files that you will get once you have extracted the zip files from the, folder. After that we will just need a Matlab so we will open a Matlab on our system so here in the Matlab first we need a c plus compiler and 2 tool boxes. So to get these toolboxes you can just go to home on the Matlab GUI and then open these add-ons here in the search panel you can type image processing toolbox.

So this is the toolbox we need so I have already added this toolbox in my Matlab but in case if you do not have it you can just add it from this search panel here I have already installed added this toolbox in my Matlab. So it is already showing to manage but if you do not have this toolbox it is sure it will show an option to add. So you can just add it the second toolbox that we need is a statistics toolbox.

So this is the toolbox that will require for this open source, algorithm this also I have added already the third we need to add is a c plus compiler. So this is the c plus-plus compiler that in general works for windows so you can just add this compiler so once you have done this 3 steps you can just close this window. And first let us add or this c plus-plus compiler so we just have to type max setup c plus so in case if you do not have a c plus compiler, it is going to set up this compiler.

So in my case it is already configured then start or install installation so we have to type this handles encore equals to anchor this will automatically install all the files of this software and it is asking me to add the path. In your case I it might like when you are doing the installation for the first time it might ask you for few more, information's. You can just click yes and it is going to ask you to add the course which are there on your laptop you can you can check how many cores you are system has in just by just going to a task manager.

So here in the performance option on the c you can see how many course so my laptop has 4 cores. So I can give you a give a 3 or let us say 2 course to this open source software, while installation. So on the basis of how many cores you have you can assign all 4 also but other processes in the system will get slow if you add all fours for this software. Now we can just add path once you have added path it is going to open a GUI like this or the one shown on the screen.

So let us go over different terminologies or different functions which are there here so as we know, already that what is the first step to implement any device algorithm first step is to load the images. So in the same way we are we have option here to load the images so first option is load a reference image. So these are the 3 sample examples which are there in anchor website so I am going to use this first sample plate whole example.

So 0, 0 this is the first image which I am loading as, a reference image so once we this image is successfully loaded you are going to see a image which you have loaded in this reference image panel the next step is to load current images. So now on the screen we can see that there are two options to load a reference image one says load all and the other one is load lazy. So load all is an option which is going to load like how many let us say 100, images it is going to load all 100 images at once.

And load lazy is when you are loading all these images one by one so we will just do load all and go to the same folder and accept the first reference image I am going to load all rest of the images in this current images configuration. So I can see all the 11 images in this current image section so here all 11 images are, loaded successfully. So once we have done that what is the next step?

So in our code implementation also the next step is to define the region of interest which is the region where we want our deformation field so this is what we do while we do masking. So there are 2 options here one is set reference region of interest and other is set current region of interest. So in case of forward analysis, which we have seen in our lectures we need to set the reference region of interest. Backward analysis is something little bit different the details of that I am just going to skip for now.

But it is also the same it is just that in spite of taking a small subset from reference image and searching in the deformed image you will take a subset from a deformed image and in some sense undeform it and, select for and search for that reason in the reference image. So what we have seen in our lecture is the form is what we call as a forward analysis. So we will just click this set reference region of interest configuration now here we can see there are 2 options.

One is load region of interest and other is draw region of interest so if you have the mask made already and saved in the same, folder you can just do this load region of interest option and go to that path where you have the region of interest. Here in that sample images they have already given the mask so I can just take it and load the region of interest and click finish the other option is to draw it. So on this screen itself we can see there are multiple options to draw the region of interest so I can just select, whatever the option is suitable.

So for example I have just drawn the rectangle now I want to subtract this small circle so we can just choose the minus ellipse option and then draw it and that is how we can select or set the mask. So I will just use the same mask that they are that they have given so I will go to the same path set this region of interest click finish. So now we have, already selected what is the region where we want our deformation field?

So once we have diff loaded the images define the region of interest like next step is to set the parameters for the DIC analysis. So as we have already seen the first step is to make the grid so now you can relate all this relate all this parameter to the method that we have already seen. First you are seeing here is the subset, radius which is the size of the subset which you will take from the reference image and search for it when a while a correlation right.

So we can set this upset radius based on what is the size of our speaker patterns let us say we have 2 fine sprickle patterns then we can set subset radius which is less and get more resolution. But we need to be little bit careful while we set the subset radius, so for now I am just setting the subset radius to 30. Now next step is the subset what is the size of the grid this subset spacing is going to decide that so I can just set the subset spacing for now to be 15.

Now next option you are seeing is a difference of norm this is the parameter which is going to affect your iterative scheme. So if you remember from the lecture so when we search for p we say, that when we when our p r + 1 that means deformation in next iteration and deformation in the current iteration. When their difference is less than some limit will stop our iterative solver.

So here this is the parameter which is going to decide that what is the difference when we stop searching? So here we are just setting this limit to be 10 power minus 6 which is good enough so iterations, is the maximum number of iteration. Let us say when you are searching in iterations we are not finding any convergence so what is the maximum number of iterations till it is going to search.

So usually in correlation searches if you are specific patterns are good enough and you have selected a correct subset size it the solution converges within 15 to 20 iterations easily. So 50 is a good enough, number to set now next option is multi-threading options. So in this software they allow us to search for a correlation parallely in multiple regions which saves us some time.

So this depends on how many cores we have assigned already so right now I have assigned 4 courses so I can just give a number of threads as 4 which will parallelly search for 4 different regions and give me, the final deformation field. Now here is something interesting in the next option which is high strain analysis. So let us say our experiment includes very high strains and we have taken images.

So when we search we have to have one reference image and one deformed image right but there are two possibilities. Now let us say we I have one to ten images now one is my reference image and, in every iteration I am taking the same reference image. So I will just correlate second with first third with first fourth with first but if strains are very large or let us say deformations are very large at some point my correlation between the first and let us say sixth image is not good.

So I need to update my reference image when I move forward so this is the option that enables us to update, our reference image. So there are 2 options here one is secret propagation so let us say my first and sixth image at my correlations are not good so there is already one criteria so which will check whether the correlation is good or not. If correlation is bad it is going to auto update the reference image.

But let us say we do not want to do this and we want to manually select that after, every fifth image references reference image should be updated. So we can select just this leapfrog option and give what will be the step when we want to update our images update our reference image. So let us say I am just assigning 2 which mean every third image will have a new reference image.

So this is all when we set these DIC parameters now another option is for the discontinuous analysis. So, when we have this options where we have a hole or a crack where we do not have a proper speckle patterns we need to truncate our subsets at the boundary. So that in that regions are correlation coefficient search is not getting affected. So we need to select that this option subset truncation in that case so I am just not selecting as of now.

But you can try and implement it by your own so I will, just click finish so it is saying it so here I am getting a message that there are points in the ROI near the edges of the image this point can cause problems when the ROI is updated. So if you remember we are searching for subset from the reference and the finding the correlation in the deformed image right but let us say my subset which is there in the reference image.

Now the deformation is so, much that it has gone out from the region of interest in that case I am going to have the issues because there is no deformed configuration for that particular subset. So to avoid this we will leave out the boundaries of the images where the possibility of subsets going out is more. So right now we have selected the mass that they have already given in the images that which goes to the, full length of the image I mean the size of the image that is why we are getting this error.

But let us say if we select a region of interest with within the image this error will not show so I will just click ok because I am just showing you how to analyze so which is so we will just click yes. So now we have set already our DIC parameters which are there so now the next step is to, perform the analysis because we have already set all the parameters loaded all the images. So we will perform this DIC analysis now here it is asking us to select the region.

So this is the region where we want to do the analysis so if you see the option it is asking me to set seeds now what are the seeds? So we have already seen that we need to have an initial guess when we start the DIC iterations, right. So in this case this initial gas will be calculated only at, few points so let us say I have a grid and on that grid I am starting to search on all the grid points for the initial guess it is going to take lot of time.

So instead of there that will do search only for one; point and then use that result as an initial guess for the neighbour points so we will just set seats. This is the one, functionality of this setting seeds the other thing is it also helps in this multi-threading options. So it is going to so this four regions are going to go into separate threads and analyse parallelly while search. So I will just click finish now it is processing the seeds.

Now here is one check that you can do whether you have set your subset size grid size correctly or not. So it is showing, me that iterations have converged within the four tri 4 steps and the norm of difference vector is 10 power -7 which is good enough. And the correlation coefficient was 0.039 so that means the set the seed points have good speckle patterns. In case if your speaker patterns are not good either you will have very large number of iterations.

For example maximum iterations will, be encountered and still you will not have a good convergence or this norm of difference vectors. So this way you can check whatever you have parameters set in the dice analysis are they good enough or you need to change something so that is how you can judge also so we have selected 4 seed points already. Now it is showing us processing images so this is going to process all the images with, the reference images that we have set and now our analysis is complete.

So we now have the results for displacement and strains next step is to format the displacements. So when we take images right so in that case each pixel corresponds to some physical unit. So let us say my one pixel is approximately 0.5 mm or whatever depending upon your experiments. So you can set that scale and convert this, results into the actual physical skills that you understand.

So as of now we do not know what is the scale of the images so we will just leave these options. Now the next option is to set the correlation cut off so right now it is showing us the circulation cut off of 0.083. I will just to show you let us say if I set the cutoff to 0 so it we cannot set the cutoff to zero it, is saying that. So let us say just to show let us say I have set the correlation cut off so this correlation cut off actually what it does?

In some regions if let us say your correlation is not good and you are setting a correlation cut off so it is going to drop the results from that region. So as you can see on the screen that it has dropped the regions on the right hand side of the, image because there was the correlation cut off which was approximately 0.08 which is good enough. But just to show you what it does I have used I have shown the functionality of this option.

The next thing it asks us less distortion option we do not have to change anything here because this is what depends on the camera and experimental observation. Sso right now we are we do not need to bother, about this lens distortion option and we will just click finish here. So it is showing us all the correlation coefficient cutoff for images till 11 and it is asking is this correct so we will just click yes.

So now our all displacement fields have been formatted according to whatever options we have selected now next option is to calculate the strains. So if you remember we have already, mentioned that when we search for correlation using the subsets on the grid we get the issues of discontinuities across upset boundaries in this local DIC scheme. So this taking the subset from one small grid center and then searching this is what we call as a local DIC scheme.

So at the end we need to have some type of interpolation or some type of curve feeding which will help us avoid that, discontinuity issue. So what it does it takes a small radius and fits the surface to all the data which is there within this small radius. So let us say my radius is 10 you can see on the right hand side of this screen itself that it is fitting a surface to all the data so which is there in this displacement.

So strain radius we can search according to the data that we have in a in the experiment so, as of now I am just assigning this as a 10. Now the other option is Lagrangian and your Euclidian strains so there are we know already that there are 2 types of stress that we can define either with respect to the form configuration or with respect to the reference configuration this is what that option is. Now we can look for u and v displacement if whatever sub strained radius we have, assigned whether it is correct or we need to change it.

So strain radius 10 is showing us good enough or smooth deformation field without any spuriousness so we will just use that and click finish. So now we have already analyzed all the displacement fields strain fields for the whole set of images. So now the next step is to plot let us say I want to see what is this x displacement, field looks like so I; can see and for all the images how the displacement fields look like. And we can see that this plate with the hole was getting stretched when we were so even the images were taken so that you can see here.

Let us look at how v displacement fields look like so see the direction of stretch was in v direction that can be easily interpreted from this displacement results. So that, is how we can do an analysis now you can just capture the images of your experiments use some air spray or some other way of giving this sprickle patterns and just use this open source software to analyse them.

Now I will just briefly show you how to save all this data because let us say at the end we want to save the data and use it for further post processing right. So in this file option, they are giving us the option to save the data and the data will be saved in dot net format which you can read for further post processing in the Matlab. So I am just assigning as a sample pleat hole so now this data is saved here if you see this is the file that we have just created.

So I am just double clicking so or else you can just write in the command window load and, this file name in the codes so it is going to load all the data which was there. Now here you are see you are seeing this current save option so which is showing all the files and here is all the DIC data. So these are the data for the displacement fields we have u, v and whatever correlation coefficients were there.

Then there are this displacement information that we had assigned while, doing performing the analysis. Then we can also see whatever strains we have assigned so each so we can see that the grid size was 65 by 25. So there were actually 65 by 25 grade points where we had to perform this analysis here. So at each grade point it is giving us the value of the deformation field.

So hope this session helped in getting the brief introduction of how you can implement your, DIC algorithm in this open source software and analyze your images.
(Video Ends: 32:08)

And you can just try all other data sets which they have provided or take your own experimental data sets and use this software in spite like saving some effort in writing your own codes and get the good deformation fields. In any doubts you can always go back to the manual which is provided on their website and you can write to us, also thank you.